LMK

Post Tensioning System



Contents


LMK System

In Brief

The **LMK** Post Tensioning system has been designed and developed by Engineers of various disciplines with long-standing activity and experience in construction and project management, meeting the requirements of complex PT projects by providing know-how, quality and application consistency.

Its vision has always been focused on applying new technologies contributing to high quality engineering with respect to safety and environmental issues.

LMK PT system responds proactively to the trends of Int'l markets having successfully accomplished numerous projects involving all types of construction methods, from simply supported beams to slabs, cantilevers, incremental launching and segmental structures, demonstrating solid experience in the PT technology.

LMK PT system offers full technical support & assistance through a team of Engineers having participated in prestigious infrastructure projects of building, road and railway industry.

Main Features

Application

LMK is a Post Tensioning system in which the tensioning force is applied after concreting or after the installation of pre-casted units, through a combination of anchorages and tendons. Adequate bond between LMK system and the structure is provided through grouting. The system can also be implemented in un-bonded (un-grouted) applications.

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

LMK can achieve economic benefits by applying the stressing in phases based on the design and avoiding the need of pre-stressed apparatus, giving to the Consultants/ Designers and Contractors the advantages of a simplified construction.

LMK can use a variety of tendons and steel strand sizes by using 0,5" and 0,6" wire-strand covering the majority of designs. If required, special anchorages with various capacities can be designed and manufactured, including special designs for the construction of cable supported structures.

Advantages

LMK covers Int'l specifications and guidelines such as EN - EAD - ETAG, AASHTO LRFD, F.I.B. (Federation Int'l du Beton) & PTI (Post Tensioning Institute), demonstrating the following advantages:

- Wide selection of compact anchorages with improved load distribution surfaces.
- Easy coupling with standard or enlarged steel or plastic sheaths (flat and round).
- Frontal grouting/connection arrangement.
- Light weight configuration, facilitating the handling and installation.
- Recesses of smaller dimensions.
- Lower losses and smaller tendon's deviations contributing to the economy of the design & construction.

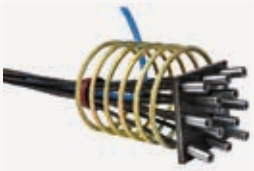










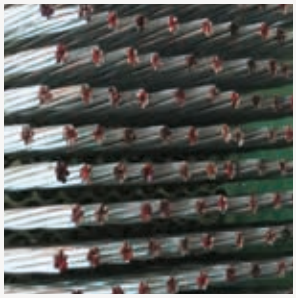



Strands

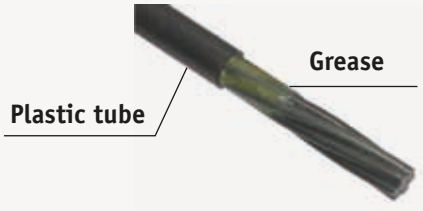
7-wire strands

The strands are made of high tensile strength steel produced by low relaxation process, consisted of 7 steel wires (one central and six helically wrapped) having 13 mm (0.5") or 15 mm (0,6") nominal diameter and characteristics listed in Tables 1.1 & 1.2.
The strands are generally supplied already stabilized (low relaxation) and certified according to standards in testing labs (EN & ASTM). They are usually shipped in coils having the following typical dimensions:

- Outer diameter: 1,2-1,5 m
- Inner diameter: 0,7-0,8 m
- Width: 0,7-0,75 m
- Weight: 3-4 tonns



LMK can use any type of pc strand meeting the project requirements. When needed, oiled, greased or waxed/gelled strands can be applied using plastic sheath (PP or PE), i.e. in case of external post-tensioning or in un-bonded applications. If required, strands can also be supplied galvanized, considering different mechanical properties in comparison with common strand types.



Tendons are consisted of a specific number of wire strands according to the design. The number of strands defines usually the type of anchorage (LMK typical range of production from 1 up to 37 strands).
All types of strands are following the common stress-strain diagram. The yield point of the steel is the reaching of an irreversible plastic strain of 0.1%, defined as $f_{p0,1}$.

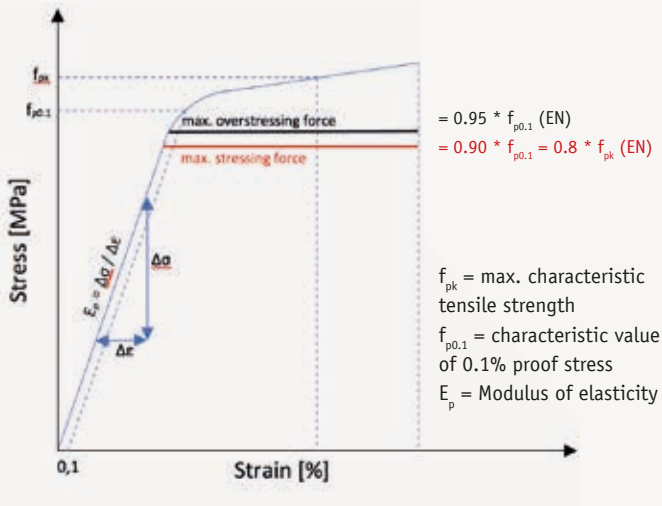


Fig.1 Strands Typical Stress-Strain Graph

Table 1.1 - Strands Data

(0,5") M13	prEN 10138					ASTM A416				prEN 10138				ASTM A416		prEN 10138				ASTM A416		prEN 10138				ASTM A416	
	Y1770S7	Y1860S7	Kg/m	Y1770S7	Y1860S7	Kg/m	Grade 250	Kg/m	Grade 270	Kg/m	Y1770S7	Y1860S7	Y1770S7	Y1860S7	Grade 250	Grade 270	Y1770S7	Y1860S7	Y1770S7	Y1860S7	Grade 250	Grade 270	Y1770S7	Y1860S7	Y1770S7	Y1860S7	Grade 250	Grade 270
											Tensile Strength (N/mm²)						Yield Strength (N/mm²)						Tensile strength under max force (N/mm²)					
d (mm)	12,5		0,726	12,9		0,781	12,7	0,730	12,7	0,775	1770	1860	1770	1860	1725	1860	1559	1634	1560	1640	1551	1675	1403,1	1470,8	1404	1476	1380	1488
A (mm²)	93			100			92,9		98,7		Breaking Load (KN) (f_{pm})						Proof load (KN) ($f_{p0,1k}$)						Anchorage indicative max force prior of seating as per EC2					
Strands / tendon	STRAND DATA - 13mm (0,5")										165	173	177	186	160,1	183,7	145	152	156	164	144,1	165,3	min (0,8 f_{pm} / 0,9 $f_{p0,1k}$)					
Nos.	mm²	kg/m	mm²	Kg/m	mm²	kg/m	mm²	kg/m			KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN
1	93	0,726	100	0,781	93	0,730	99	0,775			165	173	177	186	160	184	145	152	156	164	144	165	131	137	140	148	128	147
2	186	1,452	200	1,562	186	1,460	197	1,550			330	346	354	372	320	367	290	304	312	328	288	331	261	274	281	295	256	294
3	279	2,178	300	2,343	279	2,190	296	2,325			495	519	531	558	480	551	435	456	468	492	432	496	392	410	421	443	384	441
4	372	2,904	400	3,124	372	2,920	395	3,100			660	692	708	744	640	735	580	608	624	656	576	661	522	547	562	590	512	588
5	465	3,630	500	3,905	465	3,650	494	3,875			825	865	885	930	801	919	725	760	780	820	721	827	653	684	702	738	640	735
6	558	4,356	600	4,686	557	4,380	592	4,650			990	1038	1062	1116	961	1102	870	912	936	984	865	992	783	821	842	886	768	882
7	651	5,082	700	5,467	650	5,110	691	5,425			1155	1211	1239	1302	1121	1286	1015	1064	1092	1148	1009	1157	914	958	983	1033	897	1029
8	744	5,808	800	6,248	743	5,840	790	6,200			1320	1384	1416	1488	1281	1470	1160	1216	1248	1312	1153	1322	1044	1094	1123	1181	1025	1176
9	837	6,534	900	7,029	836	6,570	888	6,975			1485	1557	1593	1674	1441	1653	1305	1368	1404	1476	1297	1488	1175	1231	1264	1328	1153	1323
10	930	7,260	1000	7,810	929	7,300	987	7,750			1650	1730	1770	1860	1601	1837	1450	1520	1560	1640	1441	1653	1305	1368	1404	1476	1281	1470
11	1023	7,986	1100	8,591	1022	8,030	1086	8,525			1815	1903	1947	2046	1761	2021	1595	1672	1716	1804	1585	1818	1436	1505	1544	1624	1409	1617
12	1116	8,712	1200	9,372	1115	8,760	1184	9,300			1980	2076	2124	2232	1921	2204	1740	1824	1872	1968	1729	1984	1566	1642	1685	1771	1537	1764
13	1209	9,438	1300	10,153	1208	9,490	1283	10,075			2145	2249	2301	2418	2081	2388	1885	1976	2028	2132	1873	2149	1697	1778	1825	1919	1665	1910
14	1302	10,164	1400	10,934	1301	10,220	1382	10,850			2310	2422	2478	2604	2241	2572	2030	2128	2184	2296	2017	2314	1827	1915	1966	2066	1793	2057
15	1395	10,890	1500	11,715	1394	10,950	1481	11,625			2475	2595	2655	2790	2402	2756	2175	2280	2340	2460	2162	2480	1958	2052	2106	2214	1921	2204
16	1488	11,616	1600	12,496	1486	11,680	1579	12,400			2640	2768	2832	2976	2562	2939	2320	2432	2496	2624	2306	2645	2088	2189	2246	2362	2049	2351
17	1581	12,342	1700	13,277	1579	12,410	1678	13,175			2805	2941	3009	3162	2722	3123	2465	2584	2652	2788	2450	2810	2219	2326	2387	2509	2177	2498
18	1674	13,068	1800	14,058	1672	13,140	1777	13,950			2970	3114	3186	3348	2882	3307	2610	2736	2808	2952	2594	2975	2349	2462	2527	2657	2305	2645
19	1767	13,794	1900	14,839	1765	13,870	1875	14,725			3135	3287	3363	3534	3042	3490	2755	2888	2964	3116	2738	3141	2480	2599	2668	2804	2434	2792
20	1860	14,520	2000	15,620	1858	14,600	1974	15,500			3300	3460	3540	3720	3202	3674	2900	3040	3120	3280	2882	3306	2610	2736	2808	2952	2562	2939
21	1953	15,246	2100	16,401	1951	15,330	2073	16,275			3465	3633	3717	3906	3362	3858	3045	3192	3276	3444	3026	3471	2741	2873	2948	3100	2690	3086
22	2046	15,972	2200	17,182	2044	16,060	2171	17,050			3630	3806	3894	4092	3522	4041	3190	3344	3432	3608	3170	3637	2871	3010	3089	3247	2818	3233
23	2139	16,698	2300	17,963	2137	16,790	2270	17,825			3795	3979	4071	4278	3682	4225	3335	3496	3588	3772	3314	3802	3002	3146	3229	3395	2946	3380
24	2232	17,424	2400	18,744	2230	17,520	2369	18,600			3960	4152	4248	4464	3842	4409	3480	3648	3744	3936	3458	3967	3132	3283	3370	3542	3074	3527
25	2325	18,150	2500	19,525	2323	18,250	2468	19,375			4125	4325	4425	4650	4003	4593	3625	3800	3900	4100	3603	4133	3263	3420	3510	3690	3202	3674
26	2418	18,876	2600	20,306	2415	18,980	2566	20,150			4290	4498	4602	4836	4163	4776	3770	3952	4056	4264	3747	4298	3393	3557	3650	3838	3330	3821
27	2511	19,602	2700	21,087	2508	19,710	2665	20,925			4455	4671	4779	5022	4323	4960	3915	4104	4212	4428	3891	4463	3524	3694	3791	3985	3458	3968
28	2604	20,328	2800	21,868	2601	20,440	2764	21,700			4620	4844	4956	5208	4483	5144	4060	4256	4368	4592	4035	4628	3654	3830	3931	4133	3586	4115
29	2697	21,054	2900	22,649	2694	21,170	2862	22,475			4785	5017	5133	5394	4643	5327	4205	4408	4524	4756	4179	4794	3785	3967	4072	4280	3714	4262
30	2790	21,780	3000	23,430	2787	21,900	2961	23,250			4950	5190	5310	5580	4803	5511	4350	4560	4680	4920	4323	4959	3915	4104	4212	4428	3842	4409
31	2883	22,506	3100	24,211	2880	22,630	3060	24,025			5115	5363	5487	5766	4963	5695	4495	4712	4836	5084	4467	5124	4046	4241	4352	4576	3970	4556
32	2976	23,232	3200	24,992	2973	23,360	3158	24,800			5280	5536	5664	5952	5123	5878	4640	4864	4992	5248	4611	5290	4176	4378	4493	4723	4099	4703
33	3069	23,958	3300	25,773	3066	24,090	3257	25,575			5445	5709	5841	6138	5283	6062	4785	5016	5148	5412	4755	5455	4307	4514	4633	4871	4227	4850
34	3162	24,684	3400	26,554	3159	24,820	3356	26,350			5610	5882	6018	6324	5443	6246	4930	5168	5304	5576	4899	5620	4437	4651	4774	5018	4355	4997
35	3255	25,410	3500	27,335	3252	25,550	3455	27,125			5775	6055	6195	6510	5604	6430	5075	5320	5460	5740	5044	5786	4568	4788	4914	5166	4483	5144
36	3348	26,136	3600	28,116	3344	26,280	3553	27,900			5940	6228	6372	6696	5764	6613	5220	5472	5616	5904	5188	5951	4698	4925	5054	5314	4611	5291
37	3441	26,862	3700	28,897	3437	27,010	3652	28,675			6105	6401	6549	6882	5924	6797	5365	5624	5772	6068	5332	6116	4829	5062	5195	5461	4739	5438

Table 1.2 - Strands Data

(0,6") M15	prEN 10138								ASTM A416								prEN 10138						ASTM A416		prEN 10138						ASTM A416		prEN 10138						ASTM A416	
	Y1770S7	Y1860S7	Kg/m	Y1770S7	Y1860S7	Kg/m	Y1770S7	Y1860S7	Kg/m	Grade 250	Kg/m	Grade 270	Kg/m	Grade 270	Kg/m		Y1770S7	Y1860S7	Y1770S7	Y1860S7	Y1770S7	Y1860S7	Grade 250	Grade 270	Y1770S7	Y1860S7	Y1770S7	Y1860S7	Y1770S7	Y1860S7	Grade 250	Grade 270	Y1770S7	Y1860S7	Y1770S7	Y1860S7	Y1770S7	Y1860S7	Grade 250	Grade 270
																	Tensile Strength (N/mm²)								Yield Strength (N/mm²)								Tensile strength under max force (N/mm²)							
d (mm)	15,2		1,0816	15,3		1,093	15,7		1,172	15,2	1,094	15,2	1,102	15,7	1,200		1770	1860	1770	1860	1770	1860	1725	1860	1554	1640	1557	1636	1560	1640	1550	1676	1676	1399	1476	1401	1472	1404	1476	1380	1488	1448
A (mm²)	139			140			150			139,4		140		150			Breaking Load (KN) (f_{pk})									Proof load (KN) ($f_{p0,1k}$)									Anchorage indicative max force prior of seating (EC2)							
Strands / tendon	STRAND DATA - 15mm (0,6")																246	259	248	260	266	279	240	261	279	216	228	218	229	234	246	216	235	251	min (0,8 f_{pk} / 0,9 $f_{p0,1k}$)							
Nos.	mm²	kg/m	mm²	Kg/m	mm²	Kg/m	mm²	kg/m	mm²	kg/m	mm²	kg/m	mm²	kg/m			KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN	KN
1	139	1,09	140	1,09	150	1,17	139	1,09	140	1,10	150	1,20					246	259	248	260	266	279	240	261	279	216	228	218	229	234	246	216	235	251	194	205	196	206	211	221	192	209	223
2	278	2,17	280	2,19	300	2,34	279	2,19	280	2,20	300	2,40					492	518	496	520	532	558	480	521	558	432	456	436	458	468	492	432	469	503	389	410	392	412	421	443	384	417	446
3	417	3,26	420	3,28	450	3,52	418	3,28	420	3,31	450	3,60					738	777	744	780	798	837	721	782	837	648	684	654	687	702	738	649	704	754	583	616	589	618	632	664	576	626	670
4	556	4,34	560	4,37	600	4,69	558	4,38	560	4,41	600	4,80					984	1036	992	1040	1064	1116	961	1043	1116	864	912	872	916	936	984	865	938	1006	778	821	785	824	842	886	769	834	893
5	695	5,43	700	5,47	750	5,86	697	5,47	700	5,51	750	6,00					1230	1295	1240	1300	1330	1395	1201	1304	1395	1080	1140	1090	1145	1170	1230	1081	1173	1257	972	1026	981	1031	1053	1107	961	1043	1116
6	834	6,52	840	6,56	900	7,03	836	6,56	840	6,61	900	7,20					1476	1554	1488	1560	1596	1674	1441	1564	1674	1296	1368	1308	1374	1404	1476	1297	1408	1508	1166	1231	1177	1237	1264	1328	1153	1251	1339
7	973	7,60	980	7,65	1050	8,20	976	7,66	980	7,71	1050	8,40					1722	1813	1736	1820	1862	1953	1681	1825	1953	1512	1596	1526	1603	1638	1722	1513	1642	1760	1361	1436	1373	1443	1474	1550	1345	1460	1562
8	1112	8,69	1120	8,74	1200	9,38	1115	8,75	1120	8,82	1200	9,60					1968	2072	1984	2080	2128	2232	1922	2086	2232	1728	1824	1744	1832	1872	1968	1730	1877	2011	1555	1642	1570	1649	1685	1771	1537	1668	1786
9	1251	9,77	1260	9,84	1350	10,55	1255	9,85	1260	9,92	1350	10,80					2214	2331	2232	2340	2394	2511	2162	2346	2511	1944	2052	1962	2061	2106	2214	1946	2111	2263	1750	1847	1766	1855	1895	1993	1729	1877	2009
10	1390	10,86	1400	10,93	1500	11,72	1394	10,94	1400	11,02	1500	12,00					2460	2590	2480	2600	2660	2790	2402	2607	2790	2160	2280	2180	2290	2340	2460	2162	2346	2514	1944	2052	1962	2061	2106	2214	1922	2086	2232
11	1529	11,95	1540	12,02	1650	12,89	1533	12,03	1540	12,12	1650	13,20					2706	2849	2728	2860	2926	3069	2642	2868	3069	2376	2508	2398	2519	2574	2706	2378	2581	2765	2138	2257	2158	2267	2317	2435	2114	2294	2455
12	1668	13,03	1680	13,12	1800	14,06	1673	13,13	1680	13,22	1800	14,40					2952	3108	2976	3120	3192	3348	2882	3128	3348	2592	2736	2616	2748	2808	2952	2594	2815	3017	2333	2462	2354	2473	2527	2657	2306	2503	2678
13	1807	14,12	1820	14,21	1950	15,24	1812	14,22	1820	14,33	1950	15,60					3198	3367	3224	3380	3458	3627	3123	3389	3627	2808	2964	2834	2977	3042	3198	2811	3050	3268	2527	2668	2551	2679	2738	2878	2498	2711	2902
14	1946	15,20	1960	15,30	2100	16,41	1952	15,32	1960	15,43	2100	16,80					3444	3626	3472	3640	3724	3906	3363	3650	3906	3024	3192	3052	3206	3276	3444	3027	3284	3520	2722	2873	2747	2885	2948	3100	2690	2920	3125
15	2085	16,29	2100	16,40	2250	17,58	2091	16,41	2100	16,53	2250	18,00					3690	3885	3720	3900	3990	4185	3603	3911	4185	3240	3420	3270	3435	3510	3690	3243	3519	3771	2916	3078	2943	3092	3159	3321	2882	3128	3348
16	2224	17,38	2240	17,49	2400	18,75	2230	17,50	2240	17,63	2400	19,20					3936	4144	3968	4160	4256	4464	3843	4171	4464	3456	3648	3488	3664	3744	3936	3459	3754	4022	3110	3283	3139	3298	3370	3542	3075	3337	3571
17	2363	18,46	2380	18,58	2550	19,92	2370	18,60	2380	18,73	2550	20,40					4182	4403	4216	4420	4522	4743	4083	4432	4743	3672	3876	3706	3893	3978	4182	3675	3988	4274	3305	3488	3335	3504	3580	3764	3267	3546	3794
18	2502	19,55	2520	19,67	2700	21,10	2509	19,69	2520	19,84	2700	21,60					4428	4662	4464	4680	4788	5022	4324	4693	5022	3888	4104	3924	4122	4212	4428	3892	4223	4525	3499	3694	3532	3710	3791	3985	3459	3754	4018
19	2641	20,63	2660	20,77	2850	22,27	2649	20,79	2660	20,94	2850	22,80					4674	4921	4712	4940	5054	5301	4564	4953	5301	4104	4332	4142	4351	4446	4674	4108	4457	4777	3694	3899	3728	3916	4001	4207	3651	3963	4241
20	2780	21,72	2800	21,86	3000	23,44	2788	21,88	2800	22,04	3000	24,00					4920	5180	4960	5200	5320	5580	4804	5214	5580	4320	4560	4360	4580	4680	4920	4324	4692	5028	3888	4104	3924	4122	4212	4428	3843	4171	4464
21	2919	22,81	2940	22,95	3150	24,61	2927	22,97	2940	23,14	3150	25,20					5166	5439	5208	5460	5586	5859	5044	5475	5859	4536	4788	4578	4809	4914	5166	4540	4927	5279	4082	4309	4120	4328	4423	4649	4035	4380	4687
22	3058	23,89	3080	24,05	3300	25,78	3067	24,07	3080	24,24	3300	26,40					5412	5698	5456	5720	5852	6138	5284	5735	6138	4752	5016	4796	5038	5148	5412	4756	5161	5531	4277	4514	4316	4534	4633	4871	4228	4588	4910
23	3197	24,98	3220	25,14	3450	26,96	3206	25,16	3220	25,35	3450	27,60					5658	5957	5704	5980	6118	6417	5525	5996	6417	4968	5244	5014	5267	5382	5658	4973	5396	5782	4471	4720	4513	4740	4844	5092	4420	4797	5134
24	3336	26,06	3360	26,23	3600	28,13	3346	26,26	3360	26,45	3600	28,80					5904	6216	5952	6240	6384	6696	5765	6257	6696	5184	5472	5232	5496	5616	5904	5189	5630	6034	4666	4925	4709	4946	5054	5314	4612	5005	5357
25	3475	27,15	3500	27,33	3750	29,30	3485	27,35	3500	27,55	3750	30,00					6150	6475	6200	6500	6650	6975	6005	6518	6975	5400	5700	5450	5725	5850	6150	5405	5865	6285	4860	5130	4905	5153	5265	5535	4804	5214	5580
26	3614	28,24	3640	28,42	3900	30,47	3624	28,44	3640	28,65	3900	31,20					6396	6734	6448	6760	6916	7254	6245	6778	7254	5616	5928	5668	5954	6084	6396	5621	6100	6536	5054	5335	5101	5359	5476	5756	4996	5423	5803
27	3753	29,32	3780	29,51	4050	31,64	3764	29,54	3780	29,75	4050	32,40					6642	6993	6696	7020	7182	7533	6485	7039	7533	5832	6156	5886	6183	6318	6642	5837	6334	6788	5249	5540	5297	5565	5686	5978	5188	5631	6026
28	3892	30,41	3920	30,60	4200	32,82	3903	30,63	3920	30,86	4200	33,60					6888	7252	6944	7280	7448	7812	6726	7300	7812	6048	6384	6104	6412	6552	6888	6054	6569	7039	5443	5746	5494	5771	5897	6199	5380	5840	6250
29	4031	31,49	4060	31,70	4350	33,99	4043	31,73	4060	31,96	4350	34,80					7134	7511	7192	7540	7714	8091	6966	7560	8091	6264	6612	6322	6641	6786	7134	6270	6803	7291	5638	5951	5690	5977	6107	6421	5573	6048	6473
30	4170	32,58	4200	32,79	4500	35,16	4182	32,82	4200	33,06	4500	36,00					7380	7770	7440	7800	7980	8370	7206	7821	8370	6480	6840	6540	6870	7020	7380	6486	7038	7542	5832	6156	5886	6183	6318	6642	5765	6257	6696
31	4309	33,67	4340	33,88	4650	36,33	4321	33,91	4340	34,16	4650	37,20					7626	8029	7688	8060	8246	8649	7446	8082	8649	6696	7068	6758	7099	7254	7626	6702	7273	7793	6026	6361	6082	6389	6529	6863	5957	6465	6919
32	4448	34,75	4480	34,98	4800	37,50	4461	35,01	4480	35,26	4800	38,40					7872	8288	7936	8320	8512	8928	7686	8342	8928	6912	7296	6976	7328	7488	7872	6918	7507	8045	6221	6566	6278	6595	6739	7085	6149	6674	7142
33	4587	35,84	4620	36,07	4950	38,68	4600	36,10	4620	36,37	4950	39,60					8118	8547	8184	8580	8778	9207	7927	8603	9207	7128	7524	7194	7557	7722	8118	7135	7742	8296	6415	6772	6475	6801	6950	7306	6341	6882	7366
34	4726	36,92	4760	37,16	5100	39,85	4740	37,20	4760	37,47	5100	40,80					8364	8806	8432	8840	9044	9486	8167	8864	9486	7344	7752	7412	7786	7956	8364	7351	7976	8548	6610	6977	6671	7007	7160	7528	6533	7091	7589
35	4865	38,01	4900	38,26	5250	41,02	4879	38,29	4900	38,57	5250	42,00					8610	9065	8680	9100	9310	9765	8407	9125	9765	7560	7980	7630	8015	8190	8610	7567	8211	8799	6804	7182	6867	7214	7371	7749	6726	7300	7812
36	5004	39,10	5040	39,35	5400	42,19	5018	39,38	5040	39,67	5400	43,20					8856	9324	8928	9360	9576	10044	8647	9385	10044	7776	8208	7848	8244	8424	8856	7783	8446	9050	6998	7387	7063	7420	7582	7970	6918	7508	8035
37	5143	40,18	5180	40,44	5550	43,36	5158	40,48	5180	40,77	5550	44,40					9102	9583	9176	9620	9842	10323	8887	9646	10323	7992	8436	8066	8473	8658	9102	7999	8680	9302	7193	7592	7259	7626	7792	8192	7110	7717	8258

Sheaths

General

Strands are threaded through ducts (round or flat) made of steel strips or high-density polyethylene (HDPE) or polypropylene (PP) extruded resin, in corrugated or smooth shape depending on the project's requirements. Ducts must be sufficiently strong and durable for fabrication, transportation, installation, concrete placement, tendon stressing and sufficient leak tight meeting Int'l standards and guidelines (EN, ASTM, FIB and PTI).

To assure a better protection of the strands from corrosion - depending on the level of protection - it is advisable to use galvanized steel ducts or plastic PE/PP ducts. The latter is essential, in cases where structures are exposed to severe corrosion environment, subjected to fatigue loading, as well as in case of electrically isolated tendons (EIT) for railway bridges offering protection against stray currents.

Steel sheaths are flexible, bright, interlocked and grout tight fabricated using the continuous cold rolling and stapling of a flat steel strip (standard steel or galvanized) in widths of about 30-60 mm.
Plastic sheaths are made of polyolefin polymers. HDPE has perfect flexibility and impact strength, handling and weldability in a wide temperature range while PP has a higher shore hardness, better wear and heat resistance. Both PP and PE allow lower and more reliable friction coefficient which is beneficial due to design requirements for longer tendons.

The ducts are normally supplied (for transportation reasons) in lengths of 5,8 m (< 20 ft) or 11,8 m (< 40 ft) and are connected by means of couplers. The coupling system has a minimum typical length of 200-250 mm having a slightly larger diameter so as to be screwed or to be push-fit or even heat-shrunk (case of plastic ducts). Butt welding technique can be also applied in plastic ducts avoiding the use of couplers.


Push to fit coupler


Heat-shrink coupler


Butt welding


Segmental coupler

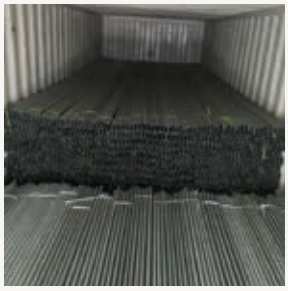
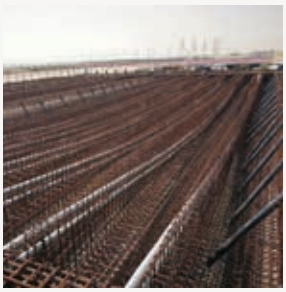
Installation

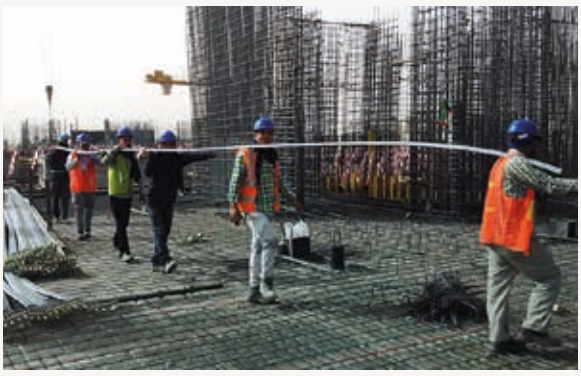
The installation of sheaths is taking place in parallel with the placement of reinforcement. Co-ordination between working staff is necessary in order to avoid installation defects and delays.

The proper installation of sheaths at the specified by the design geometry is of utmost importance. It is commonly accepted that the tendon's geometry has priority over reinforcement. The supporting points are made of stirrups located every 0.5 - 1 m as specified by the design and are wire-tight with the reinforcement forming a robust fitting, avoiding steep alignments of ducts beyond the applicable tolerances.

All couplings and connections along the sheath must be carefully tight and sealed, using a PVC tape in case of steel ducts or push to fit/heat shrink couplers and butt welding in case of plastic ducts.

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









As a rule of thumb the spacing should follow:

$X \geq \Phi_{external}$

$Y \geq \Phi_{external}$

$k \geq \Phi_{external}$

and k ≥ (concrete cover + rebars nominal diameter)

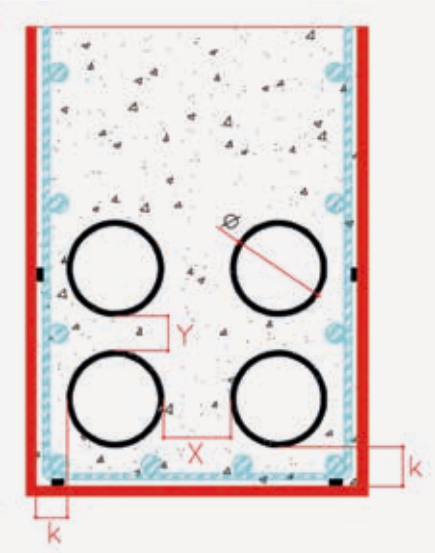


Fig.2 **Recommended Ducts Arrangement**

Installation of additional reinforcement is always recommended in areas where a tendon's geometry displays vicinity to the edge of the concrete.

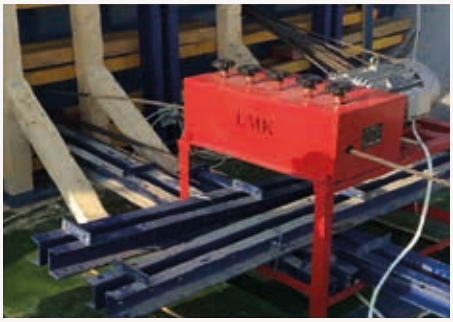
In case of external tendons applications, properly designed deviation saddles are being used. These deviators are made of pre-bended tubes casted into concrete or attached to specially designed steel units following a specific geometry. A common solution for segmental pre-casted construction is the use of bell-mouth pathways, formed by re-usable diabolo units flaring at each end within a range of angle in geometry.

External tendons are made of smooth plastic sheaths and filled with grout or grease / wax depending on design requirements.

Threading

Strands are threaded using a strand threading machine prior or after concreting according to the project's requirements (pushing or pulling method). In special cases (i.e. very long tendons and installation after concrete casting), strands can be installed using the pull through method with special sockets/ cups/torpedoes and winch.

Depending on the projects requirements (size, length and geometry of tendons), sheaths must have enlarged diameter accommodating a cross section area 2.0-2.5 times larger than the nominal net strand area.



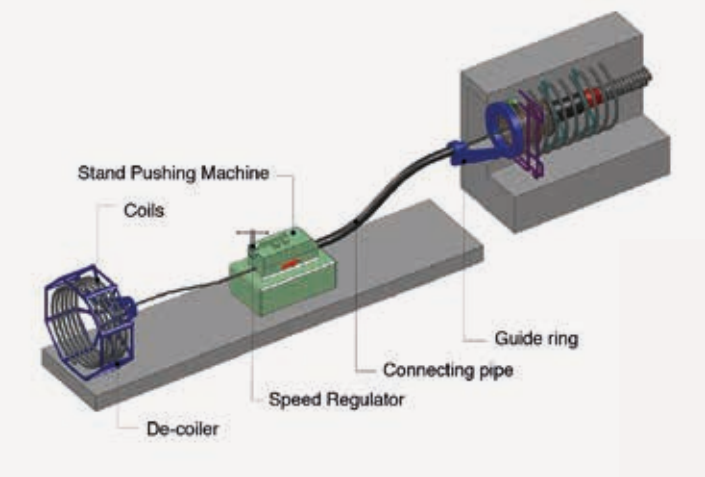


Fig.3 Pushing Method Configuration

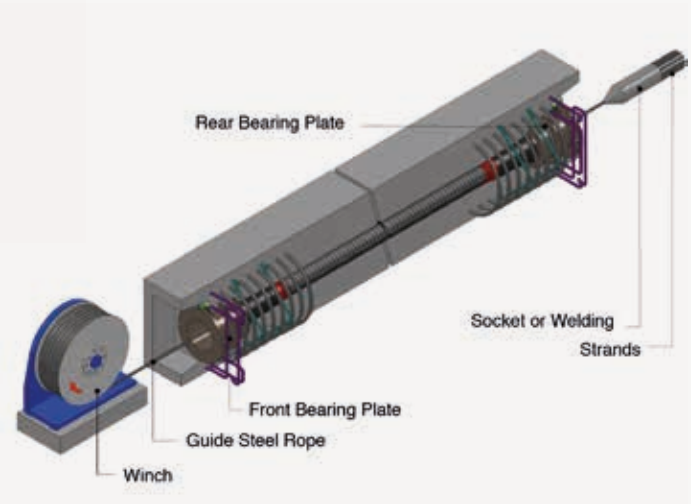


Fig.4 Pulling Method Configuration

Typical Sheath Dimensions

Table 2.1 ROUND STEEL DUCTS (0,6") CORRUGATED	DUCT		COUPLER	
				
	Φi	Φe	Φi	Φe
	mm	mm	mm	mm
up to 3 strands	45	50	50	55
4 strands	45	50	50	55
5 strands	50	55	55	60
6-7 strands	60	65	65	70
8-9 strands	75	80	80	85
10-12 strands	80	85	85	90
13-15 strands	85	90	90	95
16-19 strands	100	105	105	110
20-22 strands	105	110	110	115
23-27 strands	115	120	120	125
28-31 strands	125	130	130	135
32-37 strands	135	140	140	145

Table 2.2 ROUND STEEL DUCTS (0,5") CORRUGATED	DUCT		COUPLER	
				
	Φi	Φe	Φi	Φe
	mm	mm	mm	mm
up to 3 strands	40	45	45	50
4 strands	40	45	45	50
5 strands	40	45	45	50
6-7 strands	50	55	55	60
8-9 strands	55	60	60	65
10-13 strands	65	70	70	75
14-15 strands	70	75	75	80
16-19 strands	80	85	85	90
20-22 strands	85	90	90	95
23-27 strands	90	95	95	100
28-31 strands	100	105	105	110
32-37 strands	110	115	115	120

Table 2.3 ROUND PLASTIC DUCTS (0,6") CORRUGATED	DUCT	
		
	Φi	Φe
	mm	mm
up to 3 strands	40	55
4 strands	40	55
5 strands	50	65
6-7 strands	60	75
8-9 strands	80	96
10-12 strands	80	96
13-15 strands	85	103
16-19 strands	90	108
20-22 strands	100	122
23-27 strands	110	132
28-31 strands	110	132
32-37 strands	120	143

Table 2.4 ROUND PLASTIC DUCTS (0,5") CORRUGATED	DUCT	
		
	Φi	Φe
	mm	mm
up to 3 strands	30	45
4 strands	40	55
5 strands	40	55
6-7 strands	50	65
8-9 strands	60	75
10-13 strands	70	86
14-15 strands	80	96
16-19 strands	80	96
20-22 strands	80	96
23-27 strands	85	103
28-31 strands	90	108
32-37 strands	100	122

Table 2.5 FLAT STEEL CORRUGATED DUCTS (0,5" & 0,6")	DUCT		COUPLER	
				
	d x h	D x H	d x h	D x H
	mm	mm	mm	mm
2 strands	50x22	54x26	54x26	58x30
3 strands	60x22	64x26	64x26	70x30
4 strands	70x22	74x26	74x26	78x30
5 strands	90x22	94x26	94x26	98x30

Table 2.6 FLAT PLASTIC CORRUGATED DUCTS (0,5" & 0,6")	DUCT		COUPLER	
				
	d x h	D x H	d x h	D x H
	mm	mm	mm	mm
2 strands	50x22	65x35	65x35	75x48
3 strands	60x22	75x35	75x35	85x48
4 strands	70x22	86x35	86x35	95x48
5 strands	90x22	108x35	108x35	115x48

Table 2.7 ROUND PLASTIC DUCTS (0,6") SMOOTH	DUCT	
		
	Φi	Φe
	mm	mm
6-7 strands	66,4	75
8-9 strands	79,8	90
10-12 strands	79,8	90
13-15 strands	79,8	90
16-19 strands	97,4	110
20-22 strands	110,8	125
23-27 strands	110,8	125
28-31 strands	124	140
32-37 strands	124	140

Table 2.8 ROUND PLASTIC DUCTS (0,5") SMOOTH	DUCT	
		
	Φi	Φe
	mm	mm
8-9 strands	66,4	75
10-13 strands	79,8	90
14-15 strands	79,8	90
16-19 strands	79,8	90
20-22 strands	79,8	90
23-27 strands	79,8	90
28-31 strands	97,4	110
32-37 strands	110,8	125

Dimensions can be modified according to design requirements

Typical Tendons Geometry

Steel/Plastic Round Corrugated Sheaths

Table 3.1

INTERNAL TENDONS 0,5" & 0,6"	Tangent Length Mmin m	Radius of Curvature Rmin m
up to 2 strands	0,8	2,5
3	0,8	3
4	0,8	3,5
5	0,8	4
6	0,8	4
7	0,8	4,5
8	1	4,5
9	1	5
10	1	5,5
11	1	5,5
12	1	5,5
13	1	6
14	1	6
15	1	6,5
16	1	6,5
17	1	7
18	1	7
19	1	7
20	1	7,5
21	1	7,5
22	1	7,5
23	1	8
24	1	8
25	1	8
26	1,5	8,5
27	1,5	8,5
28	1,5	8,5
29	1,5	9
30	1,5	9
31	1,5	9
32	1,5	9
33	1,5	9,5
34	1,5	9,5
35	1,5	9,5
36	1,5	10
37	1,5	10

Recommended Values

Steel/Plastic Flat Corrugated Sheaths

Table 3.2

FLAT TENDONS 0,5" & 0,6"	Tangent Length Mmin m	Radius of Curvature Rmin m
up to 2 strands	0,5	2,5
3	0,5	2,5
4	0,5	2,5
5	0,5	2,5

Recommended Values

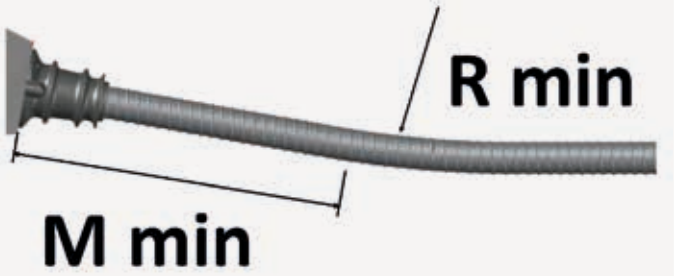


Fig.5 Tendon's Geometry

Plastic Round Smooth Sheaths

Table 3.3

EXTERNAL TENDONS	Radius of Curvature Rmin - (0,5") m	Radius of Curvature Rmin - (0,6") m
up to 6 strands	2	2
up to 7 strands	2	2,5
up to 8 strands	2	2,5
up to 9 strands	2,5	2,5
up to 13 strands	2,5	3
up to 14 strands	3	3
up to 16 strands	3	3,5
up to 17 strands	3	3,5
up to 19 strands	3	3,5
up to 25 strands	3,5	4
up to 32 strands	4	4,5
up to 33 strands	4	5
up to 37 strands	4,5	5

Recommended Values

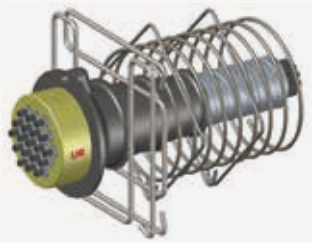
Anchorages

Types

The design of anchorages is in line with Int'l Standards (EN, AASHTO, F.I.B and PTI).

They are formed by cast iron units (bearing plates), steel anchor & coupling heads, couplers, wedges, swages, collars & protective covers, grouting ports, caps, etc. as per EN & ASTM specifications.

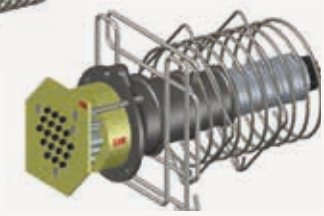
LMK-S stressing anchorages are formed by a steel anchor head where strands are individually gripped by wedges passing through the bearing plate (trump-plate).



LMK-S

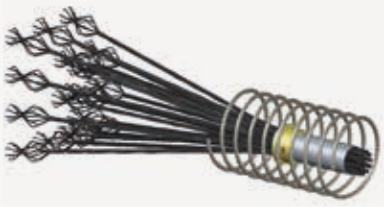
LMK-FS and **LMK-FSB** fixed anchorages are swaged types through a steel plate or through a bearing plate and anchor head with a pressing board that accommodates a better distribution of forces.

LMK-FS

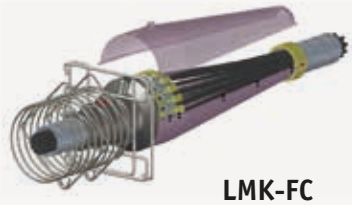


LMK-FSB

LMK-FB is a simplified solution for a fixed type where the bulb-end (known as onion type) of the strand is bonded to the concrete.



LMK-FB

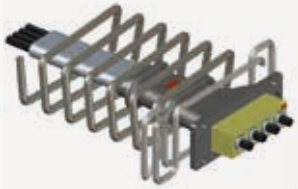


LMK-FC

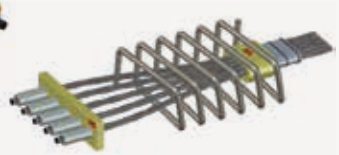
LMK-MC

LMK-FC and **LMK-MC** coupling anchorages are fixed type or movable type, used between adjoined construction members. Couplers are used to give continuity to the tendons, which due to their length or the construction method, cannot be installed or tensioned as one unit. The fixed types are used when stressing of the tendon of the previous member in a construction joint is needed, while movable types allow stressing of the tendon from the adjacent end.

LMK-FC is formed by a coupling head where strands coming from the precedent construction member are individually gripped by wedges passing through a bearing plate forming a stressing anchorage. The strands of the next adjacent member are swaged and gripped in the perimeter of the coupling head. **LMK-MC** is formed by a mono-coupling system gripping through wedges at both sides of the strands. All elements are placed inside a protective cover having a grout port.



LMK-SFL



LMK-FFL

LMK-FFC

LMK-FFB

LMK-SFL flat anchorages are stressing type, **LMK-FFL** & **LMK-FFB** fixed type and **LMK-FFC** coupling type. Flat anchorages are commonly used in building's thin slabs/ walls and bridge decks. Slab post-tensioning enables deflections and cracks under service conditions to be controlled while permitting larger and thinner spans.

Un-bonded mono-strand system, both for 13 mm (0.5") and 15 mm (0.6") type **LMK-U** can be used in cases where the design specifies un-bonded strands applications (greased and PE coated).

LMK-U

Block-out dimensions & reinforcement

The characteristic spacings X, Y and Z for typical concrete classes, according to the characteristic strength at 28 days, are given in Table 5. For concrete of intermediate strength interpolated data can be utilized.

The minimum recommended distances should not be considered when stressing adjacent anchorages simultaneously. In such case, the recommended distance X_2 must be modified accordingly.

In addition to the reinforcement according to the design, supplementary reinforcement is recommended to be placed in the force distribution zone behind the anchorage.

In cases where the length of a spiral is insufficient, lap splicing is required, considering overlapping length ≥ 52 times of spiral bar diameter (ΦH) (EN 1992-1-1/ section 8).

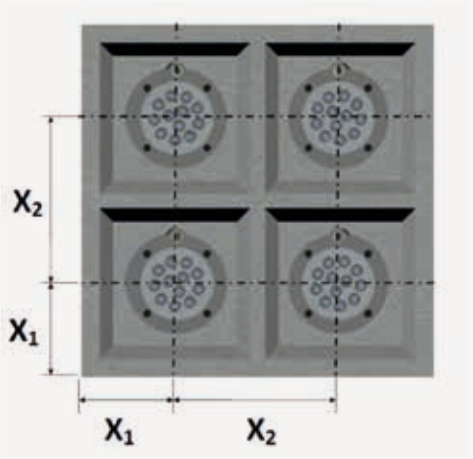


Fig.6 Typical Block-out Configuration Round Anchorages

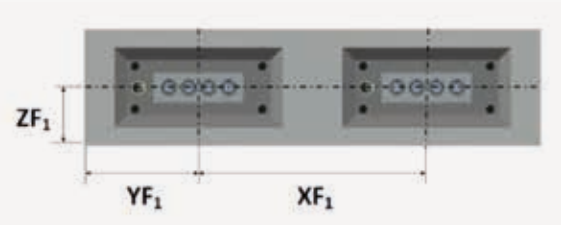


Fig.7 Typical Block-out Configuration Flat Anchorages

The provided values in the following Tables are recommended values and can be modified according to the needs and specifications of each individual project.

Table 4 Recommended Concrete Cover depending on the Environment

Exposure Classes EN 206	Environment	Typical Cases	Cover (mm)
Corrosion induced by carbonation			
XC1	Dry or permanently wet	Buildings	30
XC2	Wet, rarely dry	Foundations	45
XC3	Moderate humidity	Sheltered from rain	45
XC4	Cyclic wet and dry	Water contact	50
Corrosion induced by chlorides excluding sea-water			
XD1	Moderate humidity	Concrete exposed to chlorides	50
XD2	Wet, rarely dry	Swimming pools	55
XD3	Cyclic wet and dry	Pavements & car park slabs	55

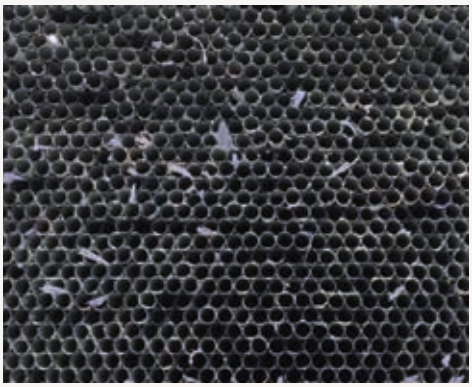
Recommended Minimum Anchorages Arrangement

Tables 5 Round & Flat Anchorages

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

STRAND Nos.	min XF_1	min YF_1	min ZF_1	min XF_1	min YF_1	min ZF_1
	Cement Class C30/37			Cement Class C35/45		
	mm	mm	mm	mm	mm	mm
2	340	115	75	330	110	70
3	360	135	80	350	130	75
4	390	170	95	380	165	90
5	410	185	100	400	180	95

Concrete cover must be added to the above X_1, YF_1 and ZF_1 values as per design requirements

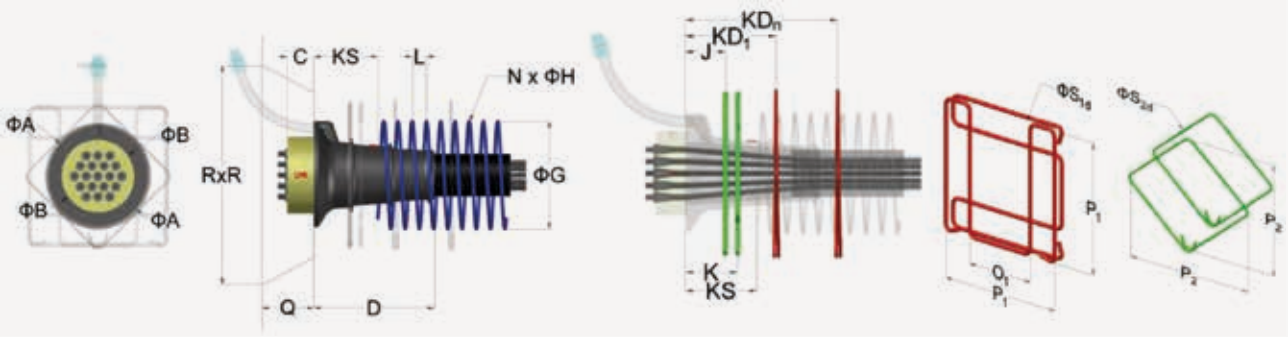


LMK-S M15 (0.6") - STRESSING ANCHORAGE

Table 6.1

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	KD_1	KD_2	KD_3	KD_4	KD_5	R x R	Q
TYPE	mm	mm	mm	mm	mm	Nos	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm	Nos	mm	mm	mm	mm	mm	mm x mm	mm
1M15	--	--	50	48	140	6	10	50	15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	165	90
2M15	132	80	86	50	180	6	10	50	15	210	110	6	65	2	85	--	--	--	--	--	--	--	--	220	90
3M15	136	110	91	50	200	6	10	50	15	210	110	6	65	2	85	--	--	--	--	--	--	--	--	270	90
4M15	150	130	102	50	210	6	10	50	15	210	110	6	65	2	85	--	--	--	--	--	--	--	--	270	90
5M15	165	135	115	50	230	7	10	50	15	265	140	8	65	2	85	--	--	--	--	--	--	--	--	330	90
6M15	180	170	126	52	280	8	10	50	15	310	160	10	60	2	90	300	8	3	140	270	400	--	--	330	120
7M15	180	170	126	53	280	8	10	50	15	310	160	10	60	2	90	300	8	3	140	270	400	--	--	360	120
8M15	210	190	146	55	320	8	12	60	20	340	190	12	70	2	100	350	8	3	145	275	405	--	--	360	120
9M15	210	190	146	55	320	8	12	60	20	340	190	12	70	2	100	350	8	3	145	275	405	--	--	395	120
10M15	225	230	166	58	370	9	12	60	20	380	195	14	70	2	110	390	8	3	170	320	470	--	--	395	120
11M15	225	230	166	60	370	9	12	60	20	380	195	14	70	2	110	390	8	3	170	320	470	--	--	395	120
12M15	225	230	166	60	370	9	12	60	20	380	195	14	70	2	110	390	8	3	170	320	470	--	--	420	130
13M15	255	250	176	63	400	10	14	60	20	425	205	14	70	2	110	430	10	4	170	320	470	620	--	420	130
14M15	255	250	176	65	400	10	14	60	20	425	205	14	70	2	110	430	10	4	170	320	470	620	--	470	130
15M15	255	250	186	68	400	10	14	60	20	425	205	14	70	2	110	430	10	4	170	320	470	620	--	470	140
16M15	280	325	196	70	450	11	14	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--	485	140
17M15	280	325	196	73	450	11	14	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--	485	140
18M15	280	325	206	75	450	11	14	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--	500	140
19M15	280	325	206	75	450	11	14	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--	500	140
20M15	310	325	226	80	460	12	16	60	30	540	255	16	70	2	120	500	10	4	180	330	480	630	--	500	150
21M15	310	325	226	80	460	12	16	60	30	540	255	16	70	2	120	500	10	4	180	330	480	630	--	545	150
22M15	310	325	226	80	460	12	16	60	30	540	255	16	70	2	120	500	10	4	180	330	480	630	--	545	150
23M15	340	350	244	82	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790	575	150
24M15	340	350	244	82	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790	575	150
25M15	340	350	244	85	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790	575	150
26M15	340	350	244	85	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790	575	150
27M15	340	350	244	85	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790	620	150
28M15	360	380	260	88	500	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790	620	150
29M15	360	380	260	88	500	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790	620	150
30M15	360	380	260	90	500	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790	630	150
31M15	360	380	260	90	500	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790	630	150
32M15	405	500	296	95	520	15	18	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795	700	170
33M15	405	500	296	95	520	15	18	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795	700	170
34M15	405	500	296	95	520	15	18	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795	700	170
35M15	405	500	296	100	520	15	18	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795	700	170
36M15	405	500	296	100	520	15	18	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795	700	170
37M15	405	500	296	100	520	15	18	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795	700	170

Recommended values for Spiral, Bursting reinforcement & Recess



Stressing Anchorage Front & Side View

Reinforcement Configuration

W Stirrups

◊ Additional Bursting Reinforcement

LMK-S M15 (0.6") - STRESSING ANCHORAGE

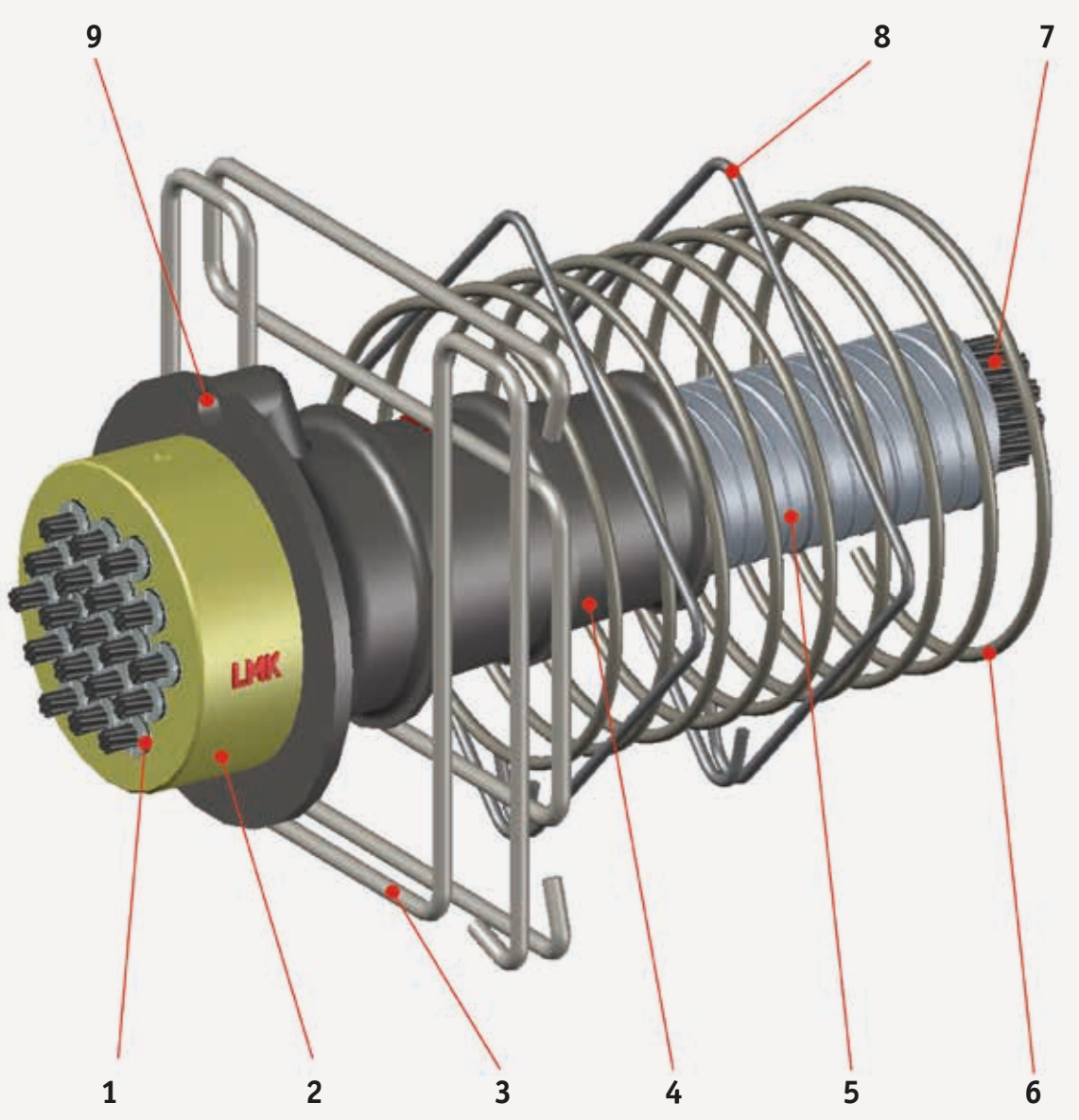


Fig.8.1 Stressing Anchorage Axonometric View

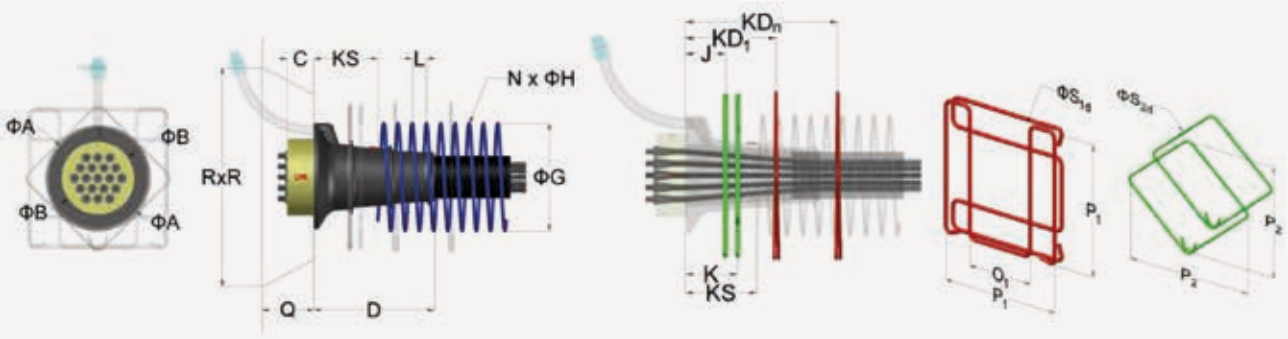
S/N	DESCRIPTION
1	WEDGES
2	ANCHOR HEAD
3	"W" STIRRUPS can be modified according to design requirements
4	BEARING PLATE ensure proper anchorage distance X_2 when simultaneously stressing
5	DUCT Sheath diameter can be modified according to design requirements
6	SPIRAL
7	STRANDS
8	"◊" ADDITIONAL BURSTING REINFORCEMENT distributed along the spiral length
9	GROUT PORT

LMK-S M13 (0.5") - STRESSING ANCHORAGE

Table 6.2

LMK - S	BEARING PLATE		ANCHOR HEAD		SPIRAL					W STIRRUPS						□ STIRRUPS							RECESS	
	ΦA	D	ΦB	C	ΦG M13	N	ΦH	L	KS	P_1	O_1	ΦS_{1d}	J	N	K	P_2	ΦS_{2d}	N	KD_1	KD_2	KD_3	KD_4	KD_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	mm	mm	mm	mm	mm x mm	mm
1M13	--	--	40	40	100	6	8	50	15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	165	90
2M13	132	80	75	45	130	6	8	50	15	210	110	6	65	2	85	--	--	--	--	--	--	--	--	220	90
3M13	132	80	80	45	130	6	12	50	15	210	110	6	65	2	85	--	--	--	--	--	--	--	--	270	90
4M13	140	110	85	48	150	6	12	50	15	210	110	6	65	2	85	--	--	--	--	--	--	--	--	270	90
5M13	140	125	100	48	170	7	12	50	15	265	140	8	65	2	85	--	--	--	--	--	--	--	--	330	90
6M13	165	135	105	48	205	8	12	50	15	310	160	10	60	2	90	300	8	3	140	270	400	--	--	330	120
7M13	165	135	105	50	210	8	12	50	15	310	160	10	60	2	90	300	8	3	140	270	400	--	--	360	120
8M13	175	170	126	52	240	8	12	60	20	340	190	12	70	2	100	350	8	3	145	275	405	--	--	360	120
9M13	175	170	126	53	240	8	12	60	20	340	190	12	70	2	100	350	8	3	145	275	405	--	--	395	120
10M13	210	210	146	53	270	9	14	60	20	380	195	14	70	2	110	390	8	3	170	320	470	--	--	395	120
11M13	210	210	146	53	275	9	14	60	20	380	195	14	70	2	110	390	8	3	170	320	470	--	--	395	120
12M13	210	210	146	55	280	9	14	60	20	380	195	14	70	2	110	390	8	3	170	320	470	--	--	420	130
13M13	210	210	146	55	305	10	14	60	20	425	205	14	70	2	110	430	10	4	170	320	470	620	--	420	130
14M13	214	230	166	57	310	10	14	60	20	425	205	14	70	2	110	430	10	4	170	320	470	620	--	470	130
15M13	214	230	166	60	320	10	14	60	20	425	205	14	70	2	110	430	10	4	170	320	470	620	--	470	140
16M13	255	270	176	62	340	11	16	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--	485	140
17M13	255	270	176	62	340	11	16	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--	485	140
18M13	255	270	176	65	345	11	16	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--	500	140
19M13	255	270	176	65	340	11	16	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--	500	140
20M13	260	365	196	68	355	12	16	60	30	540	255	16	70	2	120	500	10	4	180	330	480	630	--	500	150
21M13	260	365	196	70	355	12	16	60	30	540	255	16	70	2	120	500	10	4	180	330	480	630	--	545	150
22M13	260	365	196	70	360	12	16	60	30	540	255	16	70	2	120	500	10	4	180	330	480	630	--	545	150
23M13	275	380	216	73	375	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790	575	150
24M13	275	380	216	73	375	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790	575	150
25M13	275	380	216	75	375	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790	575	150
26M13	275	380	216	75	380	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790	575	150
27M13	275	380	216	75	380	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790	620	150
28M13	300	400	224	78	395	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790	620	150
29M13	300	400	224	78	395	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790	620	150
30M13	300	400	224	80	395	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790	630	150
31M13	300	400	224	80	400	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790	630	150
32M13	330	430	244	82	405	15	16	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795	700	170
33M13	330	430	244	82	415	15	16	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795	700	170
34M13	330	430	244	82	415	15	16	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795	700	170
35M13	330	430	244	85	420	15	16	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795	700	170
36M13	330	430	244	85	420	15	16	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795	700	170
37M13	330	430	244	85	430	15	16	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795	700	170

Recommended values for Spiral, Bursting reinforcement & Recess



Stressing Anchorage Front & Side View | **Reinforcement Configuration** | **W Stirrups** | **◊ Additional Bursting Reinforcement**

LMK-S M13 (0.5") - STRESSING ANCHORAGE

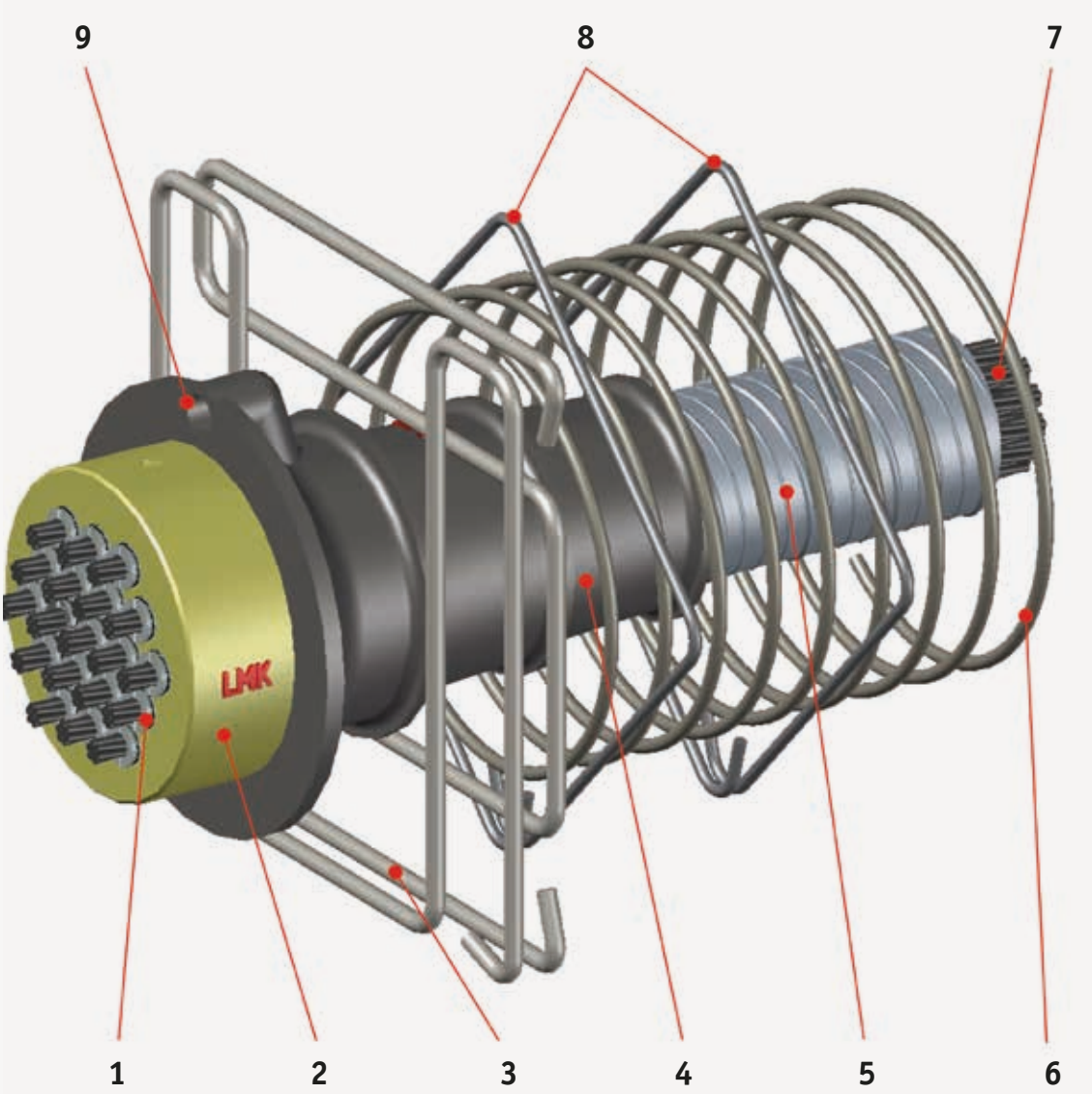


Fig.8.2 Stressing Anchorage Axonometric View

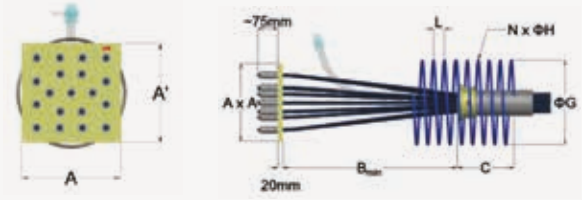
S/N	DESCRIPTION
1	WEDGES
2	ANCHOR HEAD
3	"W" STIRRUPS can be modified according to design requirements
4	BEARING PLATE ensure proper anchorage distance X_2 when simultaneously stressing
5	DUCT Sheath diameter can be modified according to design requirements
6	SPIRAL
7	STRANDS
8	"◊" ADDITIONAL BURSTING REINFORCEMENT distributed along the spiral length
9	GROUT PORT

LMK-FS M15 (0.6") & M13 (0.5") - FIXED SWAGED ANCHORAGE

Table 6.3

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

Recommended values for Spiral



Fixed Swaged Anchorage Front & Side View

LMK-FS M15 (0.6") & M13 (0.5") - FIXED SWAGED ANCHORAGE

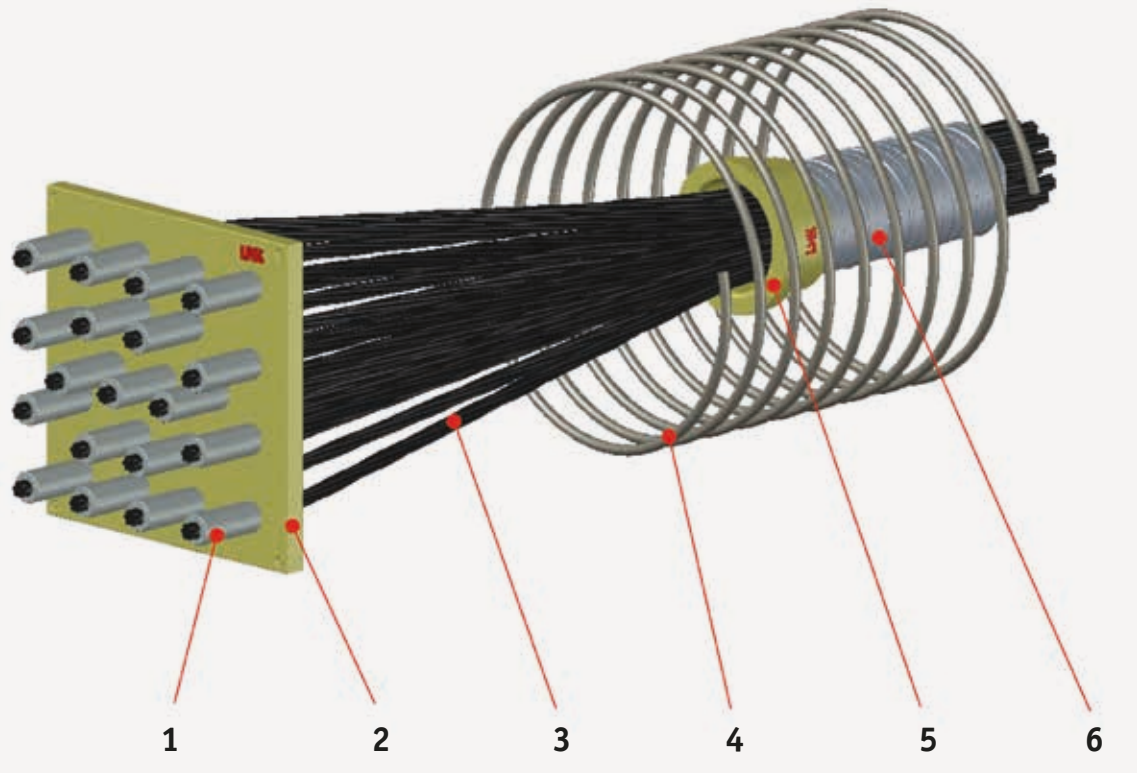


Fig.9 **Fixed Swaged Anchorage Axonometric View**

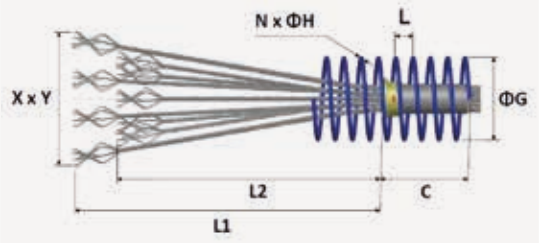
S/N	DESCRIPTION
1	SWAGES
2	ANCHOR HEAD
3	STRANDS
4	SPIRAL
5	COLLAR
6	DUCT Sheath diameter can be modified according to design requirements

LMK-FB M15 (0.6") & M13 (0.5") - FIXED BULB ANCHORAGE

Table 6.4

LMK - FB	BULB CONFIGURATION			SPIRAL				
	X x Y	L1	L2	ΦG	N	ΦH	C	L
TYPE	mm	mm	mm	mm	Nos	mm	mm	mm
2M15	190 X 210	900	--	180	6	10	110	50
2M13	190 X 210	900	--	130	6	12	85	50
3M15	190 X 210	900	--	180	6	10	110	50
3M13	190 X 210	900	--	130	6	12	85	50
4M15	190 X 210	900	--	210	6	10	110	50
4M13	190 X 210	900	--	150	6	12	110	50
5M15	250 X 270	1000	850	230	7	12	110	60
5M13	250 X 270	1000	850	170	7	12	110	60
6M15	250 X 270	1000	850	280	8	12	120	60
6M13	250 X 270	1000	850	205	8	12	110	60
7M15	250 X 270	1000	850	280	8	12	120	60
7M13	250 X 270	1000	850	210	8	12	110	60
8M15	250 X 270	1000	850	320	8	12	120	60
8M13	250 X 270	1000	850	240	8	12	110	60
9M15	280 X 420	1100	950	320	8	12	120	60
9M13	280 X 420	1100	950	240	8	14	120	60
10M15	280 X 420	1100	950	370	9	12	135	60
10M13	280 X 420	1100	950	270	9	14	120	60
11M15	280 X 420	1100	950	370	9	12	135	60
11M13	280 X 420	1100	950	275	9	14	120	60
12M15	280 X 420	1100	950	370	9	12	135	60
12M13	280 X 420	1100	950	280	9	14	120	60
13M15	380 X 390	1100	950	400	10	14	135	60
13M13	380 X 390	1100	950	305	10	16	135	60
14-15M15	380 X 390	1100	950	400	10	14	135	60
14-15M13	380 X 390	1100	950	320	10	16	135	60
16M15	380 X 390	1100	950	450	11	14	135	60
16M13	380 X 390	1100	950	340	11	16	135	60
17M15	380 X 490	1200	1050	450	11	14	135	60
17M13	380 X 490	1200	1050	340	11	16	135	60
18-19M15	380 X 490	1200	1050	450	11	14	135	60
18-19M13	380 X 490	1200	1050	340	11	16	135	60
20-23M15	470 X 470	1300	1150	460	12	16	135	60
20-23M13	470 X 470	1300	1150	355	12	16	135	60
24-27M15	560 X 470	1400	1250	480	13	16	135	60
24-27M13	560 X 470	1400	1250	380	13	16	135	60
28-31M15	510 X 570	1500	1350	500	14	16	135	60
28-31M13	510 X 570	1500	1350	400	14	16	135	60
32-35M15	600 X 650	1600	1450	520	15	18	135	60
32-35M13	600 X 650	1600	1450	420	15	16	135	60
36-37M15	600 X 650	1600	1450	520	15	18	135	60
36-37M13	600 X 650	1600	1450	430	15	16	135	60

Recommended values for Spiral



Fixed Bulb Anchorage Side View

LMK-FB M15 (0.6") & M13 (0.5") - FIXED BULB ANCHORAGE

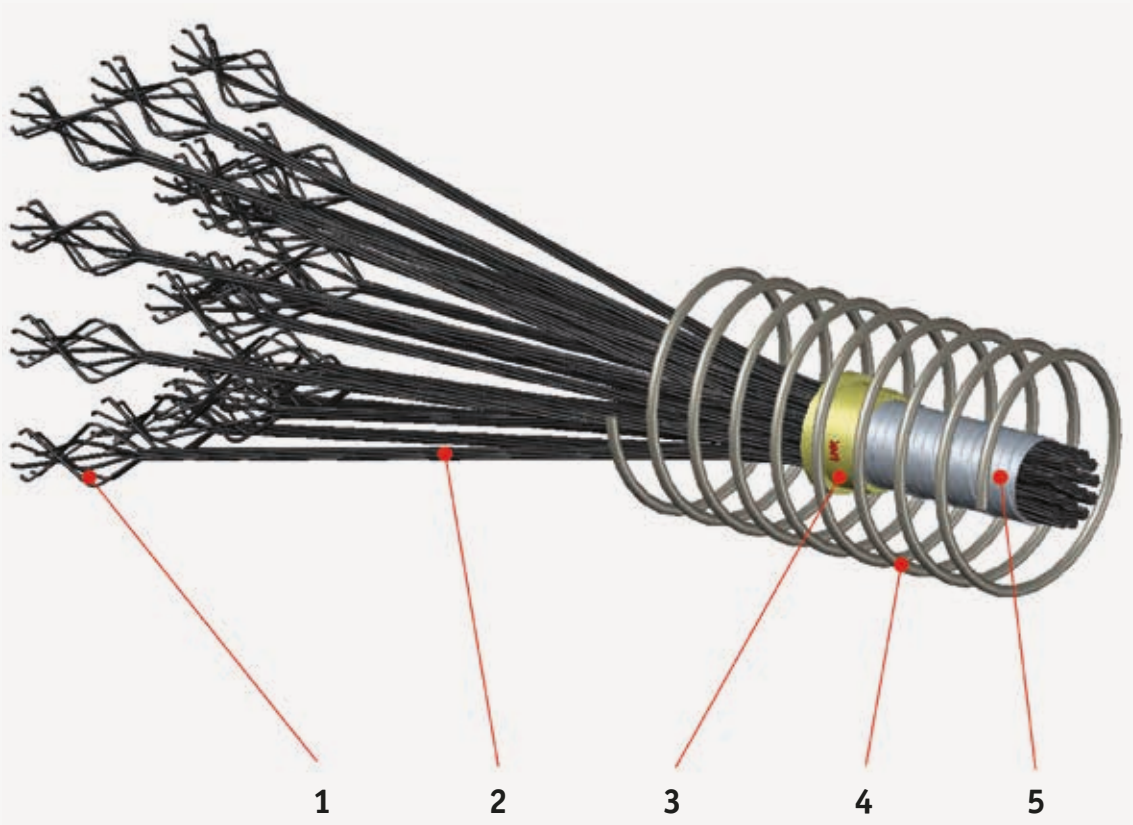


Fig.10 **Fixed Bulb Anchorage Axonometric View**

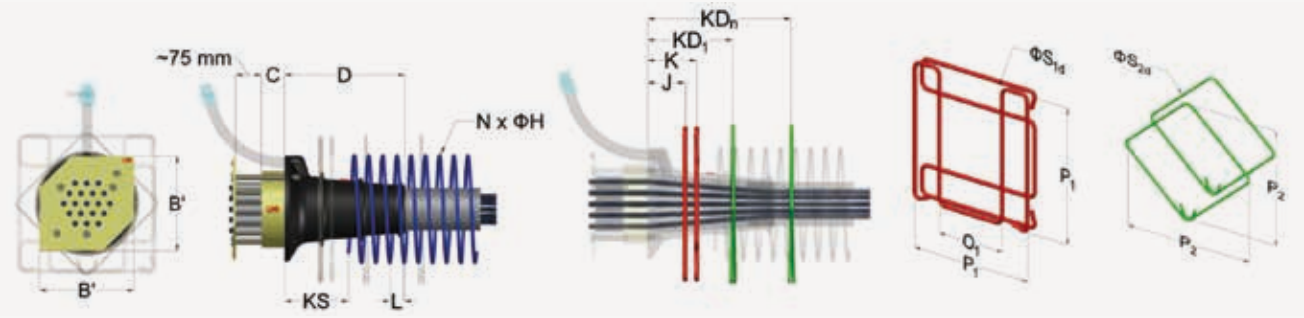
S/N	DESCRIPTION
1	BULBS
2	STRANDS
3	COLLAR
4	SPIRAL
5	DUCT Sheath diameter can be modified according to design requirements

LMK-FSB M15 (0.6") & M13 (0.5") - FIXED SWAGED ANCHORAGE with BEARING PLATE

Table 6.5 (for M13 refer to Table 6.2)

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_{1a}	J	N	K	P_2	ΦS_{2a}	N	KD_1	KD_2	KD_3	KD_4	KD_5
TYPE	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm	Nos	mm	mm	mm	mm	mm
3M15	136	110	91	50	135	8	200	6	10	50	15	210	110	6	65	2	85	--	--	--	--	--	--	--	--
4M15	150	130	102	50	150	8	210	6	10	50	15	210	110	6	65	2	85	--	--	--	--	--	--	--	--
5M15	165	135	115	50	170	8	230	7	10	50	15	265	140	8	65	2	85	--	--	--	--	--	--	--	--
6M15	180	170	126	52	180	8	280	8	10	50	15	310	160	10	60	2	90	300	8	3	140	270	400	--	--
7M15	180	170	126	53	180	8	280	8	10	50	15	310	160	10	60	2	90	300	8	3	140	270	400	--	--
8M15	210	190	146	55	195	8	320	8	12	60	20	340	190	12	70	2	100	350	8	3	145	275	405	--	--
9M15	210	190	146	55	215	8	320	8	12	60	20	340	190	12	70	2	100	350	8	3	145	275	405	--	--
10M15	225	230	166	58	230	8	370	9	12	60	20	380	195	14	70	2	110	390	8	3	170	320	470	--	--
11M15	225	230	166	60	240	8	370	9	12	60	20	380	195	14	70	2	110	390	8	3	170	320	470	--	--
12M15	225	230	166	60	240	8	370	9	12	60	20	380	195	14	70	2	110	390	8	3	170	320	470	--	--
13M15	255	250	176	63	245	8	400	10	14	60	20	425	205	14	70	2	110	430	10	4	170	320	470	620	--
14M15	255	250	176	65	250	8	400	10	14	60	20	425	205	14	70	2	110	430	10	4	170	320	470	620	--
15M15	255	250	186	68	255	8	400	10	14	60	20	425	205	14	70	2	110	430	10	4	170	320	470	620	--
16M15	280	325	196	70	265	8	450	11	14	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--
17M15	280	325	196	73	235	8	450	11	14	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--
18M15	280	325	206	75	270	8	450	11	14	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--
19M15	280	325	206	75	270	8	450	11	14	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--
20M15	310	325	226	80	300	8	460	12	16	60	30	540	255	16	70	2	120	500	10	4	180	330	480	630	--
21M15	310	325	226	80	300	8	460	12	16	60	30	540	255	16	70	2	120	500	10	4	180	330	480	630	--
22M15	310	325	226	80	300	8	460	12	16	60	30	540	255	16	70	2	120	500	10	4	180	330	480	630	--
23M15	340	350	244	82	315	8	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790
24M15	340	350	244	82	315	8	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790
25M15	340	350	244	85	315	8	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790
26M15	340	350	244	85	315	8	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790
27M15	340	350	244	85	315	8	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790
28M15	360	380	260	88	330	8	500	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790
29M15	360	380	260	88	330	8	500	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790
30M15	360	380	260	90	330	8	500	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790
31M15	360	380	260	90	330	8	500	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790
32M15	405	500	296	95	440	8	520	15	18	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795
33M15	405	500	296	95	440	8	520	15	18	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795
34M15	405	500	296	95	440	8	520	15	18	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795
35M15	405	500	296	100	440	8	520	15	18	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795
36M15	405	500	296	100	440	8	520	15	18	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795
37M15	405	500	296	100	440	8	520	15	18	60	45	680	350	20	75	2	125	600	14	5	195	345	495	645	795

Recommended values for Spiral & Bursting Reinforcement



Stressing Anchorage Front & Side View

Reinforcement Configuration

W Stirrups

◊ Additional Bursting Reinforcement

LMK-FSB M15 (0.6") & M13 (0.5") - FIXED SWAGED ANCHORAGE with BEARING PLATE

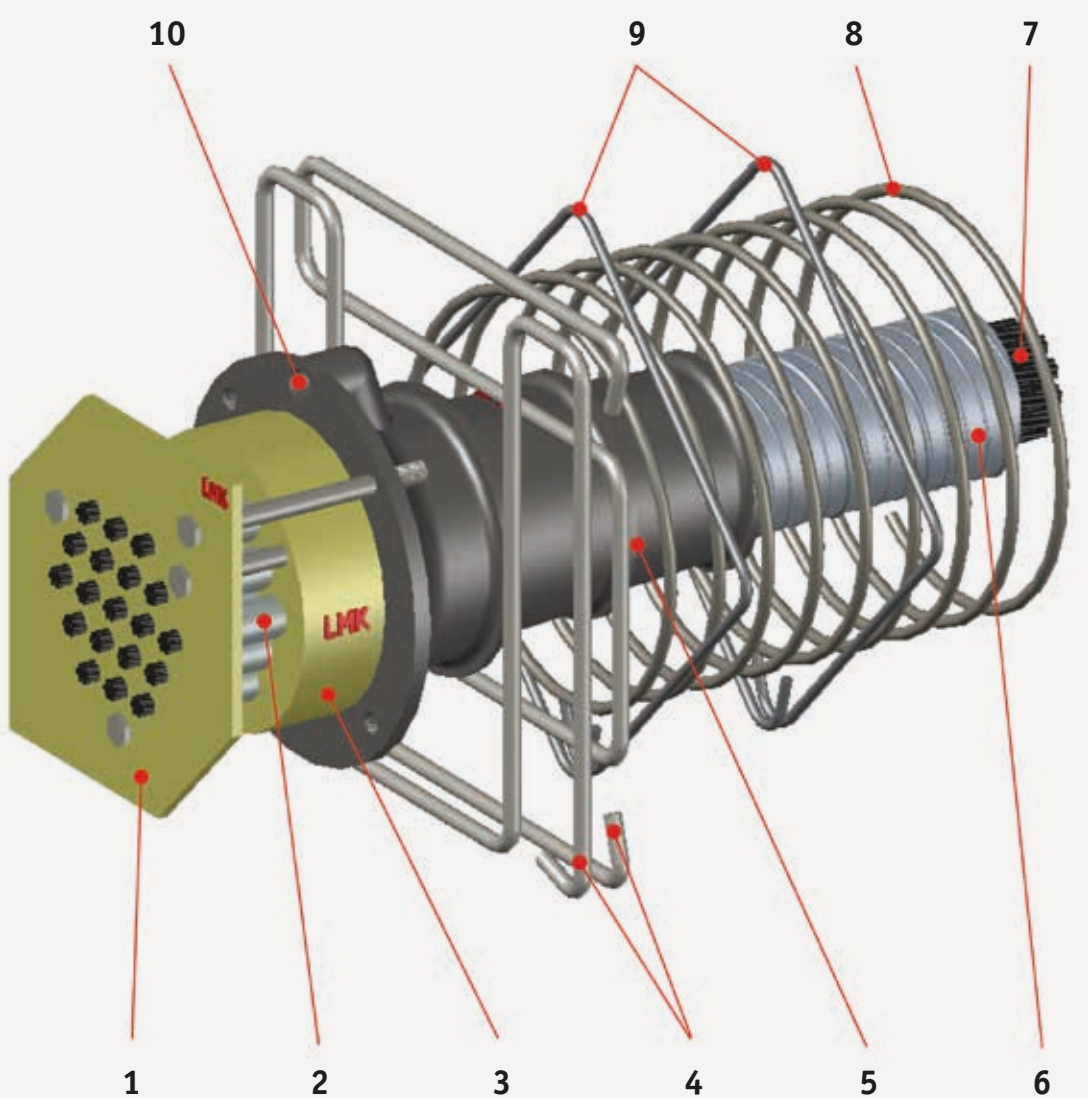


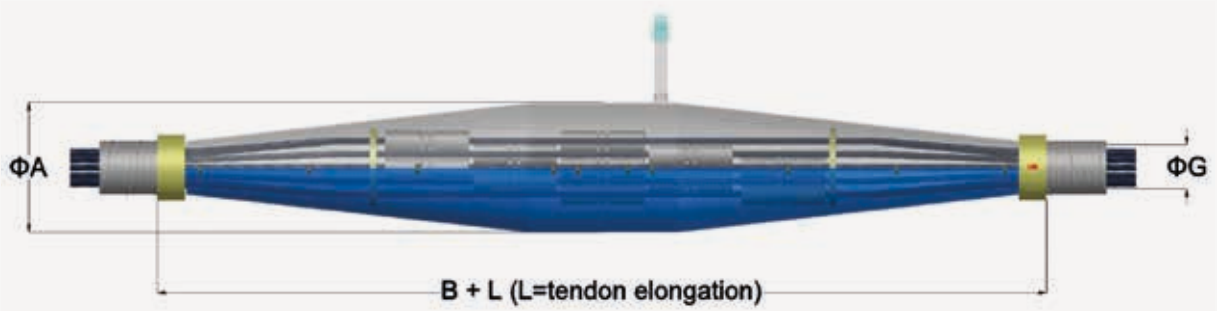
Fig.11 Fixed Swaged with Bearing Plate Anchorage Axonometric View

S/N	DESCRIPTION
1	PRESSING BOARD
2	SWAGES
3	ANCHOR HEAD
4	"W" STIRRUPS can be modified according to design requirements
5	BEARING PLATE ensure proper anchorage distance X_2 when simultaneously stressing
6	DUCT Sheath diameter can be mod ified according to design requirements
7	STRANDS
8	SPIRAL
9	"◊" ADDITIONAL BURSTING REINFORCEMENT distributed along the spiral length
10	GROUT PORT

LMK-MC M15 (0.6") & M13 (0.5") - MOVABLE COUPLER

Table 6.6

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



Movable Coupler Side View

Movable Coupler Rear View

LMK-MC M15 (0.6") & M13 (0.5") - MOVABLE COUPLER

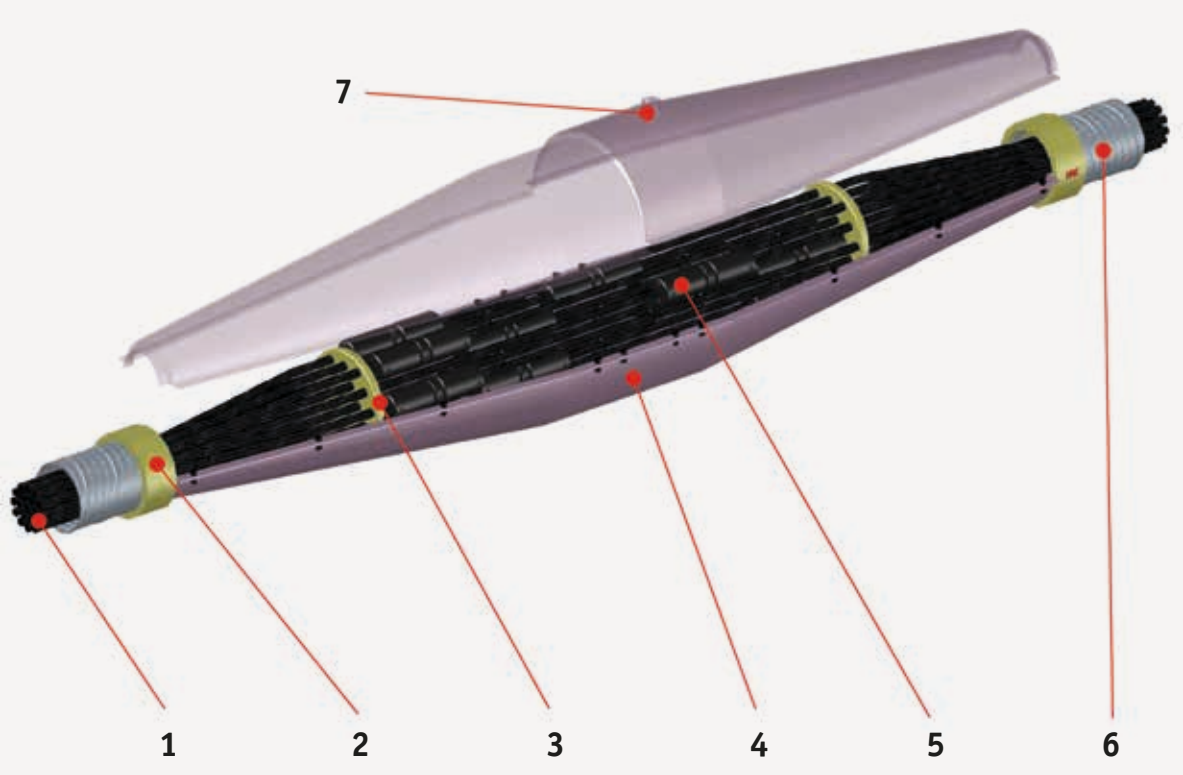


Fig.12.1 Movable Coupler Axonometric View

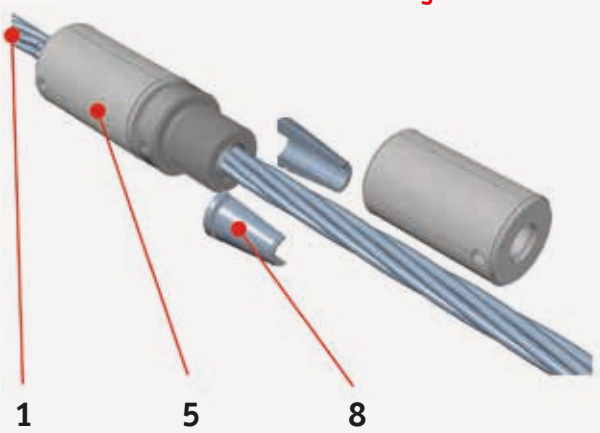


Fig.12.2 Mono-Coupler Axonometric View

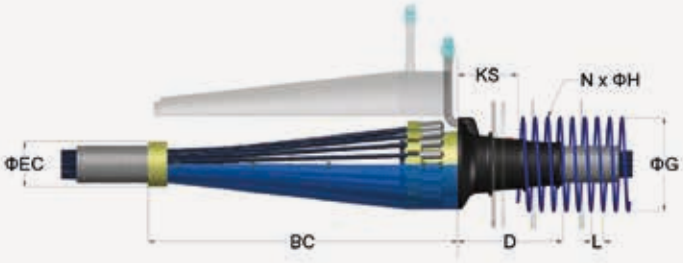
S/N	DESCRIPTION
1	STRANDS
2	COLLAR
3	SPREADING BOARD
4	PROTECTIVE COVER
5	MONO-COUPLER
6	DUCT Sheath diameter can be modified according to design requirements
7	GROUT PORT
8	MONO-COUPLER INNER WEDGES

LMK-FC M15 (0.6") & M13 (0.5") - FIXED COUPLER

Table 6.7 (for M13 refer to Table 6.2)

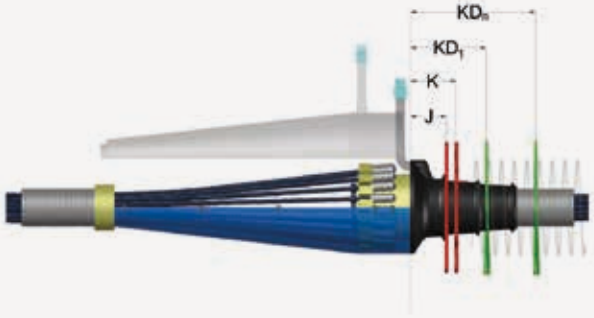
LMK - FC	BEARING PLATE		COUPLER BEARING PLATE & PROTECTIVE COVER				SPIRAL					W STIRRUPS						□ STIRRUPS							
	ΦA	D	AC	BC	ΦDC	ΦEC	ΦG	N	ΦH	L	KS	P1	O1	ΦS_{1d}	J	N	K	P_2	ΦS_{2d}	N	KD_1	KD_2	KD_3	KD_4	KD_5
TYPE	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm	Nos	mm	mm	mm	mm	mm
2M15	132	80	216	599	136	80	180	6	10	50	15	210	110	6	65	2	85	--	--	--	--	--	--	--	--
3M15	136	110	220	617	146	80	200	6	10	50	15	210	110	6	65	2	85	--	--	--	--	--	--	--	--
4M15	150	130	232	669	157	85	210	6	10	50	15	210	110	6	65	2	85	--	--	--	--	--	--	--	--
5M15	165	135	244	722	170	85	230	7	10	50	15	265	140	8	65	2	85	--	--	--	--	--	--	--	--
6M15	180	170	258	722	183	100	280	8	10	50	15	310	160	10	60	2	90	300	8	3	140	270	400	--	--
7M15	180	170	258	722	183	100	280	8	10	50	15	310	160	10	60	2	90	300	8	3	140	270	400	--	--
8M15	210	190	266	722	191	110	320	8	12	60	20	340	190	12	70	2	100	350	8	3	145	275	405	--	--
9M15	210	190	276	757	201	110	320	8	12	60	20	340	190	12	70	2	100	350	8	3	145	275	405	--	--
10M15	225	230	288	766	213	120	370	9	12	60	20	380	195	14	70	2	110	390	8	3	170	320	470	--	--
11M15	225	230	298	810	223	120	370	9	12	60	20	380	195	14	70	2	110	390	8	3	170	320	470	--	--
12M15	225	230	298	810	223	120	370	9	12	60	20	380	195	14	70	2	110	390	8	3	170	320	470	--	--
13M15	255	250	302	837	227	120	400	10	14	60	20	425	205	14	70	2	110	430	10	4	170	320	470	620	--
14M15	255	250	308	839	234	120	400	10	14	60	20	425	205	14	70	2	110	430	10	4	170	320	470	620	--
15M15	255	250	320	862	246	120	400	10	14	60	20	425	205	14	70	2	110	430	10	4	170	320	470	620	--
16M15	280	325	330	906	256	120	450	11	14	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--
17M15	280	325	330	906	256	120	450	11	14	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--
18M15	280	325	336	933	261	140	450	11	14	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--
19M15	280	325	336	933	261	140	450	11	14	60	30	500	215	14	70	2	110	480	10	4	170	320	470	620	--
20M15	310	325	356	1020	282	180	460	12	16	60	30	540	255	16	70	2	120	500	10	4	180	330	480	630	--
21M15	310	325	356	1020	282	180	460	12	16	60	30	540	255	16	70	2	120	500	10	4	180	330	480	630	--
22M15	310	325	356	1020	282	180	460	12	16	60	30	540	255	16	70	2	120	500	10	4	180	330	480	630	--
23M15	340	350	386	1064	310	180	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790
24M15	340	350	386	1064	310	180	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790
25M15	340	350	386	1064	310	180	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790
26M15	340	350	386	1064	310	180	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790
27M15	340	350	386	1064	310	180	480	13	16	60	40	570	275	16	75	2	125	530	12	5	190	340	490	640	790
28M15	360	380	434	1231	358	180	500	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790
29M15	360	380	434	1241	358	180	500	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790
30M15	360	380	434	1241	358	180	500	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790
31M15	360	380	434	1241	358	180	500	14	16	60	40	635	315	18	75	2	125	540	14	5	190	340	490	640	790

Recommended values for Spiral & Bursting Reinforcement

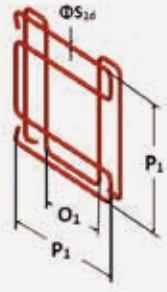


Fixed Coupler Side View

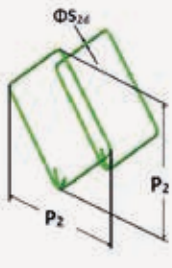
Rear View



Reinforcement Configuration



W Stirrups



◊ Additional Bursting Reinforcement

LMK-FC M15 (0.6") & M13 (0.5") - FIXED COUPLER

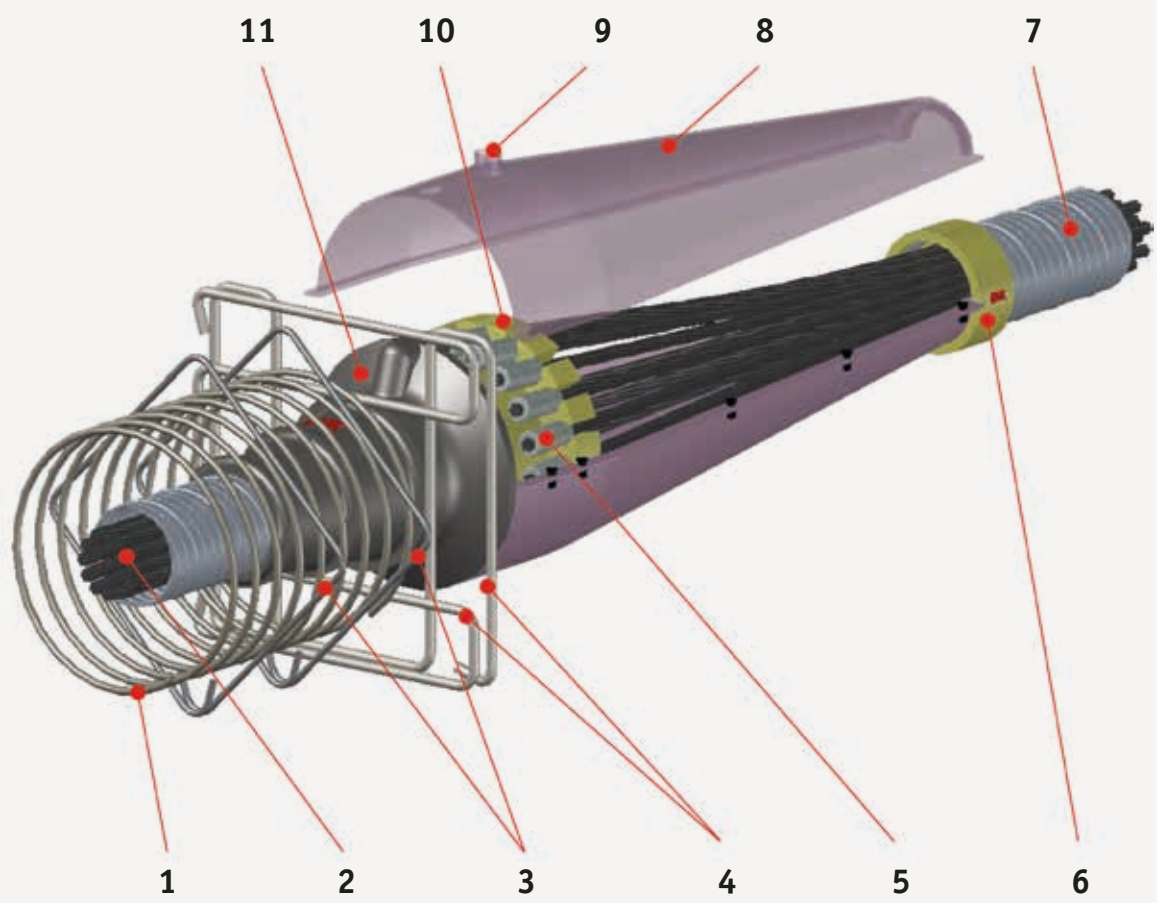


Fig.13 **Fixed Coupler Axonometric View**

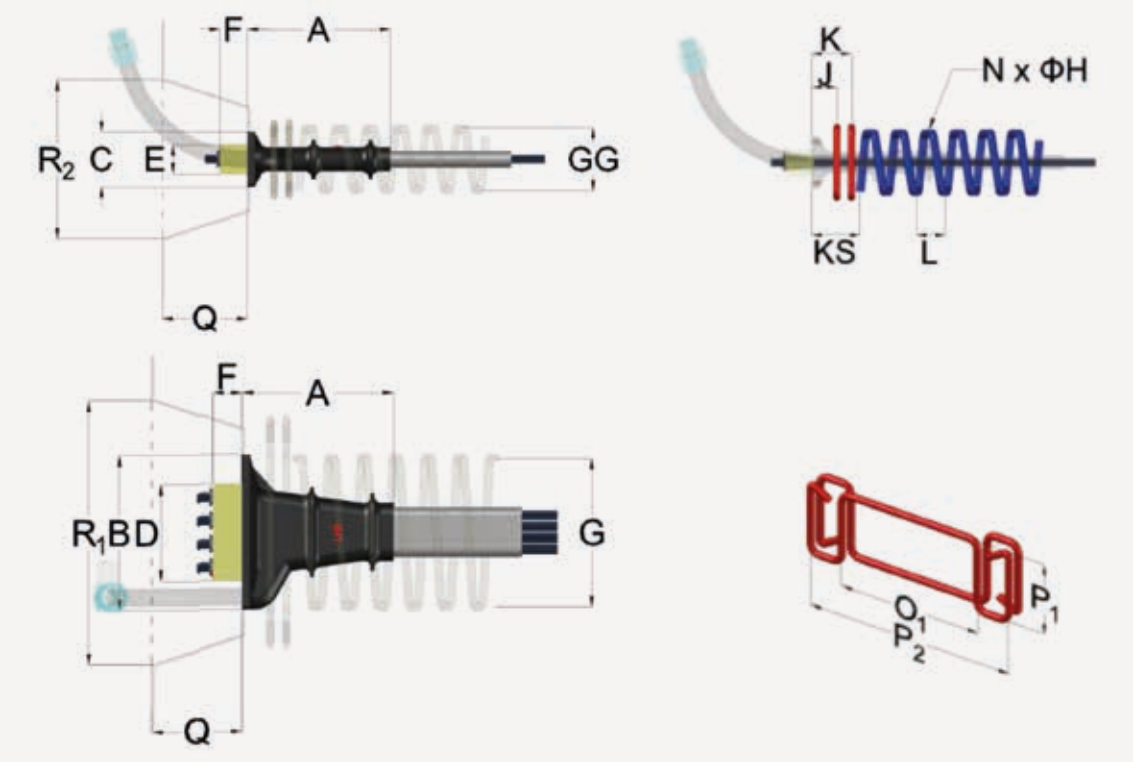
S/N	DESCRIPTION
1	SPIRAL
2	STRANDS
3	"◊" ADDITIONAL BURSTING REINFORCEMENT distributed along the spiral length
4	"W" STIRRUPS can be modified according to design requirements
5	SWAGES
6	COLLAR
7	DUCT Sheath diameter can be modified according to design requirements
8	PROTECTIVE COVER
9	GROUT PORT
10	COUPLING HEAD
11	BEARING PLATE

LMK-SFL M15 (0.6") & M13 (0.5") - STRESSING FLAT ANCHORAGE

Table 6.8

LMK - SFL	BEARING PLATE			ANCHOR HEAD			SPIRAL						W STIRRUPS							RECESS	
	A	B	C	D	E	F	G	GG	N	ΦH	L	KS	P_1	P_2	O_1	$\Phi S_1 d$	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	120	150	70	80	48	50	150	120	5	12	50	75	95	300	170	8	35	2	55	170	90
2M13	120	150	70	80	48	50	150	120	5	10	50	75	95	300	170	8	35	2	55	150	90
3M15	150	180	70	115	48	50	190	120	5	12	50	100	95	300	190	8	60	2	80	210	90
3M13	150	180	70	115	48	50	190	120	5	10	50	100	95	300	190	8	60	2	80	170	90
4M15	210	220	70	150	48	50	230	120	6	12	50	125	120	350	200	12	80	2	100	250	90
4M13	210	220	70	150	48	50	230	120	6	10	50	125	120	350	200	12	80	2	100	230	90
5M15	250	260	70	185	48	50	260	120	6	14	50	135	120	350	240	12	90	2	110	280	90
5M13	250	260	70	185	48	50	260	120	6	12	50	135	120	350	240	12	90	2	110	260	90

Recommended values for Spiral, Bursting Reinforcement & Recess



Stressing Anchorage Side & Plan View

Configuration of Spiral & W Stirrups

LMK-SFL M15 (0.6") & M13 (0.5") - STRESSING FLAT ANCHORAGE

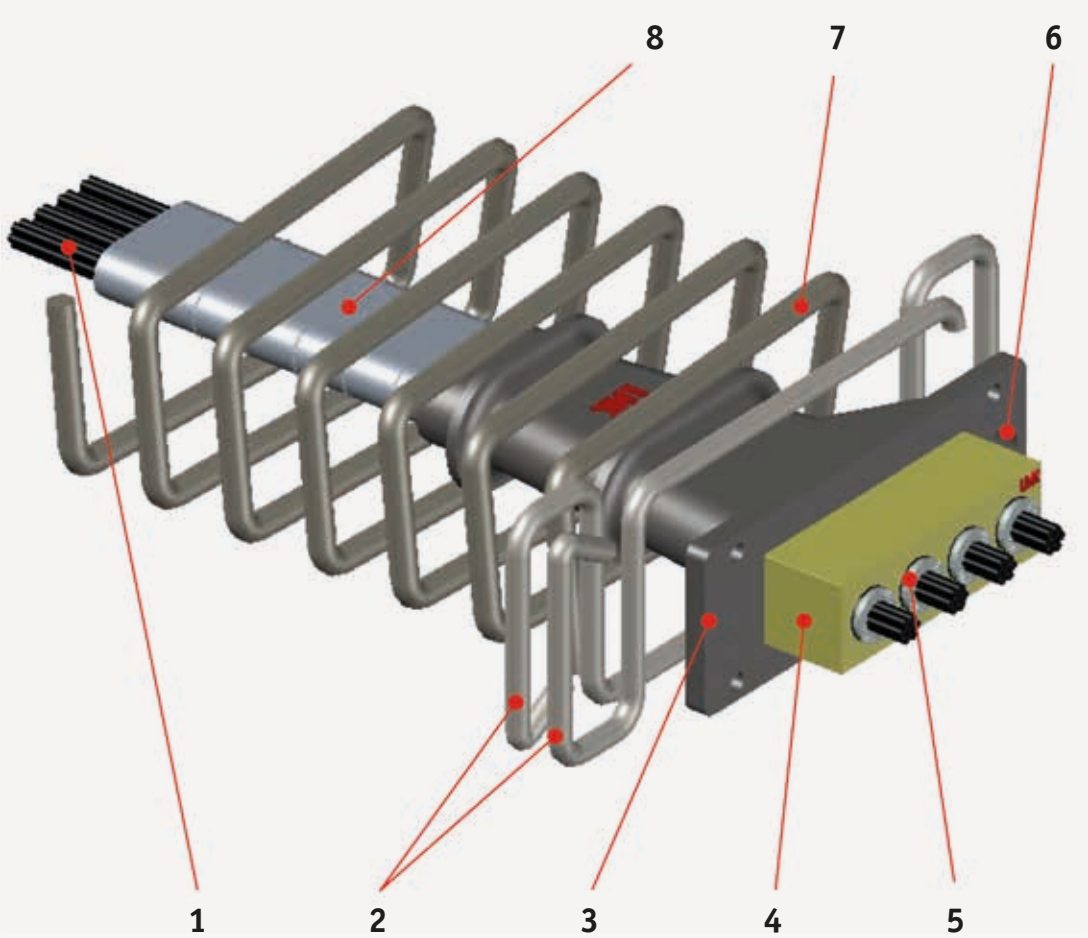


Fig.14 **Stressing Flat Anchorage Axonometric View**

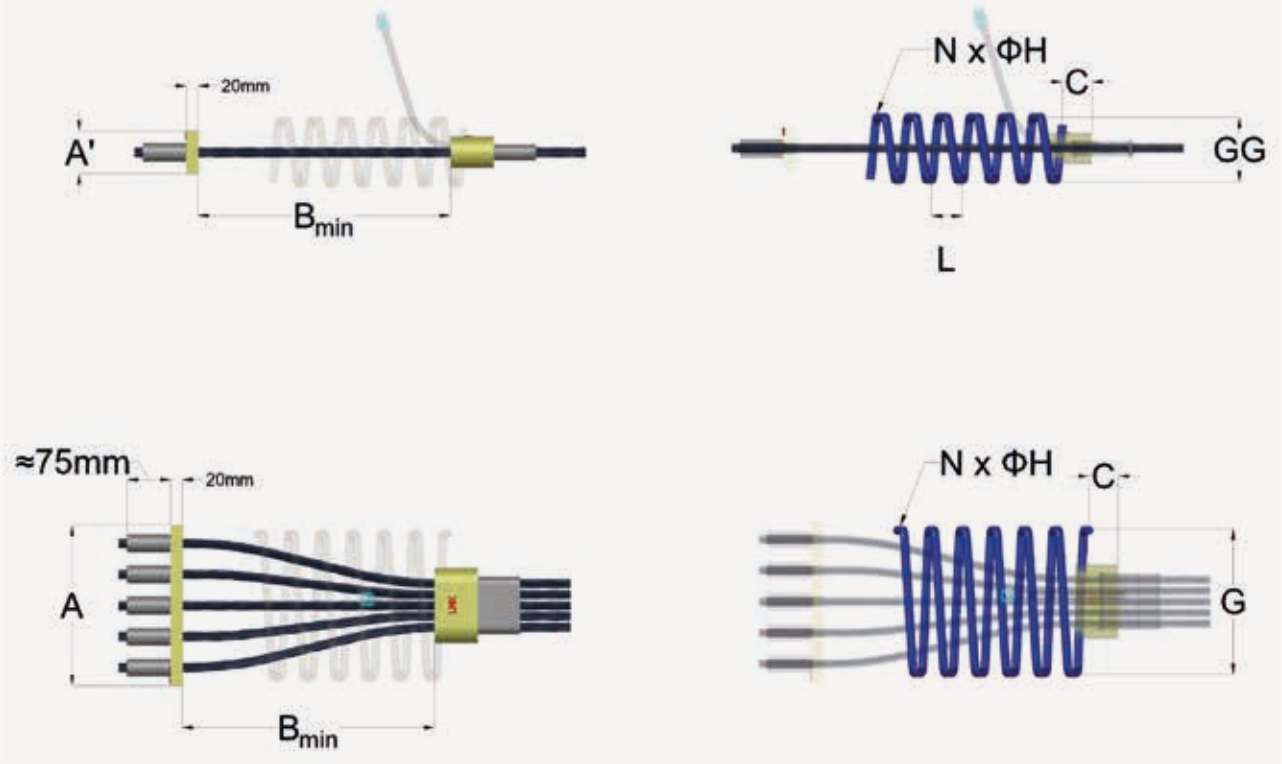
S/N	DESCRIPTION
1	STRANDS
2	"W" STIRRUPS can be modified according to design requirements
3	BEARING PLATE
4	ANCHOR HEAD
5	WEDGES
6	GROUT PORT
7	SPIRAL
8	FLAT DUCT Sheath dimensions can be modified according to design requirements

FFL M15 (0.6") & M13 (0.5") - FIXED FLAT ANCHORAGE

Table 6.9

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	130	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



Fixed Anchorage Side & Plan Views

Configuration of Spiral

FFL M15 (0.6") & M13 (0.5") - FIXED FLAT ANCHORAGE

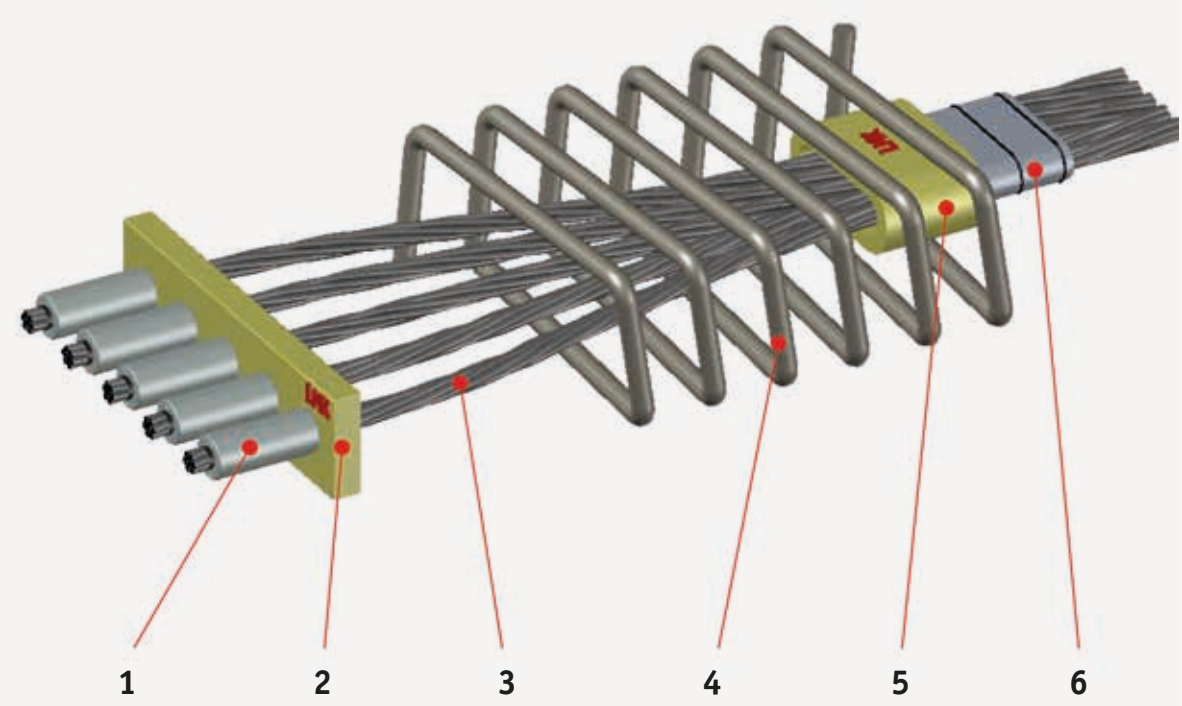


Fig.15 Fixed Flat Anchorage Axonometric View

S/N	DESCRIPTION
1	SWAGES
2	ANCHOR HEAD
3	STRANDS
4	SPIRAL
5	COLLAR
6	FLAT DUCT Sheath dimensions can be modified according to design requirements

Note: Fixed Flat Bulb (LMK-FFB) please refer to table 6.4 for 2 up to 5 strands

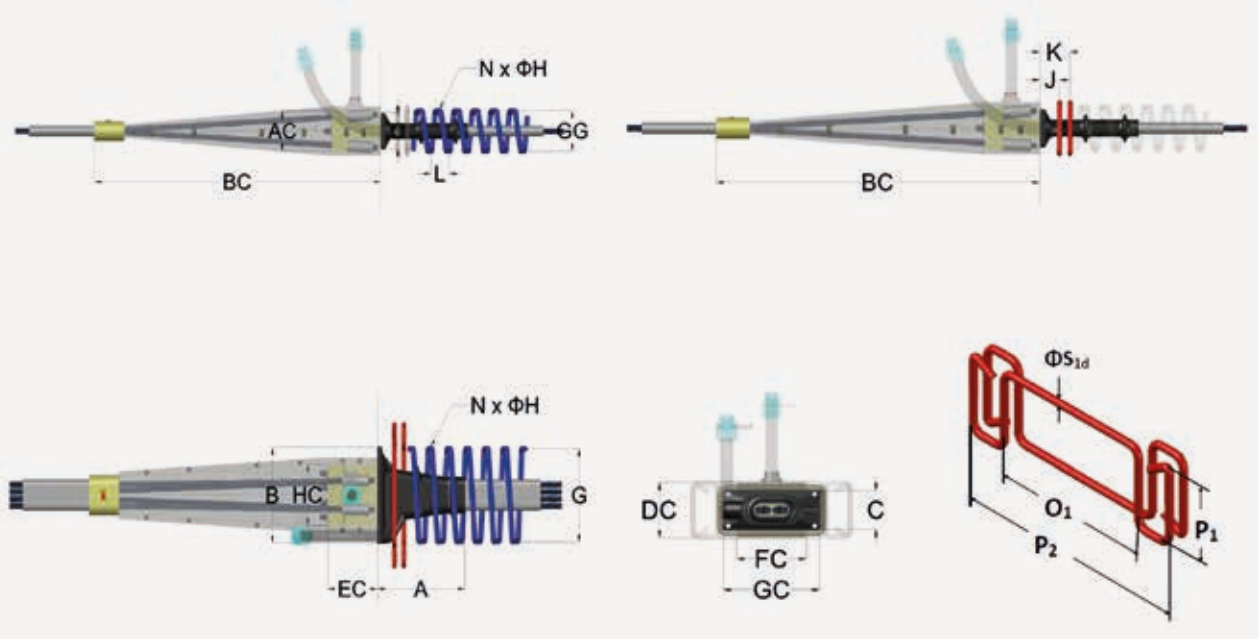
LMK-FFB

LMK-FFC M15 (0.6") & M13 (0.5") - FIXED FLAT COUPLER

Table 6.10

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	P_1	P_2	O_1	$\Phi S_1 d$	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	120	150	70	100	650	118	135	90	130	80	150	120	5	12	50	75	95	300	170	8	35	2	55
2M13	120	150	70	100	650	118	135	90	130	80	150	120	5	10	50	75	95	300	170	8	35	2	55
3M15	150	180	70	100	650	118	135	125	165	115	190	120	5	12	50	100	95	300	190	8	60	2	80
3M13	150	180	70	100	650	118	135	125	165	115	190	120	5	10	50	100	95	300	190	8	60	2	80
4M15	210	220	70	100	700	118	135	160	200	150	230	120	6	12	50	125	120	350	200	12	80	2	100
4M13	210	220	70	100	700	118	135	160	200	150	230	120	6	10	50	125	120	350	200	12	80	2	100
5M15	250	260	70	100	700	118	135	195	235	185	260	120	6	14	50	135	120	350	240	12	90	2	110
5M13	250	260	70	100	700	118	135	195	235	185	260	120	6	12	50	135	120	350	240	12	90	2	110

Recommended values for Spiral & Bursting Reinforcement



Flat Coupler Side & Plan Views, Spiral Configuration | **Rear View** | **Configuration of W Stirrups**

LMK-FFC M15 (0.6") & M13 (0.5") - FIXED FLAT COUPLER

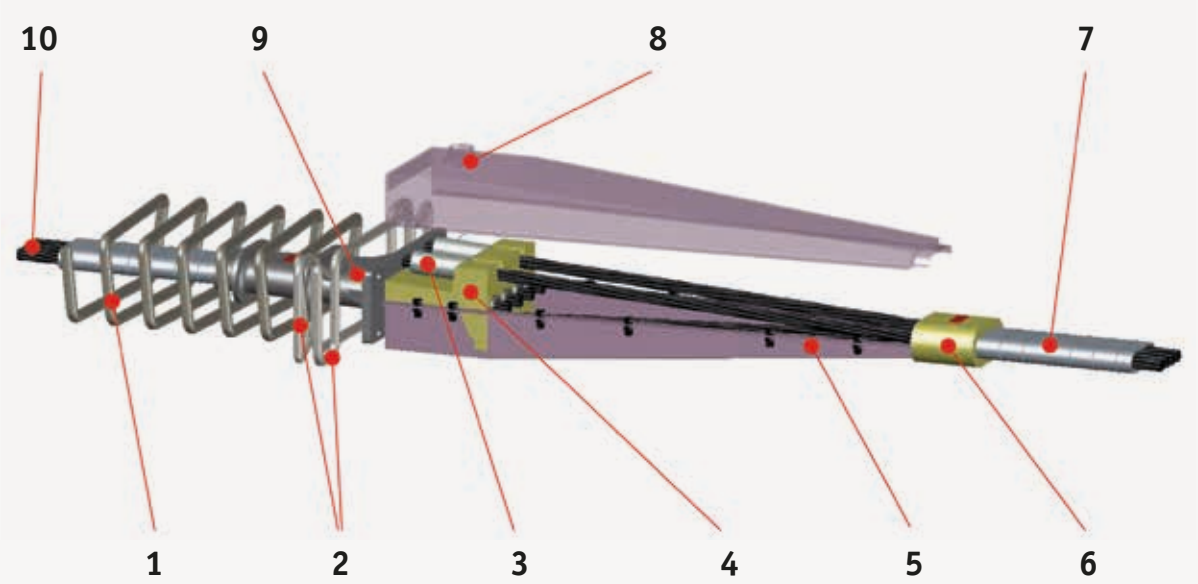


Fig.16 **Fixed Flat Coupler Axonometric View**

S/N	DESCRIPTION
1	SPIRAL
2	"W" STIRRUPS can be modified according to design requirements
3	SWAGES
4	COUPLING HEAD
5	PROTECTIVE COVER
6	COLLAR
7	FLAT DUCT Sheath dimensions can be modified according to design requirements
8	GROUT PORT
9	BEARING PLATE
10	STRANDS

Stressing

Jacks & Clearance Requirements

The jacking apparatus is specially designed and manufactured in order to reduce the weight and volume for an easier handling and a practical use/operation. Pumps have a high-pressure capacity and flow rate so as to promptly respond when using jacks of high capacity and long piston stroke.

The bundle of strands passes through the jack, thus the applied force on each strand remains equal at the entire group of strands. Depending on the type of jack (front or rear locking/hollow), a variety of stressing heads/ chairs and spacers (commonly known as stressing tools) is provided.

When the required load/elongation is reached, the pressure is released and the stressing force 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 jack's setting, depending on the required elongation and jack's piston stroke capacity.

Upon need, tensioned strands can be de-tensioned and released one by one using a proper releasing apparatus and a mono-strand jack.

The swages in fixed & coupling type anchorages utilize the cold extrusion process, by griping the strand's end using special swage jack.

Each jack is connected through a system of high pressure hoses to a pump. The developed pressure is monitored during stressing by calibrated gauges.
Maintenance and repair of hydraulic equipment follows LMK strict and frequent inspection schedule routine.

Jacks Data Table

LMK stressing jacks combine a compact design, high fidelity and easy handling. The jacks are factory calibrated with force/pressure calibration certificates and graphs. Stressing pumps and jacks are delivered fully equipped with calibrated gauges, high pressure hoses, connectors and spare fittings.

Stressing Jacks Data

Table 7

Jack Type	Front or Rear Locking	Nominal Stressing Force	Strand Diameter mm				Nos. of strands	Nominal Pressure	Piston area	Back piston area	Back pressure	Internal Sleeve Diameter ØI	Stroke (S)	Overall Dimensions Lf x ØD (Ød x Lf)	Estimated Weight	Required Clearance B x C	Required Strand Overlength Ar/Af	Recess Required R x R
		KN					Nos	Mpa	m^2	m^2	Mpa	mm	mm	mmxmm	Kg	mm x mm	mm	mm
ETS1.6/1	F	240	15,2	✓	15,7	✓	1	46	0.2383×10^{-3}	--	--	--	195	(Ø98x645)	16	1380 x 79	735	158 x 158
YCD260Q-200	R	264	15,2	✓	15,7	✓	1	48	5.105×10^{-3}	1.355×10^{-4}	<25	19	200	540×Ø115	23	1210 x 87	670	175 x 175
YCW60C	R	600	15,2	✓	15,7	✓	2	52	1.154×10^{-3}	0.408×10^{-3}	<25	58	200	356×Ø168	40	902 x 114	546	228 x 228
L4.6/4	F	900	15,2	✓	15,7	✓	4	58	1.5892×10^{-2}	--	--	--	125	(Ø175x434)	55	998 x 117	564	235 x 235
YCW100C	R	992	15,2	✓	15,7	✓	3-4	52	1.908×10^{-2}	0.777×10^{-2}	<25	78	200	353×Ø216	65	896 x 138	543	276 x 276
YCW150C	R	1512	15,2	✓	15,7	✓	5-6	50	3.024×10^{-3}	1.610×10^{-2}	<25	102	200	369×Ø280	110	930 x 170	561	340 x 340
YCW150C	R	1512	15,2	✓	15,7	×	7	50	3.024×10^{-3}	1.610×10^{-2}	<25	102	200	369×Ø280	110	931 x 170	562	340 x 340
L7.6/7	F	1570	15,2	✓	15,7	✓	7	64	2.5239×10^{-2}	--	--	--	125	(Ø220x447)	80	1027 x 140	580	280 x 280
YCW200C	R	1960	15,2	✓	15,7	✓	7-8	52	3.769×10^{-3}	1.845×10^{-2}	<25	118	200	372×Ø310	140	979 x 185	607	370 x 370
YCW200C	R	1960	15,2	✓	15,7	×	9	52	3.769×10^{-3}	1.845×10^{-2}	<25	118	200	372×Ø310	140	979 x 185	607	370 x 370
YCW250C	R	2480	15,2	✓	15,7	✓	9-11	54	4.594×10^{-3}	2.804×10^{-2}	<25	140	200	371×Ø345	165	982 x 202	611	405 x 405
L12.6/12	F	2700	15,2	✓	15,7	✓	12	63.5	4.3749×10^{-2}	--	--	--	125	(Ø285x468)	180	1076 x 172	608	345 x 345
YCW300C	R	2990	15,2	✓	15,7	✓	12-13	54	5.537×10^{-3}	3.024×10^{-2}	<25	140	200	375×Ø370	200	1013 x 215	638	430 x 430
YCW300C	R	2990	15,2	✓	15,7	×	14	54	5.537×10^{-3}	3.024×10^{-2}	<25	140	200	375×Ø370	200	1015 x 215	640	430 x 430
L15.6/15	F	3400	15,2	✓	15,7	✓	15	63.5	5.4902×10^{-2}	--	--	--	125	(Ø320x497)	200	1142 x 190	645	380 x 380
YCW350C	R	3460	15,2	✓	15,7	✓	14	51	6.785×10^{-3}	4.311×10^{-2}	<25	165	200	389×Ø416	235	1043 x 238	654	476 x 476
YCW350C	R	3460	15,2	✓	15,7	✓	15	51	6.785×10^{-3}	4.311×10^{-2}	<25	165	200	389×Ø416	235	1046 x 238	657	476 x 476
YCW350C	R	3460	15,2	✓	15,7	×	16	51	6.785×10^{-3}	4.311×10^{-2}	<25	165	200	389×Ø416	235	1048 x 238	659	476 x 476
YCW400C	R	3957	15,2	✓	15,7	✓	16	52	7.917×10^{-3}	4.595×10^{-2}	<25	175	200	389×Ø435	277	1048 x 247	659	495 x 495
YCW400C	R	3957	15,2	✓	15,7	✓	17	52	7.917×10^{-3}	4.595×10^{-2}	<25	175	200	389×Ø435	277	1051 x 247	662	495 x 495
YCW400C	R	3957	15,2	✓	15,7	×	18	52	7.917×10^{-3}	4.595×10^{-2}	<25	175	200	389×Ø435	277	1053 x 247	664	495 x 495
L19.6/19	F	4300	15,2	✓	15,7	✓	19	63.5	7.0720×10^{-2}	--	--	--	125	(Ø360x490)	255	1135 x 210	645	420 x 420
YCW450C	R	4428	15,2	✓	15,7	✓	18-19	54	8.199×10^{-3}	5.183×10^{-2}	<25	175	200	389×Ø450	300	1063 x 255	674	510 x 510
YCW450C	R	4428	15,2	✓	15,7	×	20	54	8.199×10^{-3}	5.183×10^{-2}	<25	175	200	389×Ø450	300	1068 x 255	679	510 x 510
YCW450C	R	4428	15,2	✓	15,7	×	21	54	8.199×10^{-3}	5.183×10^{-2}	<25	175	200	389×Ø450	300	1068 x 255	679	510 x 510
YCW500C	R	4926	15,2	✓	15,7	✓	20-21	49	10.053×10^{-3}	4.775×10^{-2}	<25	196	200	430×Ø495	430	1150 x 277	720	555 x 555
YCW500C	R	4926	15,2	✓	15,7	✓	22	49	10.053×10^{-3}	4.775×10^{-2}	<25	196	200	430×Ø495	430	1150 x 277	720	555 x 555
YCW500C	R	4926	15,2	✓	15,7	×	23	49	10.053×10^{-3}	4.775×10^{-2}	<25	196	200	430×Ø495	430	1152 x 277	722	555 x 555
L22.6/22	F	5000	15,2	✓	15,7	✓	22	63.5	7.9171×10^{-2}	--	--	--	125	(Ø385x525)	320	1210 x 222	685	445 x 445
YCW600C	R	5929	15,2	✓	15,7	✓	23	49	12.1×10^{-3}	6.825×10^{-2}	<25	196	200	430×Ø525	480	1172 x 292	742	585 x 585
YCW600C	R	5929	15,2	✓	15,7	✓	24-25-26	49	12.1×10^{-3}	6.825×10^{-2}	<25	196	200	430×Ø525	480	1175 x 292	745	585 x 585
YCW600C	R	5929	15,2	✓	15,7	×	27-28	49	12.1×10^{-3}	6.825×10^{-2}	<25	196	200	430×Ø525	480	1178 x 292	748	585 x 585
YCW650C	R	6590	15,2	✓	15,7	✓	27-28-29	50	12.78×10^{-3}	6.754×10^{-2}	<25	220	200	450×Ø570	650	1218 x 315	768	630 x 630
YCW650C	R	6590	15,2	✓	15,7	×	30-31	50	12.78×10^{-3}	6.754×10^{-2}	<25	220	200	450×Ø570	650	1220 x 315	770	630 x 630
L31.6/31	F	6950	15,2	✓	15,7	✓	31	63.5	11.1872×10^{-2}	--	--	--	125	(Ø455x552)	480	1274 x 257	722	515 x 515
YCW700C	R	6975	15,2	✓	15,7	✓	30-31	50	13.95×10^{-3}	7.516×10^{-2}	<25	220	200	450×Ø580	660	1220 x 320	770	640 x 640
YCW700C	R	6975	15,2	✓	15,7	×	32-33	50	13.95×10^{-3}	7.516×10^{-2}	<25	220	200	450×Ø580	660	1225 x 320	775	640 x 640
YCW800C	R	8150	15,2	✓	15,7	✓	32-33	50	15.83×10^{-3}	9.04×10^{-2}	<25	250	200	510×Ø650	930	1345 x 355	835	710 x 710
YCW800C	R	8150	15,2	✓	15,7	✓	34-35	50	15.83×10^{-3}	9.04×10^{-2}	<25	250	200	510×Ø650	930	1350 x 355	840	710 x 710
YCW800C	R	8150	15,2	✓	15,7	×	36-37	50	15.83×10^{-3}	9.04×10^{-2}	<25	250	200	510×Ø650	930	1350 x 355	840	710 x 710
YCW900C	R	9190	15,2	✓	15,7	✓	36-37	50	18.38×10^{-3}	9.04×10^{-2}	<25	280	200	510xØ690	980	1350 x 375	840	750 x 750

Swage Jack	Extrusion Force	Interval Sleeve	Overall Dimensions	Extrusion Stroke
1 strand	KN	ØI	L x ØD	mm
CYJC	503	30	565 x 150	150

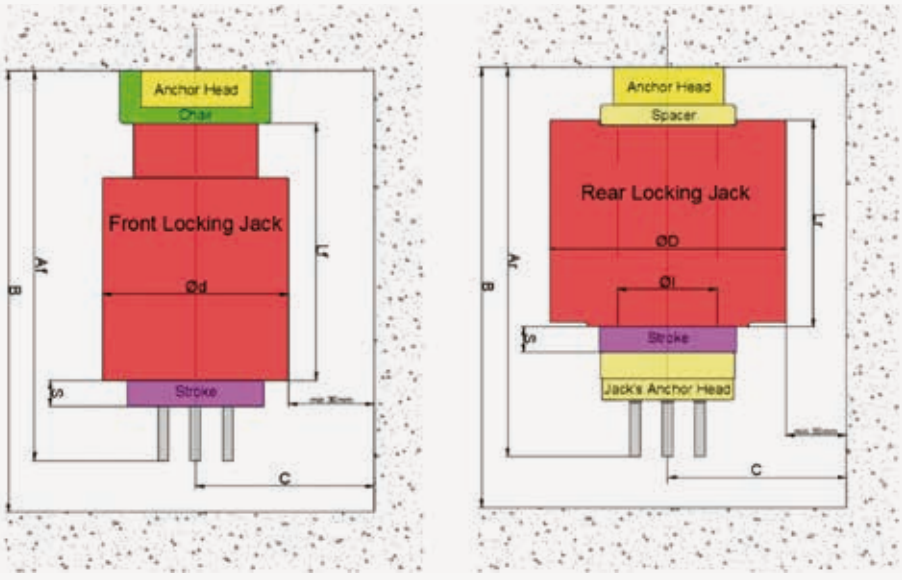
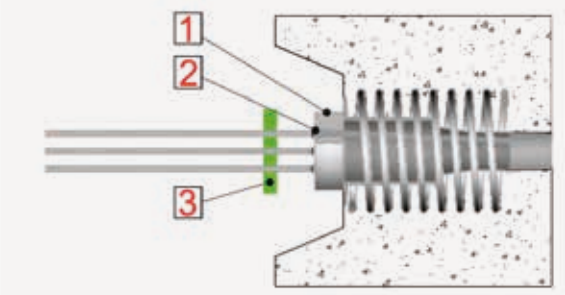


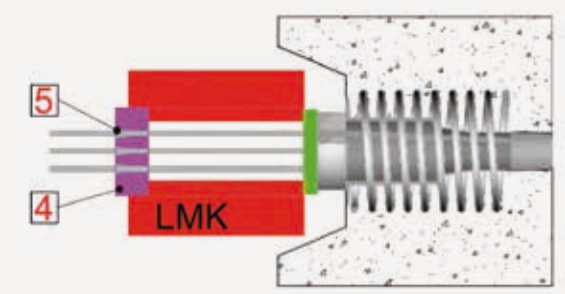
Fig.17 Required Jacks Clearance

Typical Tensioning Procedure

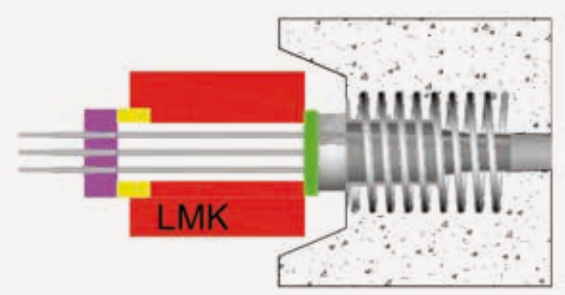
Rear Locking Jack



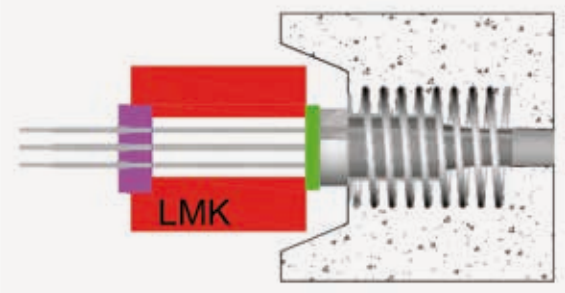
Step 1 - Positioning of anchor head (1), wedges (2) and spacer (3)



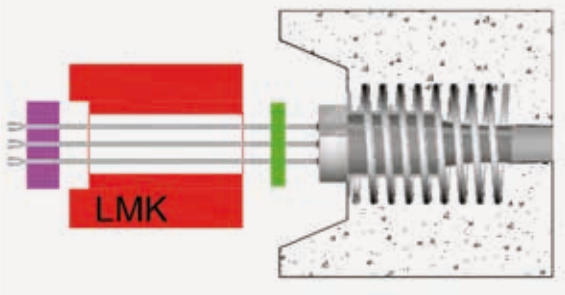
Step 2 - Positioning of jack and rear stressing head (4) with jack wedges (5)



Step 3 - Stressing in one or multiple phases

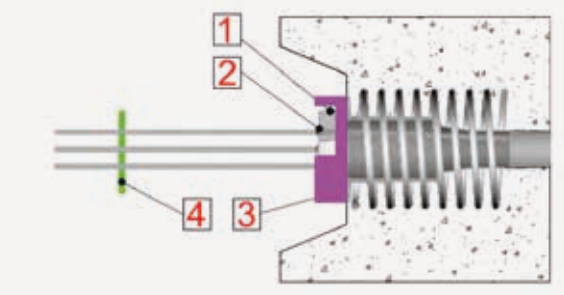


Step 4 - Release of tension and locking of wedges

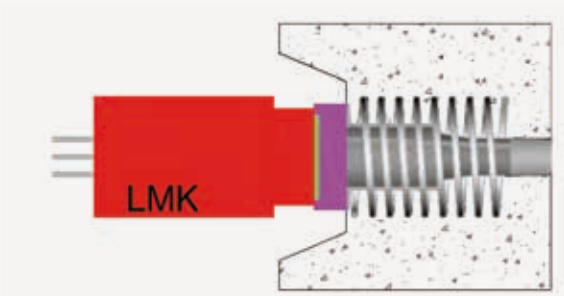


Step 5 - Removal of jack and stressing tools

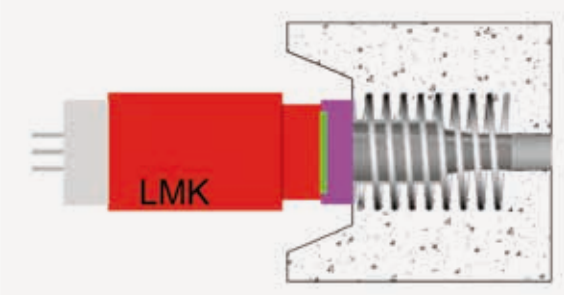
Front Locking Jack



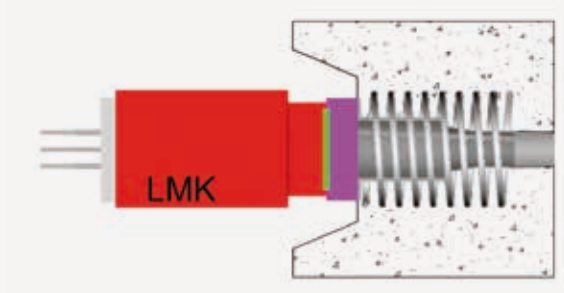
Step 1 - Positioning of anchor head (1), wedges (2), chair (3) & spacer (4)



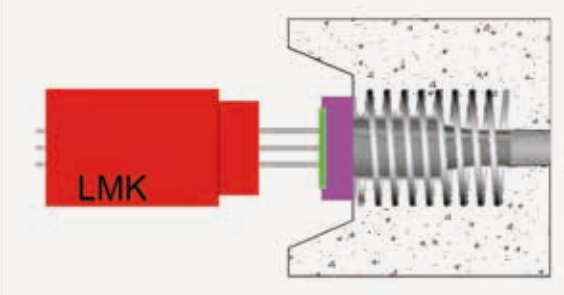
Step 2 - Positioning of jack



Step 3 - Stressing in one or multiple phases



Step 4 - Release of tension and locking of wedges



Step 5 - Removal of jack and stressing tools

Grouting

Procedure

Grout ensures the corrosion protection of the strands, providing the necessary bond between the strands and the structure as well. The quality of the produced grout should comply with Int'l standards and specifications (EN & ASTM). The grout is a mixture of cement and water and may contain admixtures such as expanding additives and water reducer/ plasticizers. The grout shall be free from chlorides, nitrates or other chemicals which cause steel corrosion and its strength should not be less than the required by the Design strength.

Tendons are grouted immediately but not earlier than 12 hours after stressing.

The permissible recommended intervals between strand installation and grouting, without use of corrosion inhibitor (water soluble oil) in ducts or directly applied to the strand, depending on exposure conditions, are:

- Very damp environment:
  (humidity > 70%) - 7 days
- Moderate environment:
  (humidity from 40% up to 70%) - 15 days
- Very dry environment:
  (Humidity < 40%) - 20 days

In order to avoid humidity concentration (water penetration and condensation) in tendons, the intervals between threading of strands and grouting should not exceed 12 weeks, considering 4 weeks out of 12 without concreting (placement on formwork) and up to 2 weeks in case of tendons under tension.

Tendons are grouted immediately after sealing of the recess in the anchorage area with concrete or grouting caps. The grout should flow from the lowest to the highest elevation of tendons geometry. Grout must be allowed to flow out from the outlets till there are no signs of trapped air.

Prior of grouting, it is recommended to check the tendons for possible blockage using compressed air. When fixed couplers are used, the grouting of the previous tendon section precedes the tensioning of the next adjacent section.

The grouted tendon must remain under pressure of no more than 3-5 bars for at least one minute, having all venting ports closed in order to verify the tightness of the system. The grouting / venting valves assure the proper accomplishment of the procedure.

Formula

The water to cement ratio (w/c) should be as low as possible, providing a grout with low bleeding and volume change having at the same time adequate fluidity, allowing tendon's proper filling. Grout temperature must be kept between 10 to 25 °C, and fluidity has to be within 14~19 sec.

Testing for fluidity is carried out at site using a fluidity cone. If the value is out of range, the batch should not be used and a new w/c ratio must be defined so as to obtain a satisfactory fluidity.
The grout quantity is defined as lit/m and can be given by the formula:

Water is batched through high-accuracy weighting devices in order to assure the stability of the produced grout. Usually, with 36-38 lit of water and 100 kg of cement, 72-74 lit of grout can be produced.

In case of vacum grouting, the use of a vacum grouting pump is required.

Grease, gel and wax can also be used as tendons filling material for un-bonded applications.

Round ducts $$\frac{\pi*\left(\frac{\Phi_i{}^2}{2}\right)-A*n}{1000}$$

Flat ducts $$\frac{\pi*r_1*r_2-A*n}{1000}$$

Φ_i (mm) = inner diameter of sheath
A (mm2) = one strand nominal area
n = number of strands per tendon
r_1 & r_2 (mm) = internal radius of flat sheath

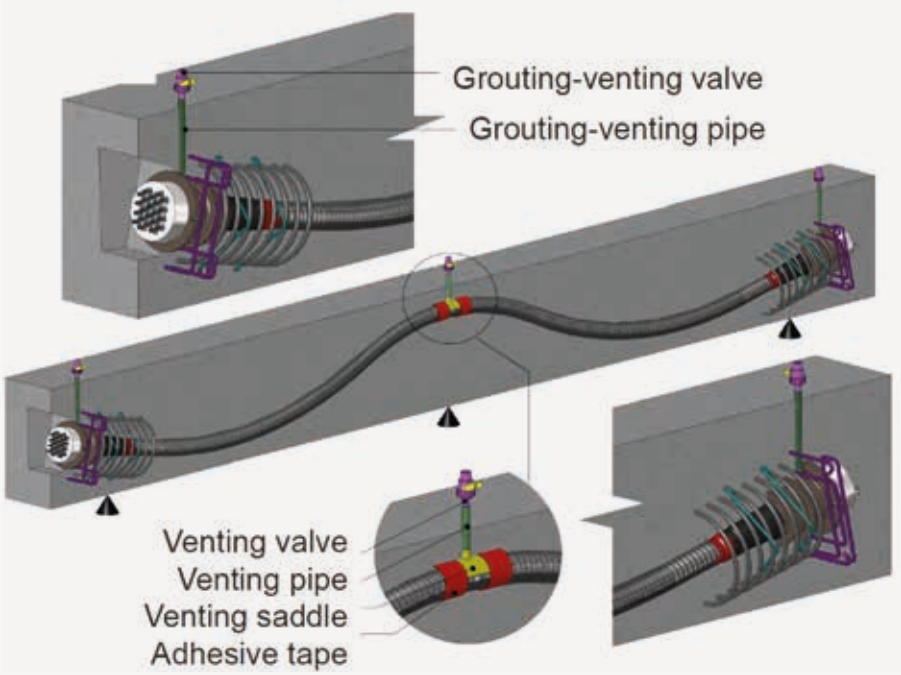


Fig.18 Typical Grouting Ancillaries Configuration

Grouting Equipment

The grouting equipment is consisted of a highspeed mixer, an agitator, a grout-pump and a power unit, capable of continuous mechanical mixing which produces a grout free of lumps and undispersed cement. The pump shall have seals adequate to prevent penetration of oil, air and other foreign substances into the grout and to prevent loss of grout or water.

The mixer shall be kept partially filled with grout at all times during the pumping operation, so as to prevent air from infiltrating the system. Under normal conditions, the grouting equipment shall be capable of continuously grouting the longest tendon on the structure in no more than 20 minutes.

Design Requirements

Tendon Force Losses

The effective stressing force differs from the initial stressing force (prior of seating as commonly known) for various reasons. The main reasons are:

Short Term - Initial losses

- Friction losses (wobble and curvature effects)
- Concrete elastic deformation
- Anchor set / wedges drawn-in

Long Term - Time dependent losses

- Creep & shrinkage of concrete
- Strand relaxation

After the wedges are finally locked, they slightly recede into the anchor head causing a loss of tension. This tension loss should be taken into account to the calculations, especially in short length tendons (< 15 m) and can be completely or partially compensated with over-stressing. The wedge draw-in is 4 mm with maximum value 6 mm.

Reference in Int'l standards and technical literature foresees the calculation of losses due to creep & shrinkage and elastic shortening of concrete, especially in cases where tendons are not stressed simultaneously in a section.

The relaxation of the strands depends primarily on the type of steel (class of relaxation), the magnitude of the pre-stress and the temperature. For low relaxation class, the maximum losses are about 2,5% after 1000 h @ 20 ^{0}C and an initial stress of about 70% of the nominal tensile strength. Further information can be obtained from strand steel Int'l literature.

Stressing Losses at Seating

Stressing losses occur when the load is transferred from the jack to the anchorage, as a result of a shortening of the tendon due to wedges drawn-in, anchor head setting and strand slippage. This loss due to wedge drawn-in affects only a certain length (d) of the tendon (see below graphs).

In case of short tendons (< 15 m), the wedge drawn-in effect dominates over the stressing losses.

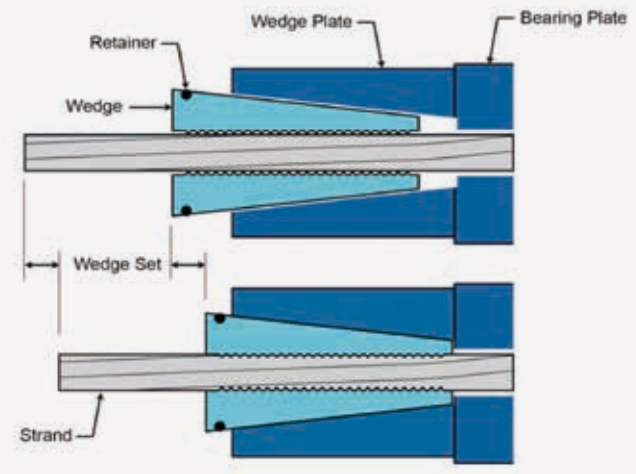
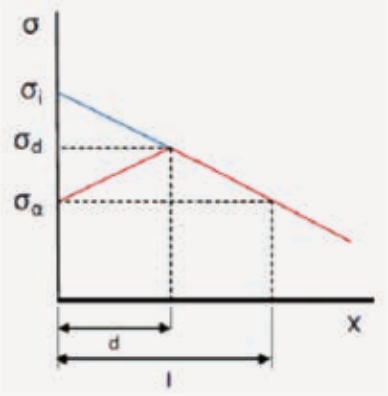


Fig.19 Wedge drawn-in mechanism

Basic Formulas



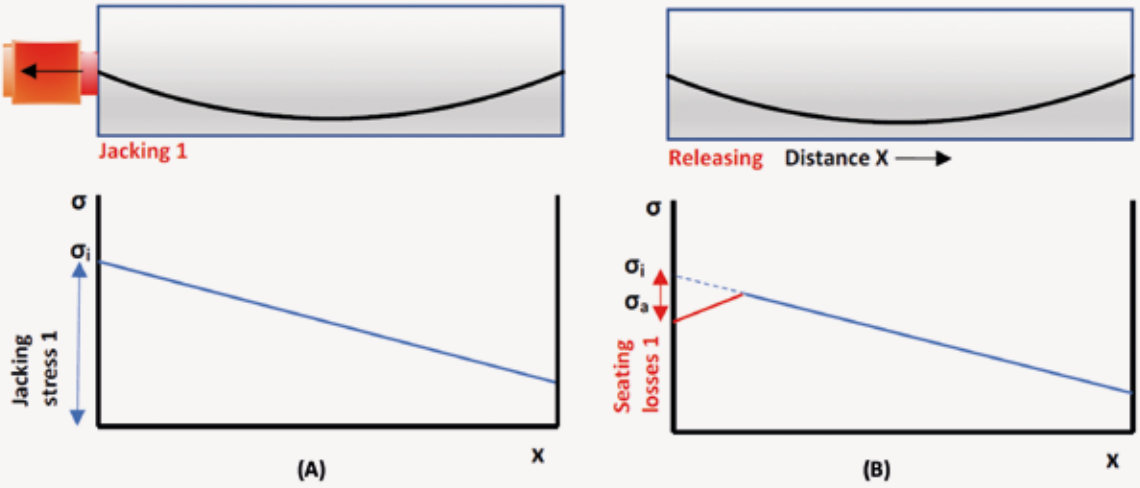
Where:

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

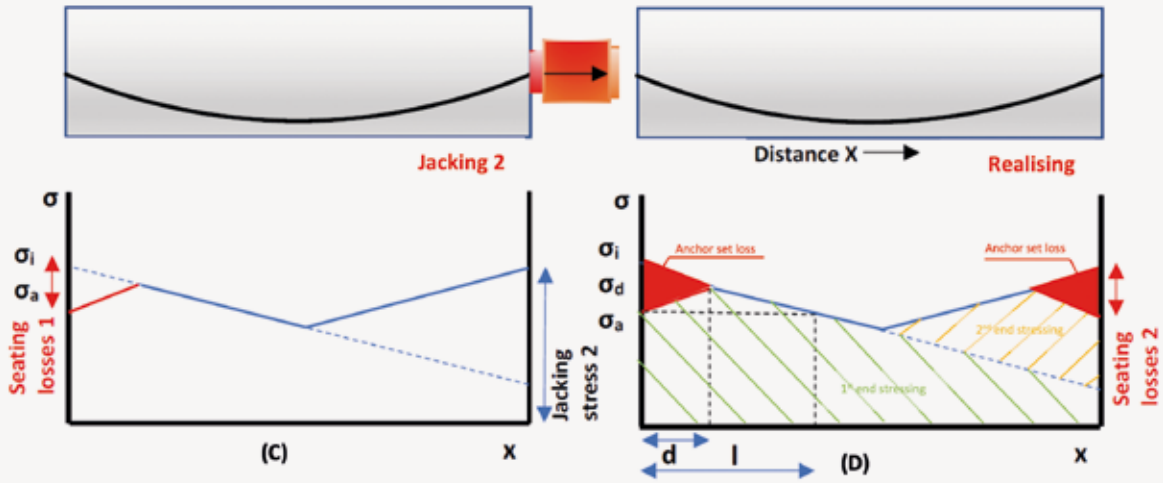
r = wedge drawn-in
l = tendon's length where the tension is known
σ_l = tension at distance l from the anchorage
σ_i = tension at jack
E = strand's modulus of elasticity (theoretical value 195-197 GPa)
d = the affected tendon length due to wedge drawn-in
σ_a = tension after wedge drawn-in
σ_d = tension at a distance d from the anchorage

Schematic View of Stressing Losses

Left side jacking



Right side jacking



Basic Equations

The tension σ in a distance X is given by the formula:

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

(LRFD equation)

or

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

(EN-1992-1-1 equation)

σ_i = tension at the anchorage

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

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

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

k = μ*κ=coefficient of unintentional angular deviation - wobble

The friction coefficient μ depends on various factors such as inaccurate placement of PT tendon, improper placement of strands or damaged sheathing, bending radius, strands and sheaths nature and contact surfaces, etc.

The wobble coefficient is related to sloppy placement or excessive tendon deviations, stiffness of ducts, distances between tendons supports, vibrations during concreting, etc.

Table 8 Recommended values of μ, κ & k

TYPE of TENDON & DUCT	μ	κ (EN)	k (AASHTO)
	rad^{-1}	rad/m	m^{-1} (x 10^{-3})
Internal tendons-Steel corrugated ducts	0.17-0.20	0.005-0.01	0.85-2.0
Internal tendons-Plastic ducts	0.10-0.14		0.5-1.4
External tendons-Steel deviators	0.16-0.24		0.8-2.4
External tendons-Plastic deviators	0.10-0.14		0.5-1.4
Unbonded greased and coated	0.04-0.06	0.009-0.01	0.36-0.6

The following values may be assumed for design:

Table 9 AASHTO LRFD

TYPE of TENDON & DUCT	μ	k (AASHTO)
	rad^{-1}	ft^{-1}
Internal tendons-Steel corrugated ducts	0.15-0.25	0.0002
Internal tendons-Plastic ducts	0.23	0.0002
External tendons-Steel deviators	0.25	0.0002

Table 10 EN-1992-1-1

TYPE of TENDON & DUCT	μ non-lubricated	μ lubricated	κ (EN)
	rad^{-1}	rad^{-1}	rad/m
Internal tendons-Steel corrugated ducts	0.19	--	0.005-0.01
External tendons-Steel deviators	0.24	0.16	
External tendons-Plastic deviators	0.12	0.10	

The tendons' elongation is given by the formula:

$$\Delta_X = \int_0^x \frac{\sigma_x}{E} * d_x$$

where:
E = strands modulus of elasticity

LMK Solutions

Breakthrough in PT Technology

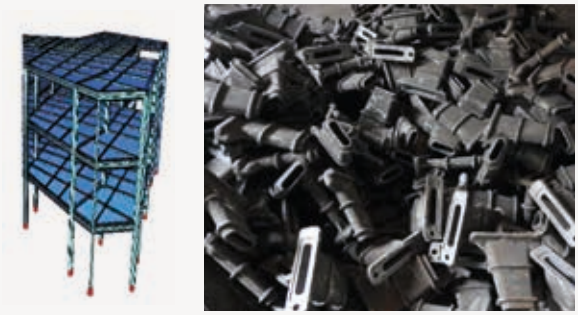
LMK anchorages have successfully passed many efficiency tests proving the quality and adequacy in line with Int'l specifications & standards (EN-ETAG-EAD, AASHTO LRFD).

The **LMK** Post Tensioning system can provide full engineering services and support, including preliminary and final designs, supply of materials, equipment/machinery, installation, training, supervision, stressing, grouting, planning and management services and customized solutions for all types of structures.

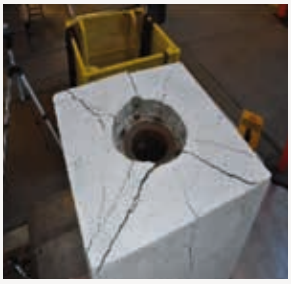
This brochure contains selectively the most characteristic topics related to PT technology and general information for design and construction.

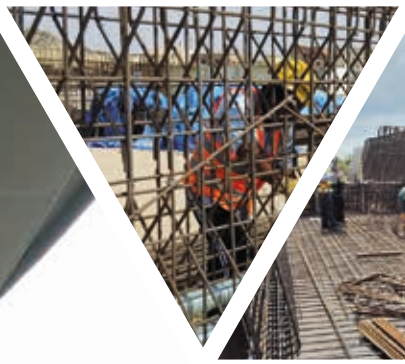
Depending on project's requirements data can be modified accordingly.

Contact **LMK** technical department for further details or stay tuned via our social media and blog website.







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