PRESTRESSING MANUAL

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INTRODUCTION

PRINCPLES OF PRESTRESSING

Prestressing is a method of inducing known permanent stresses in a structure or member before the full or live load is applied. These stresses are induced by tensioning the High Tensile Strands, wires or rods, and then anchored to the member being Prestressed, by mechanical means.

The Prestressing counteracts the stresses, produced by subsequent loading on the structures, thereby extending the range of stresses to which a structural member can safely be subjected. This also improves the behavior of the material of which the member or structure is composed. For Example; The Concrete which has relatively a low Tensile strength, shall behave like a member having high tensile strength, after Prestressing.

The High Tensile wires/strands, when bunched together are called Cables. These cables are generally placed inside a cylindrical duct made out of either metallic or HDPE material. The Anchorages, one of the main components of the Prestressing activity, are used to anchor the H.T. Cable after inducing the Load. The whole assembly of the Anchorage and the H.T. Cable is named as 'TENDON'.

APPLICATION AND USE OF PRESTRESSING

In structural Member, where the span length is very high with low rises and low structural height, the application of Reinforced Cement Concrete shall be virtually impractical. In such a case, Prestressing is used to achieve a light weight, elegant looking and much economical structure with high durability. Prestressing, therefore, is widely used for long span beams and Bridges.

In building structure also, prestressing method is very effectively used to achieve lighter beams and slabs; thus reducing their dead load considerably as compared to R.C.C. Structures. Application of Prestressing in building construction also facilitates a larger span between the columns, thus reduces the number of columns. This also makes the structure more versatile for interior planning.

Prestressing is also very widely used in the construction of Mega Structures like Containment Wall of Nuclear Reactors, LNG Storage Tanks, Cement Silos, Chimneys, Dams and Rock Anchors etc.

TYPE OF PRESTRESSING SYSTEMS

Prestressing System can be classified by two basic methods, as under:-

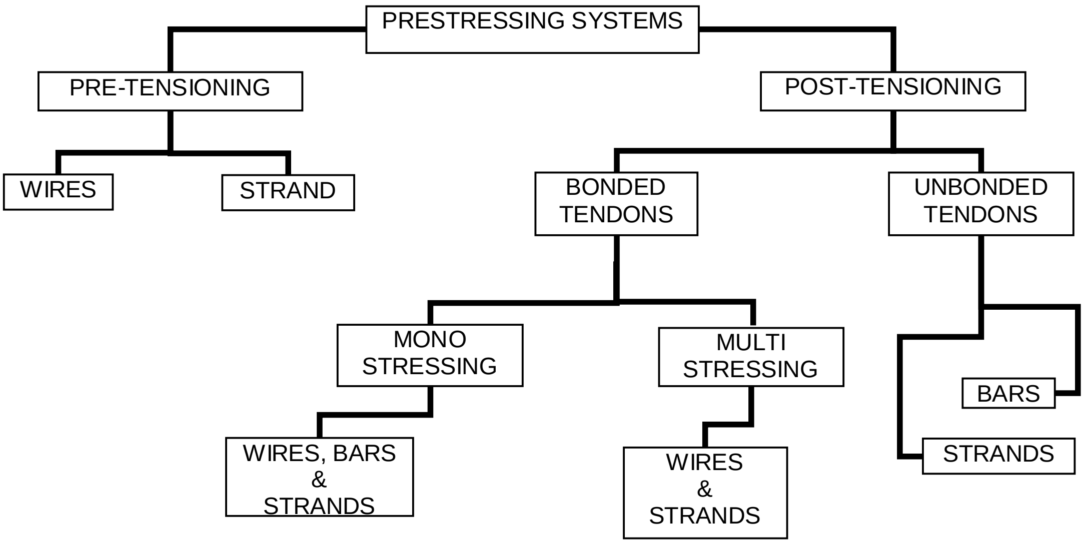
a. Pre-Tensioning
b. Post-Tensioning.

Pre-Tensioning - is a method where Prestressing Steels are pre-stressed, prior to concreting, against two rigid abutments. This method is most widely used for mass production of short span structures, where pre-stressing is also a prerequisite, such as; Railway Sleepers, Electric Polls, Fencing Polls, Pre-Tensioned Slabs and I-Section Bridge Girders etc.

In this system, a number of identical structural frames are placed in between the two rigid abutments or reaction bolster. Prestressing Steel is then placed longitudinally across these frames and abutments, in the required orientation, and stressed. After achieving required elongation and stresses they are blocked at two abutments and then concrete is poured in the frames with stressed steels in position.

Post-Tensioning - is a method where Prestressing Steels are stressed after concrete attains its preliminary strength. Two extreme ends of the structure are considered as a reaction face, against which force is applied. Ducts are placed inside the formwork alongwith reinforcement and the concreting is completed. After achieving required concrete strength, a stipulated numbers of Prestressing Steel is then inserted in each duct for stressing purpose. After achieving required elongation and stresses they are blocked at two ends with the help of Anchor Plates and grip.

The broad classifications are given as under



THE FREYSSINET PRESTRESSED CONCRETE COMPANY LTD.

The FPCC Post-Tensioning systems have been successfully used throughout the country since 1954. They are time tested and have earned a reputation for their quality and reliability.

The FPCC Post-Tensioning system has been used in every sector of prestressed concrete constructions. While primarily used for Rail or Road Bridges, now extended it's application in various other structures such as; Nuclear Reactors, Cement Silos, Dams and buildings etc. FPCC Post-Tensioning is also used for Rock and Soil Anchors and for lifting and shifting of heavy loads.

USERS OF THE MANUAL

This manual presents detailed technical information about various FPCC Systems, and is intended as a working guide for Consulting Engineers, Government Authorities, Clients and the Inspection Agencies, who are responsible for execution and supervision at site.

We hope to give information to all those who have as yet little or no experience in Prestressed concrete and who wish to acquire a wider knowledge of its details and site usage.

FPCC SYSTEM OF PRESTRESSING

FPCC has developed a range of Anchorages, to cater to a wide range of Prestressing tendons. The fundamental concept of Mono-Strand and Multi-Strand system remains the same; regardless of Prestressing elements are used. i.e. - Wire/Strand, Steel/Concrete Anchorages, No. of Wires/Strands in a tendon or method of stressing.

The Prestressing cables, when fitted with their Anchorages, are called 'TENDONS'. They are made up of Wires / Strands grouped generally in a cylindrical duct made out of metal strips or HDPE.

FPCC Anchorages, an important component of Tendon, cater to a wide range of Prestressing forces starting from an U.T.S. of 18.75 MT to 700MT. Anchorages for larger capacity tendons and for special purposes are also available on request.

The Tension members of the FPCC post-tensioning systems are made up of high strength steel strands, either in the form of mono-strand or as multi-strand tendons. The term "INTERNAL" and "EXTERNAL" tendons are used, according to the position of the cables with respect to cross section of the structures.

This Manual provides the details of the FPCC post-tensioning systems and contains the most important information for design and construction. Details about the Pre-tensioning system can be provided on special request.

Anchorages are categorised in two types, given as under:-

1. Mono-Group Anchorages
2. Slab Stress Anchorages

Multi-Strand Anchorages are recommended for Prestressing of concrete structures where higher capacity of Prestressing forces are required; such as Bridges, Silos, Dams and containment walls etc.

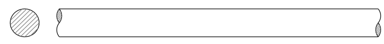
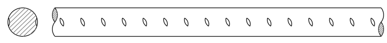
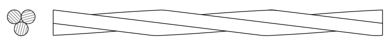
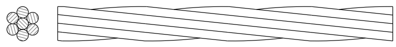
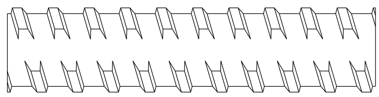
Slab Stress Anchorages are developed for using in flat concrete structure such as buildings etc. where Prestressing forces are considerably low.

PRESTRESSING MATERIALS

PRESTRESSING STEELS

Prestressing Steels are best known as the High Tensile Steel Wires, Strand or Bars and are available in various sizes and configurations to impart a range of UTS.

A few of them are as listed below:

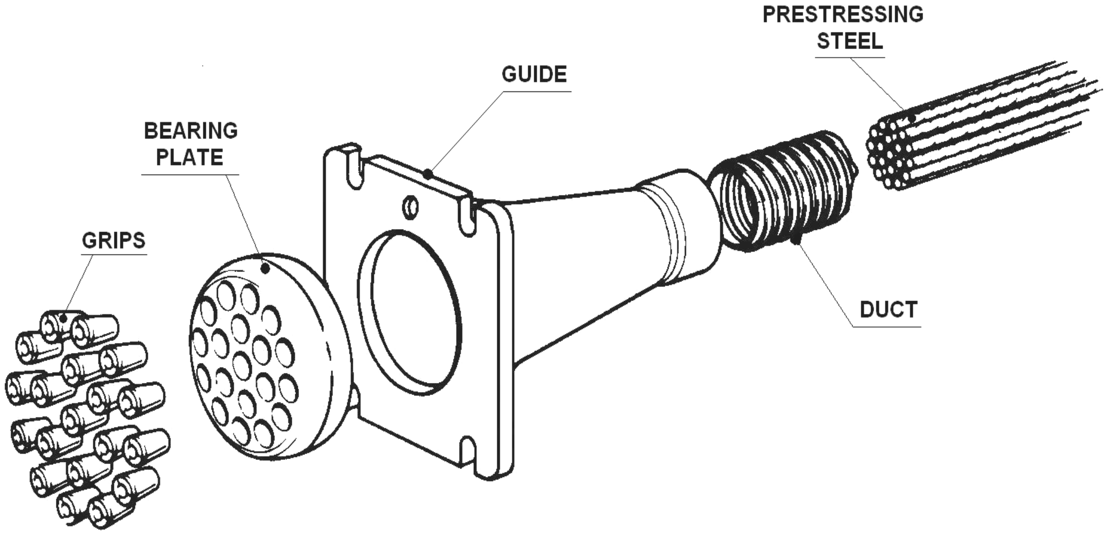
TYPES	DIAMETER RANGE	BREAKING STRENGTH	SHAPE
Plain Round Wire	2.5 mm. - 8 mm.	9.87 kN - 69 kN	
Indented Wire	4 mm. - 7 mm.	23 kN - 61 kN	
Strands - 3Ply	3.0mm. x 3 Wire	38.25 kN	
Strands - 7Ply	9.5mm. - 15.7mm.	89 kN - 265 kN	
Threaded Bar *(McALLOY)*	20 mm. - 40 mm.	173 kN - 691 kN	

High strength prestressing steels requires careful handling during transportation and storage. They should neither be dragged on hard rough surface nor laid unprotected on naked soil. It should be properly wrapped and covered with tarpaulin etc. to prevent ingress of moisture and dirt in a humid or corrosive atmosphere.

They should be stored at an elevated platform to prevent them from rising moisture if any, from the humid / wet ground condition. The Storage area must also have an adequate ventilation, to prevent condensation.

ANCHORAGE SYSTEMS

Prestressing forces of the Tendons are transferred to the concrete structures through Anchorages. Anchorage for the Post Tensioning system normally comprises of a steel plates with a number of conical holes, the conical Grips and the Guide (Trumpet). Trumpet or Guide is used to connect the ducts and provides a flat surface for locating the Bearing Plate on it. As shown in the figure below:



PRESTRESSING ANCHORAGES

a. Guide - This is specially formed component made out of graded Cast Iron, which generally gets embedded in the concrete and used to distribute the tendon forces to the concrete.

b. Bearing Plate - This is cylindrical round shaped component made out of forging of graded Alloy Steel. This plate contains a number of tapered holes for wedging the Prestressing Steel with the help of grips.

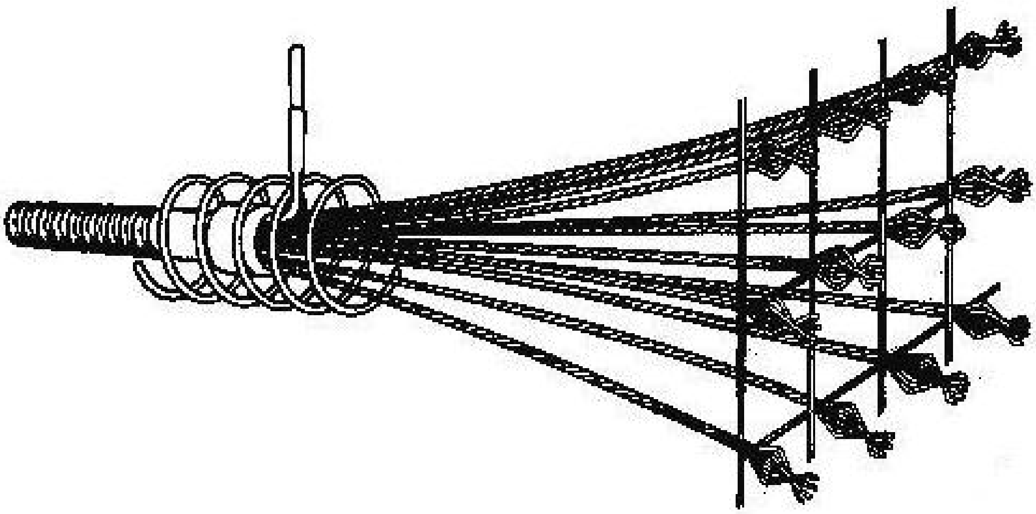
c. Grips & Circlips - This is a tapered shaped components made out of Alloy Carbon Steel and subsequently hardened & tempered. These grips are slitted in three equal parts to work like a split jaws and contains serrations inside.

FLAT ANCHORAGES

The components and the functions of the FLAT ANCHORAGES are similar to that of Prestressing Anchorages, but they are specially designed in flat shape for use in slab stress applications.

BLIND END ANCHORAGES:

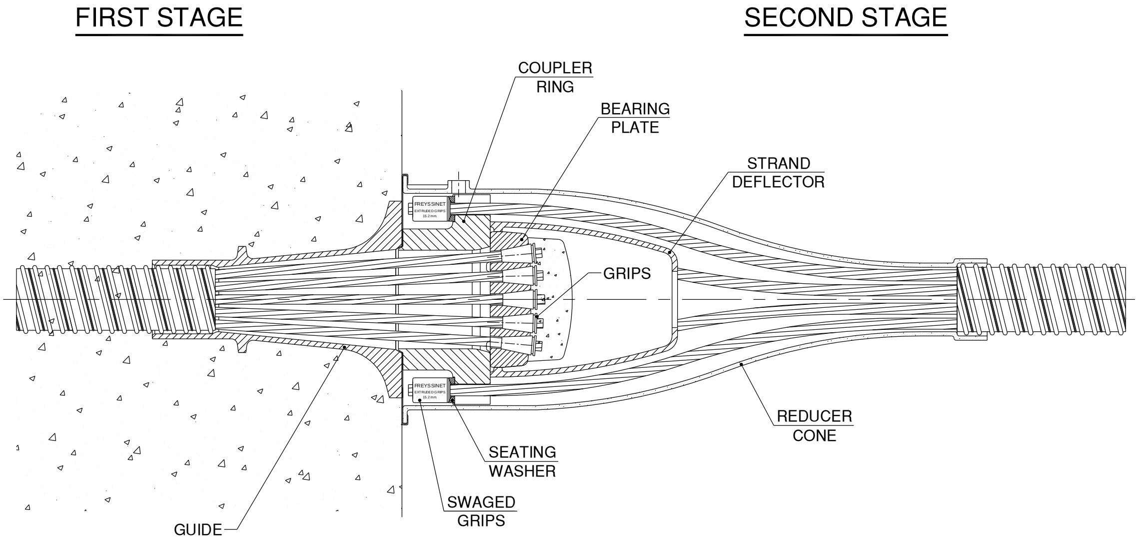
A Blind End Anchors are used where the end of the Prestressing cable is buried in concrete and or the location is in-accessible for stressing of the tendons. A typical arrangement is as shown below. BLIND-END Anchorages are also available for complete range.



ANCHORAGE COUPLERS:

In the construction of continuous deck bridges, it is essential to extend Prestressing cables as the construction proceeds. FPCC has a range of Multi Strand Anchorage Couplers in configuration of 12, 19 and 27 strands, for strand diameter of ½" (13mm.) & (0/6") 15.2mm.

In COUPLER arrangement, the first stage of Stressing is carried out in the same way as with the standard Anchorage, except that one COUPLER RING is placed between the GUIDE and the BEARING PLATE. The coupler Ring contains the required number of slotted lugs to accommodate SWAGED GRIPS fitted on the strands for Second stage cable.



After the completion of first stage of prestressing and grouting, the strands fitted with swaged grips are installed for second stage stressing. Swaged grips are prepared with the help of a specially designed sleeves and locks, on an extrusion press.

The strands are then deflected through a conical shaped trumpet called REDUCER CONE, which also prevents ingress of concrete and slurry during casting of second stage. This Reducer Cone provides a grout exit point, which should be placed at the top location to prevent any air being trapped during grouting. Small end of the Reducer cone is securely tapped to the duct of second stage.

TENDON DUCTS (SHEATHING):

Sheathing is used to create a void in the concrete structure, through which the stressing steels are inserted and remain free to stretch during stressing operation. Sheathings are available in two types:

A) Metallic Ducts
B) H.D.P.E. Ducts

A. <u>Metallic Ducts</u>: Metallic Sheathing ducts are manufactured, by rolling CRCA Steel Strips with a spiral corrugation throughout its length. These corrugations provide better bonding with the Concrete from outside and the Cement Grout from inside.

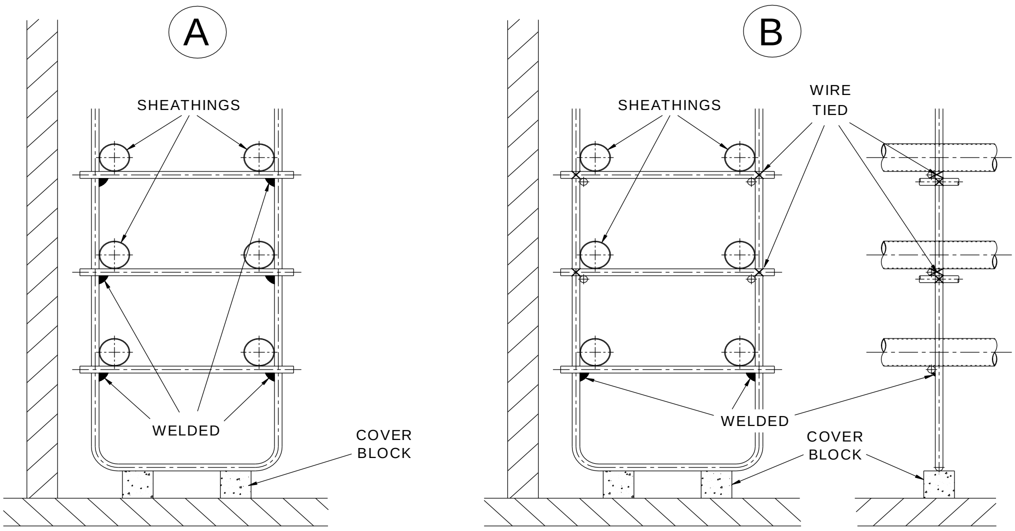
These spiral corrugations also work as a helical thread and facilitate coupling of two ducts by screwing another oversize duct. This way a continuous length of the duct can be formed. These ducts are available in different diameters and varying wall thickness to suit various configurations of Tendons. Since these ducts are made out of Steel and the chances of corrosion is very high and hence a lot of precautions are needed to store them at work site. However coated steel strips are some times used to protect them for corrosion for a longer period and enhance its service life. However, the need for using a perfect corrosion resisting material, has introduced a non-metallic ducts in the construction work.

B. <u>H.D.P.E. Ducts</u>: Non-metallic ducts are made out of High Density Poly Propylene (HDPE) or Poly-Propylene and have a number of advantages over metallic ducts, such as-

I. They are highly corrosion resistant
II. They are effectively resistant to passage of chloride ions.
III. They are very poor for electrical conductivity.
IV. The duct materials has a high co-efficient of thermal expansion (Typically - 140 x 10^{-6} deg$^{\circ}$C)
V. It has a low Young's Modulus (Nearly 800 N/mm^2)
VI. Can be sealed against ingress of contaminants.
VII. Can be pressure tested during construction to demonstrate integrity.

TENDON SUPPORTS:

To ensure the adequate transfer of calculated forces to the structure, it is very important that the tendon profile and the location of the duct, in 'X' & 'Y' directions are maintained as shown in the drawing. For this purpose; the ducts needs to be properly supported and secured at an intervals of 0.50 – 0.70 meter. The axis of the duct is considered as the line of Center of Gravity of the tendon.



TENDON SUPPORT

Examples shown above are two typical arrangements of Tendon Supports:

A. Standard Solution: The ducts are inserted through the Tendon Support.

B. Typical Arrangement for Pre-assembled tendons placed from above.

PROPER CARE TO BE TAKEN FOR INSTALLING TENDON SUPPORT:

1. In the case of lightly curved tendons or ducts, which are not supported by the strands during concreting, the supports must be placed at shorter distance to prevent uplift.
2. Tendon supports shall never be placed directly underneath the Guide Castings, Duct Joints or Sleeve for Grout Vent.
3. Tendon Supports shall never be welded near ducts or already placed tendons.

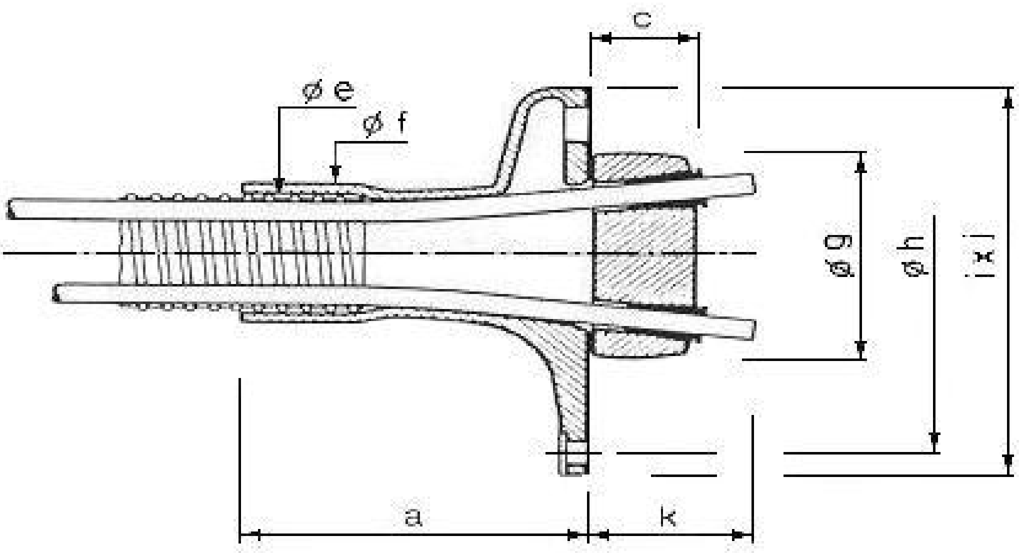
ANCHORAGE DIMENSIONS AND SETTING-OUT DETAILS

<u>THE ANCHORAGES</u>: The term Anchorage is referred to the assembly of three components, used for pre-stressing purposes

They are namely –

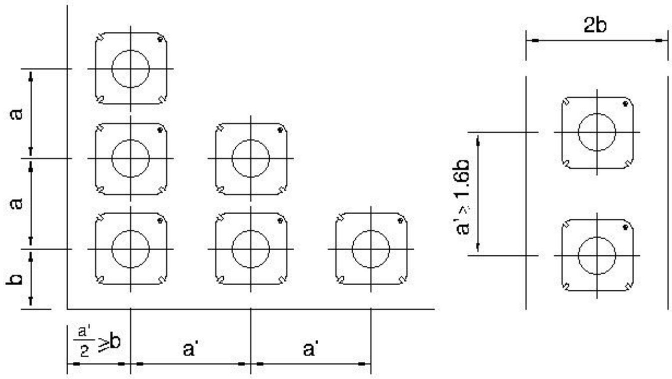
a. GUIDE
b. BEARING PLATE &
c. GRIPS

GUIDE is used as a pocket former and is made out of S.G. Iron Casting; in the shape of conical tubular form. It has a square flange with for notches at four corners for securing it to the formwork. The GUIDE is fixed in the position prior to concreting. The sheathing duct is then fitted on the smaller end of the tubular guide with the help of waterproof adhesive tape or a heat shrink sleeve. The BEARING PLATE with the GRIPS is mounted over it at the time of tensioning the tendons.

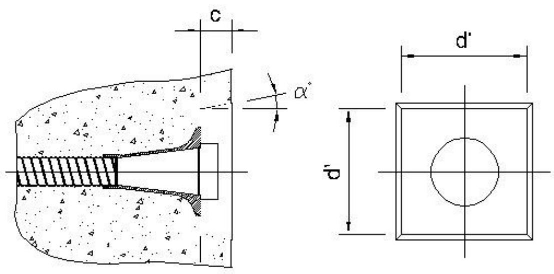


ANCHORAGE TYPE		a	c	e	f	Ø g	Ø h	i	j	k
4 K 13	**-**	104	45	45	56	85	158	147	147	75
7 K 13	**4 K 15**	103	50	62	72	120	184	160	160	85
12 K 13	**7 K 15**	180	55	84	100	140	254	220	235	90
19 K 13	**12 K 15**	190	60	95	105	160	190	244	244	95
27 K 13	**19 K 15**	270	70	127	136	200	234	275	293	105
37 K 13	**27 K 15**	395	78	171	190	252	425	365	365	115
-	**37 K 15**	467	85	178	206	270	495	425	425	125

ANCHORAGE SPACING & EDGE DISTANCE



ANCHORAGE CENTERS & EDGE CLEARANCES



RECESS DIMENSIONS

CONC. CUBE STRENGTH in N/mm. ^{2}

ANCHORAGE TYPE	TENDON FORCE kN	BASE SQUARE OF GUIDE mm. X mm.	M30		M35		M40		M45		M50		M55		M60		RECESS DIMENSIONS			
			a	b	a	b	a	b	a	b	a	b	a	b	a	b	c	d'	Jack	α°
4K13	734.8	147 X 147	200	150	185	135	170	120	170	120	170	120	170	120	170	120	100	205	K100	10
4K15	1042.8	160 X 160	220	170	200	150	180	130	180	130	180	130	180	130	180	130	110	220	K100	10
7K13	1285.9		220	170	200	150	180	130	180	130	180	130	180	130	180	130	110	270	K200	10
7K15	1824.9	220 X 220	280	220	260	200	240	180	240	180	240	180	240	180	240	180	120	270	K200	10
12K13	2204.4		280	220	260	200	240	180	240	180	240	180	240	180	240	180	120	300	K350	10
12K15	3128.4	244 X 244	325	250	300	230	290	210	270	185	270	185	270	185	270	185	125	300	K350	10
19K13	3490.3		325	250	300	230	290	210	270	185	270	185	270	185	270	185	125	350	K500	10
19K15	4953.3	275 X 292.5	430	320	400	280	360	250	320	220	320	220	320	220	320	220	125	350	K500	10
27K13	4959.9		430	320	400	280	360	250	320	220	320	220	320	220	320	220	125	500	K700	10
37K13	6796.9	365 X 365	520	400	490	360	460	330	430	300	400	270	400	270	400	270	145	500	K700	30
27K15	7038.9		520	400	490	360	460	330	430	300	400	270	400	270	400	270	145	500	K700	30
37K15	9645.9	425 X 425	580	440	560	400	540	380	500	350	460	320	460	320	460	320	160	600	K1000	30

Assumptions:

a. The minimum distances between anchorages "a" and the minimum distance "b" from the nearest free edge are given for various concrete strength levels.

b. The minimum distance "a" must be combined with a distance between a' > a in the orthogonal direction to provide for each anchorage a rectangular distribution area that satisfies the conditions aa' ≥ $3b^2$.

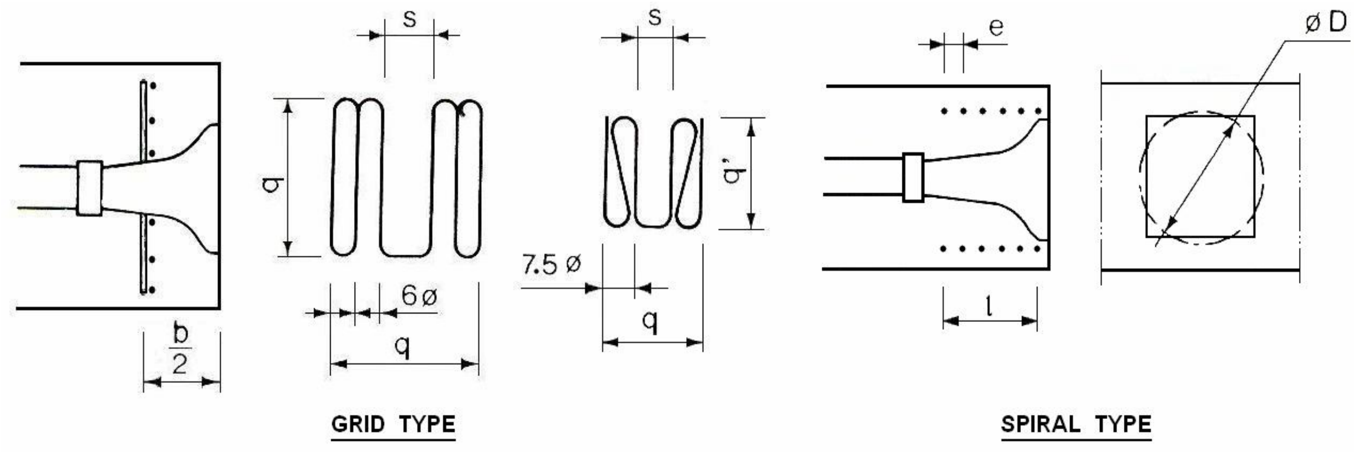
c. **M30 / M35 / M40 /....** are Characteristic Breaking Strength of Concrete Cube after 28 days.

d. Nominal Breaking Strength: for Ø 15.2mm. Strand – 260.7 kN.
for Ø 12.7mm. Strand – 183.7 kN.

e. Recess dimension d' (eg.220/270) are shown with basic Jack/Optional Jack.

f. All Dimensions shown here are in millimeters.

REINFORCEMENT DETAILS OF THE ANCHORAGE ZONES



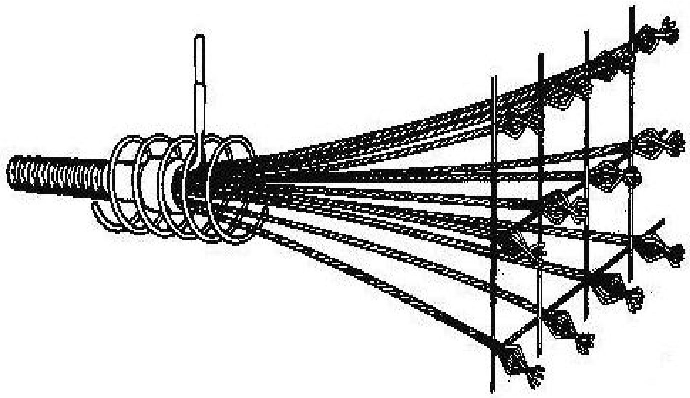
The reinforcement of the anchorage zones basically provides "Bursting Reinforcements", and applies to structures with a minimum number of bars such that all the reinforcement in the End-Block Zone, to a depth 2b, corresponds to a minimum steel percentage of 1% in each direction perpendicular to the Prestressing axis.

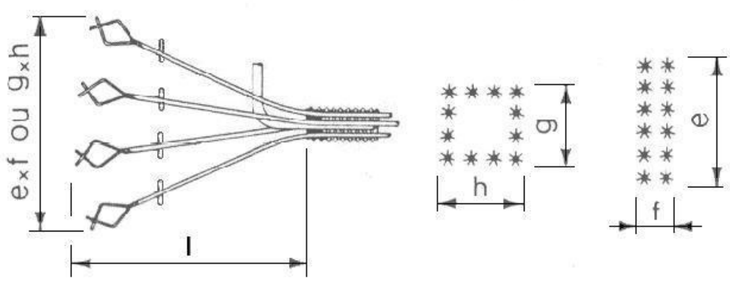
This type of reinforcement must be adapted to particular cases whenever there is a group of anchorages or a risk of cracking at the boundary of the End-Block zone; independent small size reinforcement cages must then be replaced by continuous reinforcement of equivalent cross-section. A selection guide is given in the table below.

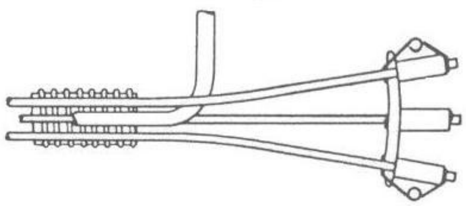
UNIT TYPE		**GRID TYPE REINFORCEMENT**						**SPIRAL REINFORCEMENT**				
		Nb	**Dia**	**b / 2**	**s**	**q**	**q'**	**Nb**	**Dia.**	**D**	**e**	**f**
7 K 13	4 K 15	6	10	80	100	350	260	6	10	200	50	300
12 K 13	7 K 15	6	12	100	120	420	312	6	12	280	50	300
19 K 13	12 K 15	6	14	120	150	500	374	6	14	360	60	360
27 K 13	19 K 15	6	16	150	170	570	426	6	16	440	65	390
37 K 13	27 K 15	2 X 6	14	180	210	560	434	7	18	540	70	490
55 K 13	37 K 15	2 X 6	16	200	240	640	496	8	20	640	70	560

DETAILS OF THE BLIND END ANCHORAGES

When a Prestressing tendon can be stressed from one end only, a dead end anchorage can be used at the other end. When the anchorage is accessible, a manually blocked type jacking anchorage (Type A or B) can be used; the anchoring jaws are driven in by sledge hammer. If the Non-tensioned end of the tendon is not accessible during stressing, a buried and fixed anchorage must be provided and the tendon is then put in place before concreting.





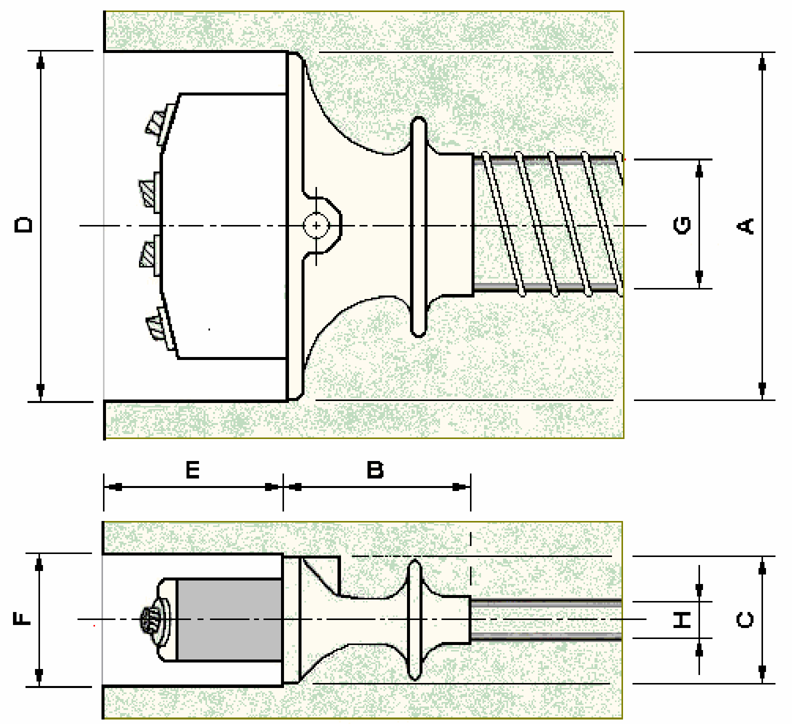


In one type of Blind end Anchors; the end of each strand is provided with a swaged sleeve. The swaged sleeve ends are positioned on a distribution plate and are held in position with the help of a spring or a retaining ring.

In another type of Blind end Anchors; the end of the strands is unwound in the form of bulbs or flower and can be laid out in square or rectangular orientation.

UNIT TYPE	e	f	g	h	l
4 K 13	350	70	150	170	800
4 K 15	390	90	190	210	950
7 K 13	370	70	170	190	1280
7 K 15	450	90	210	230	1300
12 K 13	350	190	310	270	1280
12 T 13 S	350	190	310	270	1280
12 K 15	430	230	390	330	1300
19 K 13	470	190	310	390	1280
19 K 15	570	230	390	470	1300
27 K 13	670	220	470	430	1280
27 K 15	810	260	570	510	1700
37 K 13	870	310	570	430	1680
37 K 15	1050	370	690	510	2000
55 K 13	1170	350	670	550	1980

FLAT-SLAB PRESTRESSING



The F.P.C.C. Flat-slab Prestressing System is used for all types of slabs in buildings, bridge decks and similar other applications. FPCC Flat-Slab Anchorages are available in the range consists of 2, 3, 4 & 5 strands of 13mm. (0.5”) & 15mm. (0.6”) diameter, placed in flat ducts, with respective anchorages. Strands are stressed and locked-off individually. Tendon placement and grouting procedures are similar to those of multi-strand systems.

Flat Slab Prestressing enables deflections and cracks under service conditions to be kept under control. This permits the use of a larger span with thinner slab, and can effect a substantial reduction in construction cost and time due to reduction in material and labour cost. Application of Flat-Slab prestressing also gives some important indirect savings on foundations, column and beam sizes, walls and vertical services.

UNIT TYPE	TENDON FORCE	A	B	C	D	E	F	DUCT SIZE G X H (INNER)
	kN	mm.	mm.	mm.	mm.	mm.	mm.	mm. X mm.
2 S 13	367.40	145	78	80	165	95	90	40 X 20
3 S 13	551.10	165	88	82	185	100	95	60 X 20
4 S 13	734.80	192	96	88	215	105	98	70 X 20
5 S 13	918.50	220	110	88	240	110	110	90 X 20
2 S 15	521.40	160	85	82	180	100	95	45 X 25
3 S 15	782.10	192	96	85	215	120	100	70 X 25
4 S 15	1042.80	230	110	100	250	120	110	90 X 25
5 S 15	1303.50	280	170	100	300	125	110	100 X 25

Assumptions:

a. Nominal Breaking Strength: for Ø 12.7mm. Strand - 183.7 kN.
for Ø 15.2mm. Strand - 260.7 kN.

b. All Dimensions shown here are in millimeters

STEEL CHARACTERISTICS

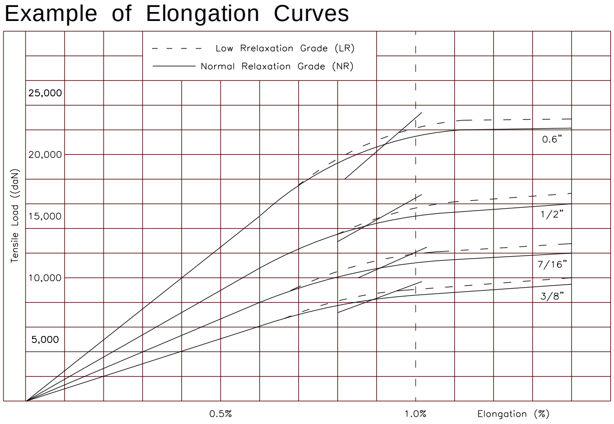
Prestressing steel stressed and embedded in concrete losses a part of its initial tension, as times goes by. This loss is known as "stress relaxation", and must be taken care of in the design of prestressed structures. Any reduction in the amount of relaxation losses will substantially improve the efficiency of the prestressed tendons.

"Low Relaxation" steels give a relaxation loss not greater than 2.5% (after 1,000 hours, at 20°C / 68° F), when initially loaded at 70% of the specified minimum breaking strength. Normal stress relieved steel exhibits, in comparison, losses of around 7%.

The Introduction of Super Strand represents a significant development for the prestressed concrete industry. It has higher breaking load than normal strand without sacrificing any of the other mechanical properties. Higher strength strand means an initial savings in material costs, and fewer strands in a prestressed member results in a further savings due to lower handling cost.

STANDARD	GRADE	SIZE	NOM. DIA. mm.	NOM. SECTION $mm.^2$	NOM. WEIGHT Kg/m	SPECIFIED BREAKING LOAD kN	SPECIFIED BREAKING LOAD kips	SPECIFIED LOAD AT 1% ELONGATION kN	SPECIFIED LOAD AT 1% ELONGATION kips
Euronorm 138-6/79 Standard	1770 MPa	½" – T13	12.50	93.00	0.730	164	36.9	139	31.3
	1860 MPa	½" – T13	12.50	93.00	0.730	173	38.9	147	33.1
	1670 MPa	0.6" – T15	15.20	139.0	1.090	232	52.2	197	44.3
	1770 MPa	0.6" – T15	15.20	139.0	1.090	246	55.3	209	47.0
Euronorm 138-6/79 Super	1860 MPa	½" – T13	12.90	100.0	0.785	186	41.8	158	35.5
	1770 MPa	5/8" – T13	15.70	150.0	1.180	265	59.6	225	50.6
A.S.T.M. A 416/80	250 kpsi	½" – T13	12.70	92.90	0.730	160.1	36.0	144.2	32.4
	270 kpsi	½" – T13	12.70	98.71	0.775	183.7	41.3	165.4	37.2
	250 kpsi	0.6" – T15	15.24	139.35	1.094	240.2	54.0	216.3	48.6
	250 kpsi	0.6" – T15	15.24	140.00	1.102	260.7	58.6	234.7	52.8

Example of Elongation Curves



Example of Relaxation Curves

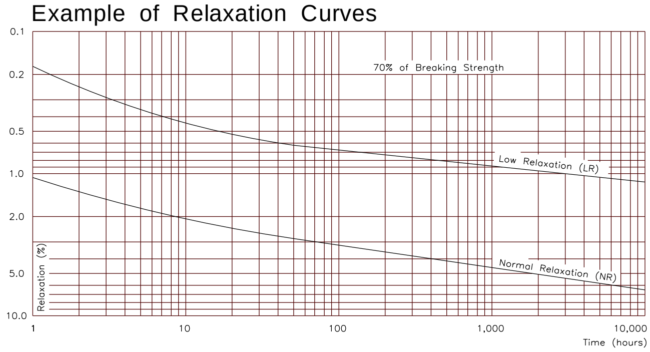


TABLE FOR STANDARD PRESTRESSING TENDONS

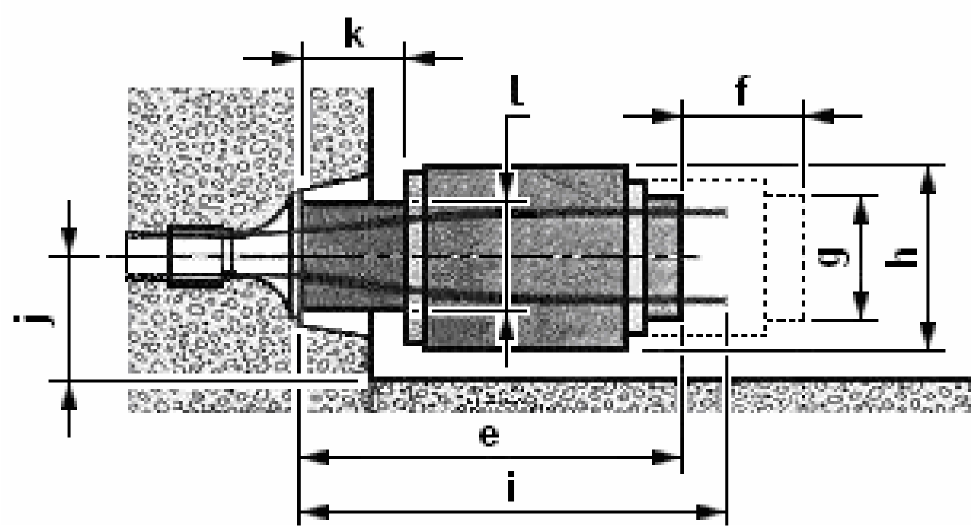
The 'K' Range of anchorages has been designed for use with all existing grades of strand and in particular those possessing the highest performance characteristics, such as those complying with the Euronorm Super Grade.

Engineers should of course refer to the specific manufacture's characteristics (e.g. – Nom. Breaking Strength, Cross-Sectional Area, Relaxation etc.) for the type of strands specified for any particular structure.

For all anchorage systems listed, individual or groups of strands may be omitted to optimize the system. However, it should be borne in mind that the tendons containing maximum possible number of strands for any particular anchorage, represents the most efficient use of that anchorage.

CABLE FORCES (in kN)

STANDARD	EURONORM 138 - 6/79						A.S.T.M. – A 416/80			
	Grade 1770		Grade 1860		Super Grade 1860		Grade 250 K		Grade 270 K	
UNITS	**100%**	**80%**	**100%**	**80%**	**100%**	**80%**	**100%**	**80%**	**100%**	**80%**
4 K 13	656	525	692	554	744	595	640	512	735	588
7 K 13	1148	918	1211	969	1302	1042	1121	897	1286	1029
12 K 13	1968	1574	2076	1661	2232	1786	1921	1537	2204	1764
19 K 13	3116	2493	3287	2630	3534	2827	3042	2434	3490	2792
27 K 13	4428	3542	4671	3737	5022	4018	4323	3458	4960	3968
37 K 13	6068	4854	6401	5121	6882	5506	5924	4739	6797	5438
55 K 13	9020	7216	9515	7612	10230	8184	8806	7045	10104	8083
	Grade 1670		**Grade 1770**		**Super Grade 1770**		**Grade 250 K**		**Grade 270 K**	
4 K 15	928	742	984	787	1060	848	865	692	1043	834
7 K 15	1624	1299	1722	1378	1855	1484	1514	1211	1825	1460
12 K 15	2784	2227	2952	2362	3180	2544	2596	2077	3128	2502
19 K 15	4408	3526	4674	3739	5035	4028	4110	3288	4953	3962
27 K 15	6264	5011	6642	5314	7155	5724	5840	4672	7039	5631
37 K 15	8584	6867	9102	7282	9805	7844	8003	6402	9646	7717



K-RANGE JACKS

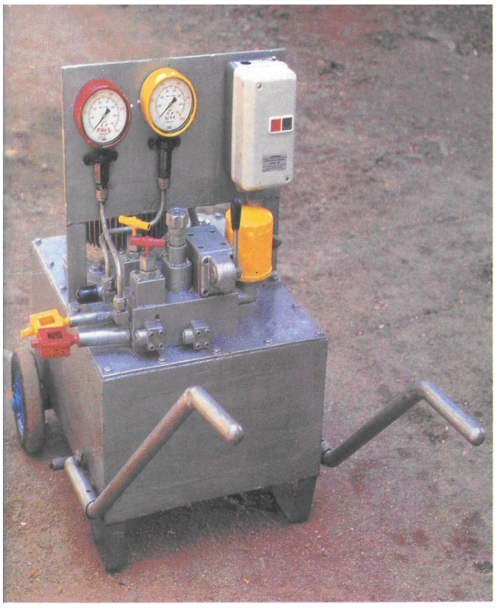
The FPCC is manufacturing a range of Jacking Units, to cover the entire range of Prestressing Systems; with Mono-Strand and the Multi-Stressing System. The K-Range Jacks are designated as Central Hole, Twin Cylinder Double Acting Hydraulic Jacks. The Main Jacking Unit has a to-n-fro moving piston and is used as Stressing Cylinder. Strands are being anchored at the rear end of the Piston with the help of specially designed Anchor Plate and self releasing Conical Grips. Another Jacking Unit located at the front end, is a hollow cylinder Single Acting Hydraulic Jack and is used for blocking purposes. Depending on the tendon type and the available spaces; a complete range of Jacks are available.

The table below can be referred for the selection of the Jack for Prestressing of Cables:-

JACK TYPE	ANCHORAGE TYPE		e	f	g	h	i	j	k	l
K 100	4 K 13	-	635	200	185	275	785	190	126	192
	7 K 13	4 K 15	635	200	185	275	785	190	126	192
K 200	7 K 13	4 K 15	720	200	220	350	875	230	228	274
	12 K 13	7 K 15	726	200	220	350	875	230	231	274
K 350	12 K 13	7 K 15	820	250	267	440	970	270	235	324
	19 K 13	12 K 15	820	250	267	440	970	270	230	324
K 500	19 K 13	12 K 15	940	250	267	515	1090	310	230	410
	27 K 13	19 K 15	933	250	267	515	1090	310	222	410
K 700	27 K 13	19 K 15	881	260	350	610	1030	360	142	478
	37 K 13	27 K 15	973	260	350	610	1125	360	104	478
K 1000	37 K 13	27 K 15	1062	220	400	710	1220	410	268	535
	55 K 13	37 K 15	1171	220	400	710	1320	410	279	535

ELECTRICALLY OPERATED HIGH PRESSURE PUMP:

The FPCC Prestressing Jacks are being operated using FPCC manufactured E.O.H.P. Pumps. Three variants of these power packs are used to suit the individual need of the various jacks.



The Pumping unit used in these power packs is of Multi-Plunger, Axial Flow and Positive Displacement type. They are suitably coupled with a TEFC Electric Motor and are mounted on a special designed Oil Tank.

The power pack also houses suitable D. C. Valve, Check Valve, Relief Valve and Shut-off Valve etc. mounted on a manifold for effective control of the Hydraulic Jacks. Two distinguished Pressure Gauges are also mounted on the front panel of the power pack to read the Stressing and Blocking Pressure; as the case may be.

Other than the EOHP, FPCC also manufactures Hand Operated High Pressure Pump (HOHP).

The table below represents the suitability of various models of the power packs:

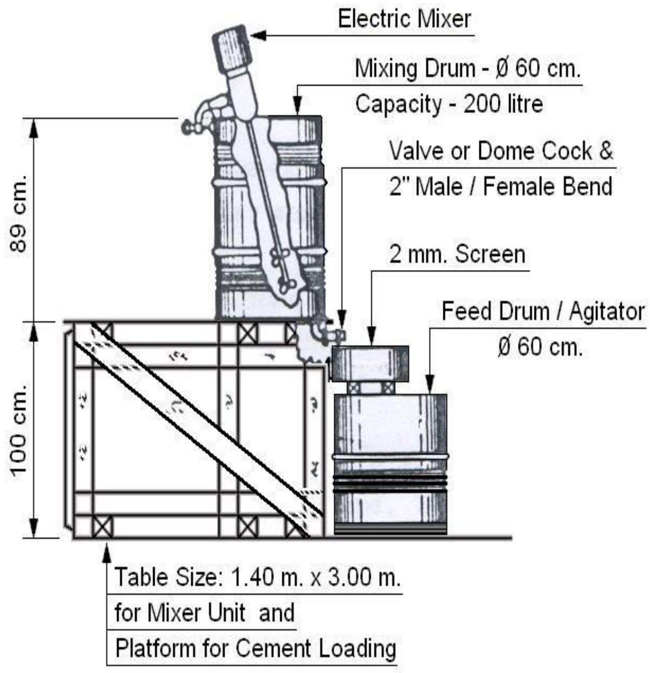
SALIENT FEATURES OF THE POWER PACK	UNITS	E.O.H.P. Power Pack			H.O.H.P. Pump
		MK-I	MK-II	MK-III	
Test Pressure (Max.)	$Kg.f/cm^2$	600	650	650	640
Working Pressure (Max.)	$Kg.f/cm^2$	450	580	580	550
Oil Delivery (Max.)	Ltr./min .	1.50	1.50	2.50	0.20 (S/A) 1.50 (D/A)
Oil Tank Capacity:	Ltr.	25	60		-
- - Do - -	Ltr.	10	25		-
T.E.F.C. Electric Motor: 440 Volts, 3 ph, 1440 rpm	hp / KW	2.0 / 1.49	3.0 / 2.24	5.0 / 3.73	-
Dimensions -	mm.	575	630		600
	mm.	335	950		350
	mm.	705	800		980
Machine Weight: Dry	kgs.	45.0	110.0		58.0
With Oil	kgs.	66.0	162.0		-
Recommended Sizes of Prestressing Cable	-	4S13 - 5S13 4S15 - 5S15 4K13 - 7K13	4K13 - 12K13 4K15 - 7K15 or Equivalent	19K13 - 27K13 12K15 - 27K15 or Equivalent	4S13 - 5S13 4S15 - 5S15 4K13 - 7K13
JACK RECOMMENDATION	-	SC-2 & K100	K-100 & K-200	K-500 & K-700	SC-2 & K-100

Other than the Prestressing Jack & Power pack, FPCC also manufactures some other Special Application Jacks and Pumps to suit customer's specific needs, Such as - Heavy Lifting Jacks, Lifting & Lowering Jacks, Side Shifting Jacks and Flat Jacks etc. A special power pack is also available to operate these jacks.

GROUTING SYSTEM:

F.P.C.C. also manufactures the complete machinery & system for Grouting purpose. It comprises of Grout Mixer & Agitator and Grout Pump.

GROUT MIXER & AGITATOR:

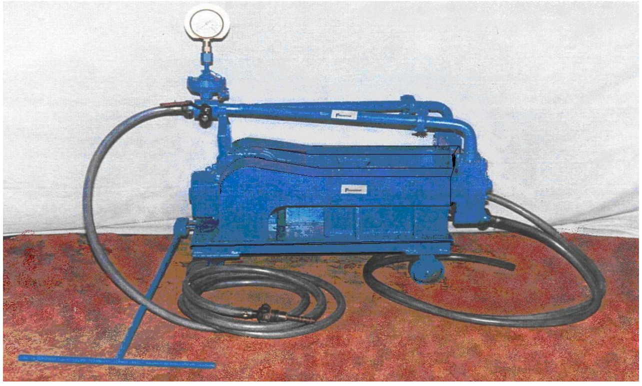


It is a combination of two circular formed drum units, where the first drum is used as Cement Mixer and the other drum is used as an Agitator for the cement slurry. The first Drum `MIXER' is equipped with an electrically driven rotary turbulating blades at the center and churning blades fixed on the inner wall of the drum. In this drum Cement is mixed with water. The Mixing Drum is generally kept at a higher level than that of Agitator Unit, such that mortar can flow directly into the second tank, the Agitator, placed just beneath the mixing drum. Before flowing into the Feed Drum (Agitator), the mortar is passed through a 2mm. mesh screen to eliminate impurities and lumps etc. Cement mortar stored in the Feed Drum (Agitator), is continuously stirred to avoid setting or segregation.
A Schematic Diagram of such an arrangement is shown above.

AGITATOR Model J-700:

Shaft Rotation : 120 rpm
Electric Power : 2 hp. / 440 volts/ 1440 rpm
Motor
Handling Weight : 38 kgs.
Overall Dimension: Length x Width x Height
125 x 25 x 48 mm.

GROUT PUMP - Model J-600:



To fill the cement mortar inside the cable duct, FPCC Manufactures, a very compact electrically driven Pump Model: J-600.

This is a reciprocating type, twin cylinder, positive displacement pump.

The Salient features of this pump are:

Delivery	:	1200 liters/hr. (Maximum)
Testing Pressure	:	30 kg.f/cm^2
Delivery Pressure	:	25 kg.f/cm^2 (Maximum)
Electric Power	:	2 hp. /440 volts/1440 rpm Motor
Handling Weight	:	214 kgs.
Overall Dimension	:	Length x Width x Height in mm.
		980 x 480 x 940

GROUT PUMP - Model P-2001:

FPCC has also developed a higher version of Grout Pump Model: P-2001, for grouting of vertical cables in the cylindrical structures such as Cement Silos, Chimneys, Containment wall of Nuclear Reactors etc.

A representative pictorial View is presented here for Reference.

The Salient features of this pump are:

Flow Rate (Range)	:	900 liters/hr. to 3900 liters/hr.
Pressure (Range)	:	10 - 40 kg.f/cm^2
Working Pressure	:	30 bar (Maximum)
Power Supply	:	7.5 hp/440 volts/3Ph., 1440 rpm Elect. Motor
For Controls	:	Solenoid Valve, Limit Switches, Pressure Switch & Control Circuits etc.
Handling Weight	:	580 kgs.
Overall Dimensions	:	Length x Width x Height in mm.
		1460 x 1455 x 1540

HAND OPERATED GROUT PUMP - Model HOGP:

For special application in shorter cables and small structures, FPCC has a unique Hand Operated Grout Pump. This pump is used where the quantum of Grouting Mortar, to be pumped, is relatively low and the cable cavity is small. Since the pump is hand operated one and does not require any electricity, it has a very wide acceptance in the remote areas where the supply of electricity is scares. A representative pictorial View is presented here for Reference.

The Salient features of this pump are:

Flow Rate	:	8.50 liters/minute
Delivery Pressure	:	14 kg.f/cm^2
Testing Pressure	:	17.5 kg.f/cm^2 (Maximum)
Handling Weight	:	55 kgs.
Overall Dimensions	:	Length x Width x Height in mm.
		580 x 300 x 900

PRESTRESSING OPERATION

This chapter shall deal with the Handling and Installation of H.T. Strands, Stressing Procedure and the Grouting Operations etc.

HANDLING & INSTALLATION OF H.T. STRANDS

The H.T. Strands are used as medium for inducing the stressing forces in the structures and thus become the most important constituent of the Prestressing Operation.

The strands are inserted or placed into the ducts, provided in the concrete structures. Placement / Insertion of the strands can be done either prior to concreting or after the concreting as well, but the insertion before the concreting is more dependable and therefore, should be given more preference.

In this case, the ducts/sheathings must be tied firmly to the tendon supports or reinforcement bars.

When the strands are inserted after concreting, necessary precaution should be taken to prevent the sheathing duct, from getting clogged with cement slurry during concreting. The most commonly used method is to insert a dummy pipe or mandrel inside the duct and regularly agitate it during concreting procedure. This prevents any settlement of cement slurry in the duct.

NECESSARY PRECAUTIONS – FOR INSTALLING DUCTS & STRANDS

1. Fix the Sheathing duct firmly on the smaller end of the Guide or trumpet

2. Test Certificate of the Prestressing Steel and Identification Label from the Strand Coil should be kept in safe custody. These data sets are very important and shall be used for Calculating the modified force and elongation at the time of carrying out stressing operation. Strand data from the “Identification label” and Tendon number, in which the strand has been used, should be recorded in the Construction Book.

3. Strand should be uncoiled in such a manner that it does not get twisted and should not be laid or dragged on soiled or rough surfaces. A wooden palate should ideally be erected in the yard for dragging & laying the strands after de-coiling.

4. Strand should not be laid or dragged on soiled or rough surfaces. A wooden palate should ideally be erected in the yard for dragging & laying the strands after de-coiling.

5. Strands should be cut evenly by an abrasive cutter in desired length.

6. Strands ends should be ground smooth, to prevent any damage to the duct during insertion by pushing. If required a suitable bullet end can also be employed to have a smooth insertion.

7. When the strands are pulled into the tendon ducts together in bundle, special care should be taken to prevent the damage to the duct or the strands. Roller cradles can be used to carry the tendons on the rough ground.

8. In case of threading of strands after concreting, it is recommended to use a De-Coiler and the Strand Pushing Machine for uncoiling and threading of strands into the duct.

9. Before concreting, check the entire length of the ducts for any opening or damages. Seal them firmly with the adhesive tape or any suitable sealant.

10. Both the ends of the duct should be closed after installation, and the strand ends should be wrapped firmly with anti moisture wraps to prevent the ingress of any foreign particles, cement slurry, concrete or moisture inside the duct. They may damage the duct and the strands in long run.

11. Precaution should be taken to prevent the sheathing/ducts from getting damaged due to the use of Needle vibrators during concrete. Damage or puncture of Sheathing may cause a severe ingress of cement slurry into the duct and will result in blocking the Strands up to certain length.

12. Clogging of strands inside the duct will cause an unequal elongation during stressing and will obstruct the passage during grouting.

STRESSING OPERATION

This chapter shall deal with the Stressing Operation of Cables with Multi-Strand System. For Stressing Operations of Wires/Bars/Mono Strand, details can be furnished on request.

PREPERATIONS FOR STRESSING OPERATION

Before starting with the actual Stressing Operations, certain preparations should be made; some are required to be done prior to concreting. They are listed out as below:-

Basic Requirements:

1. The Stressing Operation can be initiated, only after concrete attains it's strength (usually 60% to 80% of it's ultimate strength in 28 days). This can be ascertained by testing the cube strength of the concrete.

2. 3 or 4 sets of Cube Mould (Size: 150 x 150 x 150 mm) should be poured/prepared alongwith the concreting of the main structure, to be Stressed. Each set should consist of minimum 3 numbers of moulds.

3. Stressing drawing should be thoroughly studied to ascertain following parameters, and if required, should be consulted with the Principal/Design consultant.
   i. *Stressing Schedule* - Minimum Stay period after concreting, Minimum Concrete strength for Stressing, Sequence of Stressing for various cables etc. should be obtained from the drawing.
   ii. *Anchorage/Cable Type* – The configuration and type of the cables is also shown in the drawing (i.e. No. of Strand x Dia. of Strand). A suitable Guide/Trumpet and suitable size of Sheathing duct should be installed in the structure at the time of fixing of reinforcement cage and before the actual concreting is done.
   iii. *Assumptions* – At the time of designing any structure, designer assumes the standard values of certain parameters for deriving the designed forces & elongations. These parameters are shown in the drawing as Assumptions and are mainly known as Cross-Sectional Area of Prestressing steel (Strand), Modulus of Elasticity of Prestressing Steel, Friction & Wobble Coefficient of Duct and the Wedge Set etc.

iv. *Stressing Force* - Stressing force to be applied on each cable. Different cables may require to be stressed at different force level.

v. *Elongation* - Elongation to be achieved, in each cable? Different cable may require to be stressed for different elongation.

vi. *Type of Stressing* - One End Stressing or Stressing from both the ends.

Local Conditions:

1. The Prestressing Engineer should physically check the access of the Prestressing point, for personnel and equipments.

2. Jack Clearance from the structure, distance between two cables, Pocket dimensions of the End block should be checked, with respect to the size and dimensions of our equipment and accessories.

3. If required necessary platform for the personnel and equipment, and the handling gantry for the equipment should be erected for easy and comfortable access to the Stressing point.

4. Our equipments require electricity as a source of energy, hence availability of electricity to be checked to operate our equipment and to illuminate the Job site for night work.

5. Availability of potable water (calcium/sulfur/chlorine free) is also required to be checked. This is a most essential commodity for carrying out the grouting operation

Planning:

1. The Prestressing operation should be carried out by a Qualified Engineer. He should be competent enough to calculate the required forces and elongation during stressing and can take necessary decision instantly at the work site. He should also be sufficiently able to lead the team of experienced and skilled technicians and workforce.

2. Necessary planning should be made to carryout the stressing operation as per the given schedule, by effectively utilizing the available work force and machinery and a reduced downtime.

3. Each strand carries a different cross-sectional area and thus a different Modulus of Elasticity. These data has already been obtained from the "Identification Label" and the "Test Certificate" of the Prestressing steel (strand) at the time of preparing the Cables.

4. Designed Forces and Elongations, needs to be modified from the actual values of the Prestressing steel (strand) being used. Necessary formulae for calculating the same has been given in the subsequent chapter of “GENERAL DESIGN & INFORMATION”.

5. Friction & Wobble Coefficient of Ducts are the standard data and does not necessarily need any modifications in normal conditions. These values are given in various approved certificates. Unless mentioned otherwise, they remain constant irrespective of the different supplier or supplies.

6. WEDGE SET of the Anchorages and equipments are specified by the manufacturer. Necessary correction should be applied, if differs from the design assumptions.

Equipment & Accessories:

1. Make a thorough visual inspection of the equipments to ascertain, if they are visibly not damaged, or having any of its parts truncated, dislocated or damaged. Check for any visual leakages etc. in the hydraulic equipments.

2. Check the quality & quantity of all the accessories of the Hydraulic Jacks and Accessories; such as Conversion Kits, Master Grips, Terminal Adaptors, Grip releasing Agent etc., for it’s perfection.

3. Check the condition of Pressure Gauges, it’s fittings & connections etc. for correctness. Obtain necessary Gauge Calibration Certificate from the competent authority. The calibration certificates should not be older than 6 months or the 100 repetitive uses (whichever comes earlier)

4. It is recommended that sites should have Master Pressure Gauge or the Pressure Gauge Calibrator to conduct, periodical calibration of the Pressure Gauges.

5. Check the Hose pipes and it’s end fittings are intact and are connected correctly with the pump & Jack.

6. Obtain Jack efficiency data from the Factory or the manufacturer/supplier of the Jack. It should also be checked periodically at site level to update the stressing record. The detail methodology for “Jack Efficiency Test” is given in the subsequent chapter “GENERAL DESIGN & INFORMATION”.

7. Check the adequacy of handling equipments, in advance. They should not fail while lifting, holding and positioning of the jack during stressing.

Stressing Data & Records:

After complete setup and planning; Stressing operation should be carried out, as described below:-

1. Check the concrete strength and if it attains 60% to 80% strength of its prescribed value, Stressing operation may be started.

2. Apply necessary correction to the *'Stressing Force'* and 'Elongation', with respective available 'Cross-sectional Area' & 'Modulus of Elasticity' of Prestressing steel, 'Friction & Wobble Co-efficient', if any, and the recommended 'Wedge Set' for the equipment etc.

3. Stressing operation is monitored in two ways:

   a. By Pressure Gauge Reading: Pressure gauge reading on the power pack is translated into the force applied by the jack and ultimately transferred to the anchorages through Prestressing Steel. The tendon force can be calculated by multiplying the pressure gauge reading to the 'Ram Area' of the Jack. Ram area of the Prestressing Jack is generally provided by the manufacturer.

   b. By Elongation Method: Actual elongation can be compared with the theoretical elongation of the Prestressing steel. It can be calculated with respect to data available for the Prestressing steel used. Necessary calculation detail is given in the subsequent chapter "GENERAL DESIGN & INFORMATION".

4. The Measurement of forces *'By Elongation Method'* provides the measure of the average forces throughout the length of the Tendon, whereas the Pressure Gauge Method provides the measure of forces in the tendon at Anchorages.

At the Stressing Ends:

1. If the Prestressing steel (Strands) are laid prior to concreting, Try to move the strands to & fro, individually or in group, to ascertain, the cable is free from any incursions or clogging. If the cable is found to be free, we can proceed with the stressing operation. Otherwise some efforts are required to make the cables free and stress able.
2. Pull the projected length of the strands outside the cable opening, up to a length equals to the "Strand Gripping Length of the Prestressing Jack" + "Double of the Elongation required". Thoroughly clean them with some fluid cleaner and make them free from corrosion, dust and any short of inhibitions etc.

3. Repeat the above procedure from the other end of the cable too.

4. Push the extra length of the strands, inside the cable and adjust the projected length of the strands equal to the prescribed “Strand Gripping Length” for the Jack in use. Repeat this procedure from other end of the cable too.

5. Check the Taper holes of the *‘Bearing Plates’*, and if necessary, remove rust and clean them. Please consider unpacking and placing of *‘Bearing Plates’* and *‘Grips’* only shortly before the stressing. This will prevent the *‘Bearing Plate’* holes and *‘Grips’* from getting exposed to atmosphere as little as possible. They should be free from rust and corrosion, until fully stressed.

6. Thread the *‘Bearing Plate’* over the strands and rotate it for 5 to 6 times in clockwise direction and then reverse the rotation in anti-clockwise direction for equal number of times. By doing this a considerable length of strand inside the cable gets freed from entanglement.

7. Install the *‘Grips’* over the strands and push them into the taper holes of *‘Bearing Plate’* with the help of a pipe. *‘Grips’* should be pressed into the *‘Bearing Plates’* simultaneously from both the ends of the tendons, till it gets fixed on the surface of the *‘Guide Cone’*.

Set-up and Equipment Connections:

1. Check for the Oil level in the reservoir of the power pack. Top up if necessary with required quantity of ***ENKLO-68*** (Hindustan Petroleum) Hydraulic Oil.

2. Connect the Jack with high-pressure hose pipes to the hydraulic power pack. Check the connectors/couplers for the leakage, if any. Secure them firmly and keep them as clean and dry as possible. Leaking couplers attract more dust & dirt and can easily get inhibited in the hydraulic system through oil.

3. Check the hose pipes also and ensure that they are also clean dry and dirt free.

4. Check the Pressure gauges are connected properly and the end connections are leak-free, clean and dry. Leaking joints shall reflect a continuous pressure drop and will create hindrance in the stressing operation.

   It is recommended that the pressure gauges fitted on the power pack are properly calibrated with Master gauges or Dead Weight Calibrator and an authentic calibration certificate is there in the possession of the engineer.

6. After connecting all the Hoses, bleed the air from the hydraulic system. For this close the hydraulic circuit and idle run the Jack for full extension and retraction. Repeat this for 3 to 4 cycles.

   This way any air bubble present in the hydraulic circuit/system shall escape and will prevent any short of partial pressure drop and jerky or rattled movement of the piston.

Mounting of Jack & Conversion Kit:

1. Insert the *'Bearing Ring'* over the *'Bearing Plate'* at both ends of the Tendon and press to fully to sit properly over the *'Guide Ring'*.

2. Insert the *'Pressure Plate'* as per the orientation of the Bearing Plate Hole.

3. Jack should be suspended through a *'Jack Handling Gantry'* with the help of a *'Chain Pulley Block'*. The arrangement should be such that it gives a full flexibility of movement to the Jack in both transverse & longitudinal direction.

   In small projects, a rigid twin Runway beam structure could be erected at the end of bridge girder, for easy maneuvering of the Jack.

4. Insert the bunch of the Prestressing steel (strands) in the central hole of the jack and push it down towards the *'Bearing Ring'* and *'Anchorage'*. Axis of the Jack should coincide with axis of the tendon.

   Raise, lower or tilt the jack, as required, the face of the jack should be perfectly seating over the face of the *'Bearing Ring'*.

5. Insert the *'Rear Anchor Plate'* on the strands as per the orientation of the Tendon and then firmly locate it over the back seat of the Jack Piston.

6. Sprinkle *'Molylube Spray'* or apply any other *'Grip Releasing Agent'* on to the external surface of all the *'Master Grips'* and inside the taper hole of the *'Rear Anchor Plate'* as well.

   Grip Releasing Agent works as a lubrication between the metals and prevent, metal to metal locking of the *'Master Grips'* with *'Anchor Plate'*. While applying these agents, be careful not to apply or spray them on the serration /thread portion of the Master Grip.

7. Insert the 3 piece *'Master Grips'* over the strands coming out of the back side of the *'Rear Anchor Plate'* holes. Push *'Master Grips'* into the taper holes of *'Rear Anchor Plate'* with the help of a pipe, to sit tightly inside the Anchor plate.

8. Check all the connection of jack with power pack, giving flexibility to hose pipes for movement of jacks at the time of stressing

9. It is important that supporting chains or hooks should be slackened off as soon as the jack starts carrying load. Similarly they should also be ready to support the jack again while retracting.

10. Now the system is ready for STRESSING OPERATION.

11. The Operating Instructions for the Equipment and Accessories should be kept handy and available at the working site during stressing.

STRESSING DATA & RECORDS

Before starting Stressing Operations, following Data/Record should be available with the Engineer.

1. Tendon Identifications No.
2. Stressing Sequence
3. Length of the Tendon (from Anchorage end to Anchorage end)
4. Design Elongation of the Tendon - (lz)
5. Elastic Shortening of the Concrete - (lb)
6. Wedge Set at Anchorage - (ls)
7. Elongation of the Prestressing Steel - (le)
   Within the length of Stressing Jack
   (From Bearing Plate Grip to Master Grip)
8. Total Calculated Elongation lo = (lz + lb + ls + le)
9. Specified Stressing Force - (P)
10. Specified Cross-Sectional Area of Prestressing Steel
11. Specified Modulus of Elasticity of Prestressing Steel
12. Actual Cross-Sectional Area of Prestressing Steel
13. Actual Modulus of Elasticity of Prestressing Steel = (Ea)
14. Ram Area of the Stressing Jack
15. Pressure Gauge Calibration Report
16. Jack Efficiency Report
17. Elongation & Stressing Force to be modified/estimated on the basis of the Actual Jack Efficiency of the jack, Actual Cross-Sectional Area & Actual Modulus of Elasticity of The Prestressing Steel under use.

APPLICATION OF PRESTRESSING FORCES AND ELONGATION

Any load applied must cause an extension. Since there must be some slack in the tendon, it is very difficult to establish the datum from which elongation should be measured.

To overcome this Problem - Two methods are being followed::::

First Method:

A Nominal force 'μp', sufficient to get the Jack tightened, is applied to the tendon. It is assumed that jack gets tightened only when the slackness is removed. This level is then assumed as the datum for extension measurement. For all practical purposes a nominal load of 40-50 kg.f/cm^2 is normally considered as datum level. Remaining forces are then applied in regular succession up to the desired level. Record corresponding extension at successive applied forces and plot the recorded values on a stress/Strain diagram. This is done by plotting a graph with the Gauge Reading (Force) at abscissas and elongation as ordinates. On extra-polation, the plotted curve intersects at Y-axis, and thus defines as the effective elongation during slackness or initial tensioning. This elongation during initial tensioning should be added to the measured elongation to arrive at the actual elongation. A representative curve and data sheet is given in the document section.

Second Method:

In this method, a force equal to P/3 is applied to the tendon to establish the datum, and the extension is measured between the 'Force P/3' and the 'Force P'.
The measured extension is thus corresponds to 'Force 2/3 P' and the full extension at 'Force P' can be calculated by formulae of proportion. Here it is assumed that grip set is proportional to the applied force.

In this method, measured elongation should agree with calculated elongation within ± 15% for individual tendons, and ± 5% for all tendons. These assumptions are based on the theory that the calculations are done with actual modulus of elasticity and actual cross-sectional area of strand under use. Further, the Co-efficient of Friction and the Wobble Co-efficient are considered at an average value, and may vary slightly from project to project.

This method is very effectively used for two stages stressing where the required tendon elongation is more than the stroke length of the jack

Methodology:

Go to 1/3rd of the designed Load, Operate the blocking Jack and block the Live *'Grips'* in *'Bearing Plate'* and retract the jack. No elongation Reading is required to be taken at this stage. This forms the datum and slackness is totally removed.

Reset the Jack and go back to 1/3rd Load again and measure the Ram Extension. Now go to Full Load and note the Ram Extension. Block the Grips and return to 1/3rd Load. Note the reduction in elongation.

This reduction in elongation represents the 'Wedge Set' and 'Elastic Shortening of Strand' for 2/3rd Load. Proportionately the value of 'Wedge Set' & 'Elastic Shortening' for 1/3rd Load can also be added to get actual 'Wedge Set' and 'Elastic Shortening'.

<u>SOME TYPICAL EXAMPLE FOR TWO END STRESSING</u>: Are Given below-

i. SINGLE STAGE STRESSING – When Extension is less than 200mm, in each jack at each end.

	<u>Ist. JACK – At One End</u>	**<u>IInd. JACK – At Other End</u>**
*	Go to 1/3rd Load (1/3 P)	Go to 1/3rd Load (1/3 P)
*	Extension - Need not be recorded	Extension - Need not be recorded
*	**Block the Grips and Retract the Jack**	**Block the Grips and Retract the Jack**
*	Go to 1/3rd Load (1/3 P) again &	Go to 1/3rd Load (1/3 P) again &
	Measure Elongation - Say 38 mm.	Measure Elongation - Say 43 mm.
*	Go to Full Load (P)	Go to Full Load (P)
	Measure Elongation - Say 165 mm.	Measure Elongation - Say 176 mm.
*	Extension Measured = 165 – 38	Extension Measured = 176 – 43
	= 127 mm.	= 133 mm.
*	Multiply the Measured Extn. by 1.5 (3/2)	Multiply the Measured Extn. by 1.5 (3/2)
	∴ 127 x 1.5 = 190.5 mm.	∴ 133 x 1.5 = 199.5 mm.

* **Total Elongation would be:** 190.5 + 199.5 = 390.0 mm.
* **Block the Grips and Retract the Jack** **Block the Grips and Retract the Jack**
* If the Losses due to Blocking (Wedge Set) have not been considered in design load, then subtract the same from both the ends, from above Elongation.

ii. TWO STAGE STRESSING – When Extension is more than 200mm, in each jack at each end.

Ist. JACK – At One End	**IInd. JACK – At Other End**
* Go up to $1/3^{rd}$ Load (1/3 P)	Go up to $1/3^{rd}$ Load (1/3 P)
* Extension - Need not be recorded	Extension - Need not be recorded
* **Block the Grips and Retract the Jack**	**Block the Grips and Retract the Jack**
* Go up to $1/3^{rd}$ Load (1/3 P) &	Go up to $1/3^{rd}$ Load (1/3 P) &
Measure Elongation - Say 40 mm.	Measure Elongation - Say 47 mm.
* Go up to $2/3^{rd}$ Load (2/3 P) &	Go up to $2/3^{rd}$ Load (2/3 P) &
Measure Elongation - Say 183 mm.	Measure Elongation - Say 195 mm.
* Extn. Measured (Ist. Stage) = 183 – 40	Extn. Measured (Ist. Stage) = 195 – 47
= 143 mm.	**= 148 mm.**
* **Block the Grips and Retract the Jack**	**Block the Grips and Retract the Jack**
* Go back to $2/3^{rd}$ Load (2/3 P) &	Go back to $2/3^{rd}$ Load (2/3 P) &
Measure Elongation - Say 23 mm.	Measure Elongation - Say 32 mm.
* Go up to Full Load (P)	Go to Full Load (P)
Measure Elongation - Say 170 mm.	Measure Elongation - Say 177 mm.
* Extn. Measured (IInd. Stage) = 170 – 23	Extn. Measured (IInd. Stage) = 177 – 32
= 147 mm.	**= 145 mm.**
* Total Extension Measured = 143 + 147	Total Extension Measured = 148+ 145
= 290 mm.	**= 293 mm.**
* Multiply the Measured Extn. by 1.5 (3/2)	Multiply the Measured Extn. by 1.5 (3/2)
∴ 290 x 1.5 = 435 mm.	∴ 293 x 1.5 = 439.5 mm.

* **Total Elongation would be:** 435.0 + 439.5 = 874.5 mm.

Block the Grips and Retract the Jack	**Block the Grips and Retract the Jack**

* If the Losses due to Blocking (Wedge Set) have not been considered in design load, then subtract the same from both the ends, from above Elongation.

COMMON IRREGULARITIES DURING STRESSING & THEIR CORRECTIONS

During Stressing Operation, we normally observe that targeted extension are met at the designated level of force/pressure, but some time, some common irregularities in the tendon or the abnormal behaviours of the equipment arises in between; and forces us to stop the work. These irregularities, needs to be diagnosed and corrected properly.

Some of these irregularities and their corrective measures are described below:-

A. Desired Force is achieved but the Extension is very Low.

	PROBABLE CAUSES	CORRECTIVE MEASURES
1.	Stroke Length of the Piston has reached to the final stage.	Temporarily block the Grips and, Retract the Piston and start with new stroke.
2.	Faulty Pressure Gauge	Calibrate the Pressure Gauge or connect a Master Gauge in Pressure Line.
3.	Error in computing the Stressing Values: Incorrect assumptions or error in calculations	Notify the Design Engineer, correct error and recalculate stressing values.
4.	Cross-Section Area of Prestressing Steel is larger than assumed. (i.e. Strand Dia. is Ø15.7 instead of Ø15.2 or Ø12.9 instead of Ø12.5 mm.	Notify the Design Engineer, and recalculate the Elongation value.
5.	Tendon is clogged due to ingress of cement slurry in the duct.	Repeatedly overstress the tendon up to 80% of UTS and Relax. This may break the loose slurry, if any, and can free the tendon.
6.	Higher friction in the Sheathing/Duct. This may be caused due to rust, dents, depression or the deviation angle larger than assumed	Repeatedly overstress the tendon up to 80% of UTS and Relax. This may relieve the tendon. If not, then notify the designer.
7.	Higher friction in the Stressing Jack	Check for free travel for the Jack Piston. If tight, notify the jack manufacturer.
8.	Higher friction in the Stressing Jack due to deviation of strand, inside the jack.	Check for abnormal strand deviation, if any, inside the Jack. Take Corrective action

NOTE:

1. In the case of (5) & (6), overstressing limit should not exceed 80% of the UTS, or the 90% of the Yield Stress of the Strand, as specified in the FIP regulations.
2. During Overstressing Procedure, Don't put 'Grips' in the 'Bearing Plate'.
   Fix up the Jack over the cable and travel out the Piston for at least 100-150mm. before fixing 'Rear Anchor Plate' and 'Master Grips'. Load should be applied directly thr'u. Rear Anchor Plate.

B. Elongation achieved but the Gauge Pressure is very Low.

	PROBABLE CAUSES	CORRECTIVE MEASURES
1.	Some of the Master Grips are Missing or slipping	De-stress the tendon, check the Master grips and replace the defective ones.
2.	Faulty Pressure Gauge	Calibrate the Pressure Gauge or connect a Master Gauge in Pressure Line.
3.	Error in computing the Stressing Values: Incorrect assumptions or error in calculations	Notify the Design Engineer, correct error and recalculate stressing values.
4.	Cross-Section Area of Prestressing Steel is smaller than assumed. (i.e. Strand Dia. is Ø15.2 instead of Ø15.7 or Ø12.5 instead of Ø12.9 mm.	Notify the Design Engineer, and recalculate the Elongation value.
5.	Anchorage is yielding: Insufficient concrete strength or honeycombs in the concrete in Anchorage zone.	Essential Judgement by the Engineer may stop mishap. Stop Stressing and repair the Anchorage Zone.
6.	Some strands may be slipping at the Dead End Anchor, or the Coupler Joint or the Tendon Splice etc.	Replace the faulty Anchors, Couplers or Splices etc., if possible. Otherwise notify the engineer to check the design for reserves.
7.	Smaller friction in the Sheathing or duct.	Notify the Design Engineer to review and recalculate the Elongation value.
8.	Frictional Losses in the Jack are considerably less than assumed.	Check the Jack efficiency and re-evaluate the frictional losses. And make necessary correction in applicable forces.

C. WEDGE SET:

Wedge Set is a term used to denote the losses/gains caused due to setting of the 'Grips', during transfer of forces.

Setting of Grips in the Dead End Anchorage and in the Master Grips of Stressing Jack causes an apparent increase in extension, but does not lose any Prestressing force. Whereas the setting of Grips in the Bearing Plate certainly causes a loss of Prestressing Force, during transfer of forces from Jack to the anchorage.

Average values of such Wedge set, in normal conditions are as under:-

a) For Master Grips - 7 to 8 mm.

b) For Live Grips - 5 to 6 mm.

METHODOLOGY FOR JACK EFFICIENCY TEST

OBJECTIVE: To check the Efficiency (η) of the system, at work site, comprising of 2 (two) Prestressing Jacks & 2 (two) Power Packs.

EQUIPMENT: USED

i) Two Prestressing Jacks with distinctive Identification Nos.

ii) Two Power Packs suitable to operate above jacks, with distinctive Identification Nos.

iii) Two Pressure Gauges for STRESS line of above Power packs, with distinctive Identification Nos.

PROCESS:

Calibrate the Pressure gauges on Dead Weight Pressure Gauge Tester, and connect them on to the STRESS line of the two Power packs (under test).

Place both the Prestressing Jacks (under test) facing each other in horizontal condition as shown in Drg. No. - A4: FPCC: MISC: 012 & A4: FPCC: MISC: 013 with a Reaction Ring in between so that the concentricity of both the Jacks could be maintained.

Connect the Stressing Cylinder of both the jacks to the respective Power packs with two set of hose pipes. Ensure that the STRESS port of the Jack is connected to the STRESS port of the Power pack and the RETURN port of the jack is connected to the RETURN port of the Power Pack.

Operate both the jacks independently with their respective Power packs for full extension and retraction, at no load. Repeat this procedure for couple of times to perform the Air Bleeding operation. After completing the Air Bleeding operation, extend the Ram of both the jacks by about 100 mm. and tighten the Shut-Off Valves of both the Power packs to close the hydraulic circuit of both the system.

Insert requisite number of strands (Maximum Capacity of the Jack-Under Test) through the center hole across the two jacks and lock them with the help of Master Grips at Rear Anchor Block located at the rear end of the jacks.

Now the system is ready for starting the calibration process. One unit of Jack and Power Pack is made `ACTIVE UNIT' and the other one is made `PASSIVE UNIT', and vise versa.

Load is applied to the `ACTIVE UNIT' in small intervals and the pressure gauge reading is noted. Since both the jacks are connected to each other with the help of strands, load of `ACTIVE UNIT' shall be transferred to the `PASSIVE UNIT', through the strands; and hence the pressure gauge of the `PASSIVE UNIT' will also start indicating pressure.

Theoretically, the load indicated in the `PASSIVE UNIT' should be equal to the load applied on the `ACTIVE UNIT', but practically, due to some losses in the system, caused by the friction or other transmission hindrances, the load indicated in the `PASSIVE UNIT' is always less than the `ACTIVE UNIT', and this variation in the load is known as `LOSS OF EFFICIENCY'.

Now apply the pressure to the `ACTIVE UNIT' upto 75% of the total cable Load, in 10 intervals, in succession of 50 kg.f/cm². Note down the pressure indicated on the `PASSIVE UNIT' and calculate the EFFICIENCY LOSS at each intervals of First Stage.

In the Second Stage, Process is reversed. The `ACTIVE UNIT' is now kept (idle) closed and made a `PASSIVE UNIT' and where the pressure is applied to the other unit. Note down the pressure readings of both the UNITS (reversed) and calculate the EFFICIENCY LOSS at each intervals of the Second Stage, as described in Para 8.

The average `LOSS OF EFFICIENCY' is then calculated from the data of the both the stages, which is denoted as the `AVERAGE EFFICIENCY LOSS' of the system.

Deduct this Efficiency Loss from the Ultimate value of 100%, shall compute as Net Jack Efficiency (η)

Refer the standard format, on next page, for calculating the efficiency of the system.

EFFICIENCY TEST ON PRESTRESSING JACK

TEST REPORT No. :_________________ **DATE :**______________

TYPE OF JACK : Multipull Prestressing Jack

MODEL : `FPCC' K-500 MODEL JACK

JACK Sl. No. (Under Test) : K 500 - 94:X1X1
K 500 - 94:X2X2

POWER PACK Sl. No. (Under Test) : MK-III / 94:Y1Y1
MK-III / 94:Y2Y2

PRESSURE GAUGE No. (Under Test) : AA/BBBB for Powerpack No. - MK-III / 94:Y1Y1
CC/DDDD for Powerpack No. - MK-III / 94:Y2Y2

STRESSING RAM AREA : 765.70 cm^2 (As shown in the attached Drawing)

Sl. No.	**ACTIVE**	**PASSIVE**	**% LOSS**	**ACTIVE**	**PASSIVE**	**% LOSS**
	Jack No. 94:X1X1 Pump No. 94:Y1Y1 Gage No. AA/BBBB	Jack No. 94:X2X2 Pump No. 94:Y2Y2 Gage No. CC/DDDD		Jack No. 94:X2X2 Pump No. 94:Y2Y2 Gage No. CC/DDDD	Jack No. 94:X1X1 Pump No. 94:Y1Y1 Gage No. AA/BBBB	
	Pressure Applied	**Pressure Observed**		**Pressure Applied**	**Pressure Observed**	
1.	50 kg.f/cm^2			50 kg.f/cm^2		
2.	100 kg.f/cm^2			100 kg.f/cm^2		
3.	150 kg.f/cm^2			150 kg.f/cm^2		
4.	200 kg.f/cm^2			200 kg.f/cm^2		
5.	250 kg.f/cm^2			250 kg.f/cm^2		
6.	300 kg.f/cm^2			300 kg.f/cm^2		
7.	350 kg.f/cm^2			350 kg.f/cm^2		
8.	400 kg.f/cm^2			400 kg.f/cm^2		
9.	450 kg.f/cm^2			450 kg.f/cm^2		
10.	500 kg.f/cm^2			500 kg.f/cm^2		
	Avg. Efficiency Loss in STAGE – I			Avg. Efficiency Loss in STAGE – II		

Avg. Loss of Efficiency = $\frac{\text{(Efficiency Loss in STAGE – I) + (Efficiency Loss in STAGE – II)}}{2}$

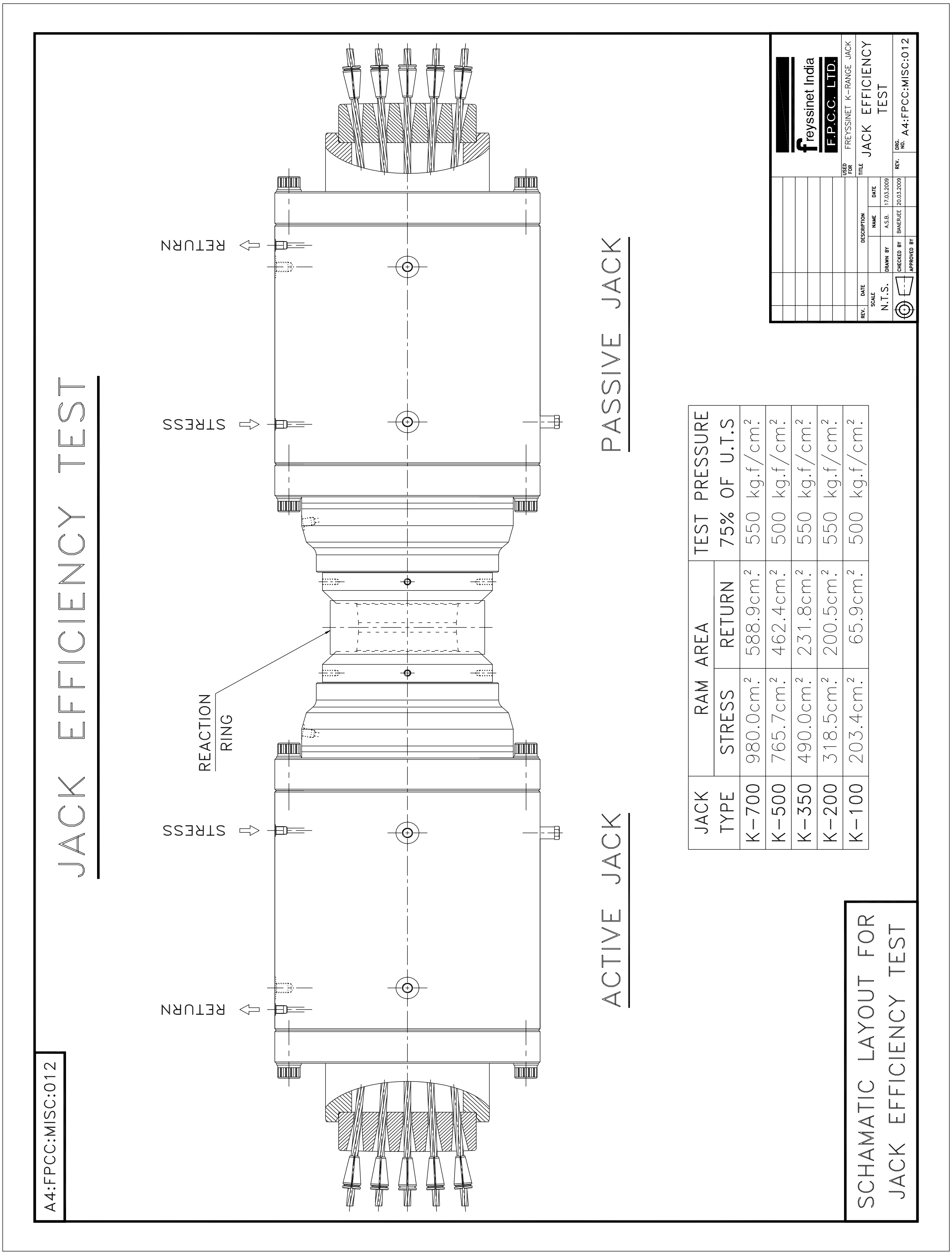
=

(η) Net Jack Efficiency = 100% - (Avg. Loss of Efficiency) =

TESTED BY **WITNESSED BY** **APPROVED BY**

Sd. **Sd.** **Sd.**

Schematic Layout for ‘Jack Efficiency Test’ is shown here



JACK TYPE	RAM AREA		TEST PRESSURE 75% OF U.T.S
	STRESS	RETURN	
K-700	980.0cm.²	588.9cm.²	550 kg.f/cm.²
K-500	765.7cm.²	462.4cm.²	500 kg.f/cm.²
K-350	490.0cm.²	231.8cm.²	550 kg.f/cm.²
K-200	318.5cm.²	200.5cm.²	550 kg.f/cm.²
K-100	203.4cm.²	65.9cm.²	500 kg.f/cm.²

GENERAL DESIGN DATA & INFORMATIONS

The data provided in this chapter are in compliance with FIP-CEB code for concrete structures. For more precise and thorough calculations, the user must refer to the information bulletins issued by COMITE EURO-INTERNATIONAL DU-BETON and their appendices or national design codes.

Determination of the final Prestressing force in a tendon must allow for the losses of tension resulting from the following factors:-

- Losses occurred due to friction of the tendon in its duct
- Losses occurred due to instantaneous deformation of the concrete; resulting out of non-simultaneous tensioning of several tendons (elastic loss).
- Losses occurred due to Anchorage pull-in.
- Losses occurred due to deferred concrete shrinkage.
- Losses occurred due to creep failure of concrete.
- Losses occurred due to relaxation of Prestressing steel.

In most cases, simply mark the losses at time 't_o' (start of tensioning) and 't_∞' (long term). But in some particular case of construction, where partial prestressing is induced initially and the final prestressing is done in phases, consideration must be given to losses at a given time't'.

Appendix (e) of the FIP-CEB code gives instructions for calculation.

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1. Losses due to Friction in Duct:

At a point on the tendon distance *(x)* from the Jacking anchorage, the stress in the prestressing steel is given by COOLEY's Law:

$$\sigma_x = \sigma_o \cdot e^{-\mu(\propto + Kx)}$$

Where: σ_o - Stress at point of anchorage ($x = 0$)

μ - Coefficient of Friction of tendon in duct (in $Radian^{-1}$)

$\propto$ - Sum of angular deviations over the distance (x) (in Radian)

K - Unwanted angle of deviation from the theoretical profile, expressed per unit of length (in Radian/meter)

x - Distance from Anchorage to calculation point (in meter)

Following is a table for μ in the absence of the information relating to the particular project or to the regulations purposes.

Values of μ (in Radian^{-1})			
Type of Duct	**Range of Standard values**	**Recommended Values**	
		Dry Non- Corroded Strands	**Lubricated Strands**
Passage through concrete holes	0.40 - 0.60	0.50	-
Non Galvanised Rigid Pipe	0.20 - 0.30	0.25	0.23
Non Galvanised Flexible Sheathing	0.18 - 0.26	0.22	0.20
Galvanised Rigid Pipe	0.16 - 0.24	0.20	0.18
Galvanised Flexible Sheathing	0.14 - 0.22	0.18	0.16
Greased & Wrapped Tubing	0.05 – 0.15	0.09	0.05

Wobble coefficient (**K**) basically depends on the accuracy with which the theoretical profile is achieved. The accuracy is directly proportional to the rigidity of the ducts and the simplicity of the tendon profile. The average value of **K** can generally be taken as 0.01 rad/m. This figure must be adapted to the diameter of the ducts, to the distance between their supports and workmanship.

2. Losses due to Instantaneous Concrete Deformation:

A tendon that is already stressed and anchored in the concrete is affected by the elastic shortening of the concrete due to the later stressing of other tendons. The resultant loss in prestressing forces in such cases is very little and is difficult to calculate. It can be compared to a uniform loss corresponding to the fraction (n-1)/2n of the total instantaneous deformation of the concrete. Following formulae give the loss of stress in the prestressing steel:

$$\Delta\sigma_i = E_s . \epsilon_{ci} \frac{n-1}{2n} \qquad \epsilon_{ci} = \frac{\sigma_{ci}}{E_{ci}}$$

Where: n - Number of tensioning Stages.

ϵ_{ci} - Instantaneous strain of concrete due to the total prestressing forces

E_s - Modulus of elasticity of steel (Average Value is 195×10^9.Pa)

σ_{ci} - Permanent prestressing force in concrete estimated at centre of gravity of prestressing tendons (in Pascal).

E_{ci} - Instantaneous longitudinal modulus of elasticity of concrete at the age, when stressed (in Pascal).

3. Losses due to Anchorage Pull-in:

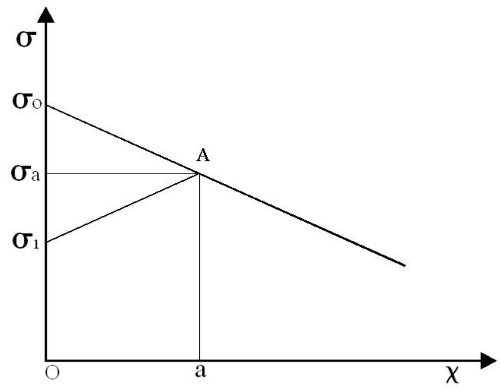
During blocking operation of Strands into the anchorages, the jaws move an average distance (ϵ) given in the table below.

Type of Anchorage Units	Without Hydraulic Blocking System	With Hydraulic Blocking System
T 13	7 mm.	5 mm.
T 15	8 mm.	6 mm.

On account of the loss of elongation, the stress in the tendon at the anchorage drops from σ_0 to σ_1.

Due to reverse friction effects, the length of tendon affected by this loss is limited to the distance (a)

It can be assumed in most cases that the loss due to friction is linear. On this assumption, the under mentioned formula gives the distance (a).



$$a = \sqrt{\frac{\epsilon . E_s}{\Delta\sigma_\chi}\chi} \qquad \Delta\sigma_o = 2a\frac{\Delta\sigma_\chi}{\chi}$$

Where: a - Maximum distance of effect of the anchorage pull-in (in meter).

ϵ - Anchorage pull-in (in meter).

E_s - Modulus of elasticity of steel (in Pascal)

$\Delta\sigma_\chi$ - Loss of Prestress by friction over the distance χ (in Pascal).

---

4. Losses due to Creep and concrete shrinkage:

It is difficult to resolve this problem precisely and in most cases, approximate solutions are acceptable. Assuming that deformation and stress are directly proportional, the formulae below indicate the loss of stress in the steel.

$$\Delta\sigma_{c+s} = E_s\,(\epsilon_{c\infty} + \epsilon_{s\infty}) \qquad \epsilon_{s\infty} = \frac{\sigma_{c\infty}}{E_{c28}}\varphi_\infty$$

Where: $\epsilon_{c\infty}$ - Concrete strain due to Creep.

$\epsilon_{s\infty}$ - Concrete strain due to shrinkage.

$\sigma_{c\infty}$ - Permanent compression stress in concrete at center of gravity of the Prestressing Tendons (in Pascal).

φ_{∞} - Coefficient of Creep.

E_{c28} - Deferred longitudinal modulus of deformation of concrete at 28 days (in Pascal).

Characteristic Strength of concrete at 28 days, fck (MPa)	12	16	20	25	30	35	40	45	50
Longitudinal Deformation Modulus, E_{c28} (10^3 MPa)	26	27.5	29	30.5	32	33.5	35	36	37

U = Perimeter in contact with Atmosphere (m) Ac = Section of Concrete (m^2) $\frac{2Ac}{U}$ = Artificial Dimension of the Structure	Humid Atmosphere Outside (Rel. Hum. 75%)		Dry Atmosphere Inside (Rel. Hum. 55%)	
	Small <0.2 m	Large >0.6 m	Small <0.2 m	Large >0.6 m
COEFFICIENT OF CREEP: φ_{∞}				
Age of concrete when loaded:				
Young (3 – 7 days)	2.7	2.1	3.8	2.9
Middle (7 -60 days)	2.2	1.9	3.0	2.5
Old (> 60 days)	1.4	1.7	1.7	2.0
SHRINKAGE: $\epsilon_{s\infty}$	10^{-3}	10^{-3}	10^{-3}	10^{-3}
Age of concrete at time t_o when effect of shrinkage is considered:				
Young (1 – 7 days)	0.26	0.21	0.43	0.31
Middle (7 -60 days)	0.23	0.21	0.32	0.30
Old (> 60 days)	0.16	0.20	0.19	0.28

5. Losses due to Relaxation in Prestressing Steel:

Relaxation is the loss of tension in highly tensioned steel that is maintained at constant length.

The suppliers give figures for relaxation of the strand (see page 16) after 1000 hours, for 60%, 70% and 80% of the characteristic breaking load. It is possible to interpolate intermediate values proportionately, with acceptable accuracy

The Table below gives a few average figures for relaxation (ϑ) of prestressing strands after 1000 hours:

Values of ϑ

Fraction of Initial Tension	**60%**	**70%**	**80%**
Non Stabilised Strand (%)	4.5	8	12
Stabilised Strands (%)	1	2	4.5

In order to take account of the interaction of losses due to shrinkage and creep of the concrete and relaxation of steel, a reducing coefficient is simply applied to the losses due to relaxation alone.

The under mentioned formulae indicates the loss of stress in steel, in simplified form:

$$\Delta\sigma_r = \sigma_o . \vartheta \left[1 - 2 \frac{\Delta\sigma_{c+s}}{\sigma_o} \right]$$

Where:
- $\Delta\sigma_r$ - Effective loss due to relaxation (in Pascal).
- σ_o - Initial tension of prestressing tendons at the relevant point (in Pascal).
- ϑ - Nominal relaxation (%)
- $\Delta\sigma_{c+s}$ - Stress losses due to creep and shrinkage already calculated (in Pascal).

It is possible to approach the problem of interaction between shrinkage, creep and relaxation more precisely. The reader may refer to the appendix of the FIP-CEB Code, but the above simplified formula is on the safe side.

The loss at time (t) greater than 1000hours can be calculated from the following formula:

$$\Delta\sigma_r (t) = \Delta\sigma_r (1000th). \left[\frac{t}{1000} \right]^{\beta}$$

Where: β - 0.20, failing precise information.

NOTE: Based on the above formulae, some typical calculations are shown, as example, in the subsequent pages.

EXAMPLE OF CALCULATIONS:

Assuming a rectangular Beam of size 0.40m X 1.20m, length 34 meters, was prestressed by 5 parabolic tendons through the beam, from one end to the other.

Parameters:

Angular deviation at anchorages α= 9° = 0.157 radian.

Initial stresses σ_o = 1330 MPa

Characteristic Concrete Strength f_{ck}= 35 MPa

Permanent compression at the Prestressing Level σ_c = 10.5 MPa

1. LOSSES DUE TO FRICTION:

   Calculation for the mid-span cross-section at x = 17m., Oil lubricated strand was used with Non-Galvanised flexible sheathing.

   μ = 0.20 rad.$^{-1}$ and K = 0.01 rad/m

   $$\sigma_{17} = 1330 \cdot e^{-0.20\,(0.157 + 0.01 \times 17)}$$

   $$= \underline{1246 \text{ MPa}}$$

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2. LOSSES DUE TO INSTANTANEOUS DEFORMATION:

   Calculation for the mid-span cross-section at x = 17m., Oil lubricated strand was used with Non-Galvanised flexible sheathing.

   E_s = 195 x 10^9 Pa

   E_{ci} = 33.5 x 10^9 Pa

   $$\epsilon_{ci} = \frac{10.5}{33.5}\, 10^{-3} = 0.31 \times 10^{-3}$$

   $$\Delta\sigma_r = 195 \times 10^9 \, \frac{5 - 1}{2 \times 5} \, 0.31 = \underline{2.5 \text{ MPa}}$$

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3. LOSSES DUE TO ACHORAGE PULL-IN:

   Anchorage Pull-in ϵ = 6 mm.

   $\Delta\sigma = \sigma_{17} - \sigma_0$ = 1330 – 1246 = 84 MPa

   Distance at which loss is nil:

   $$a = \sqrt{\frac{6 \times 10^{-3} \times 195 \times 10^9}{84 \times 10^6} \times 17} \qquad \underline{a = 15.40 \text{ meter}}$$

   Initial pressure at mid-span is unaffected by the anchorage pull-in.

   Loss at Anchorage $\Delta\sigma_0$ = 2 x 15.4 x 84/17 = $\underline{152 \text{ MPa}}$

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4. LOSSES DUE TO CREEP & SHRINKAGE:

Tensioning after 28 days of concreting
Humid Outside atmosphere
Cross-Section of Beam: $A_c = 0.4 \times 1.2 = 0.48\ m^2$
Perimeter in contact: $u = 3.2$ m
Coefficient: $2A/u = 0.3$
Interpolation between 0.2 and 0.6 for the values φ_∞, $\epsilon_{S\infty}$
$\varphi_{(0.2)} = 2.20$
$\varphi_{(0.6)} = 1.90$
$\varphi_{(0.3)} = 2.13$
$\epsilon_{S\,(0.2)} = 0.230 \times 10^{-3}$
$\epsilon_{S\,(0.6)} = 0.210 \times 10^{-3}$
$\epsilon_{S\,(0.3)} = 0.225 \times 10^{-3}$

$$\epsilon_{S\infty} = \frac{10.5 \times 10^6}{33.5 \times 10^9} \times 2.13 = 0.67 \times 10^{-3}\ \text{Pa}$$

$$\Delta\sigma_{c+s} = 195 \times 10^9 (0.67 \times 10^{-3} + 0.225 \times 10^{-3})$$
$$\Delta\sigma_{c+s} = \underline{174.5\ \text{MPa}}$$

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5. LOSSES DUE TO RELAXATION OF PRESTRESSING STEEL:

Nominal Stress $\sigma_k = 1770$MPa
Initial Stresses $x = 0$
$\sigma_0 = 75\%$ of $\sigma_k = 1330$ MPa

Initial Stresses $x = 17$
$\sigma_{17} = 70\%$ of $\sigma_k = 1240$ MPa
Stabilised strands relaxation at 1000 hrs. = 2%

$$\sigma_{r\,(1000h)} = 1246 \times 0.02 \left(1 - 2 \times \frac{174.5}{1246}\right)$$
$$\sigma_{r\,(1000h)} = 18\ \text{MPa}$$

Loss at 10^5 hours (about 12 Years)

$$\Delta\sigma_r\,(10^5\,h) = 18 \times \left(\frac{10^5}{10^3}\right)^{0.2} = \underline{45\ \text{MPa}}$$

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6. FINAL STRESSES AT MIDSPAN:

$$\Delta\sigma_{17.\infty} = (1246 - 2.5 - 174.5 - 45)\ \text{MPa} = \underline{1024\ \text{MPa}}$$

CHECKLIST FOR INSPECTION OF POST-TENSIONING OPERATION

AT MATERIAL MANUFACTURING STAGE:

For BONDED TENDONS	For UN-BONDED TENDONS
Are the Anchor Plate (Bearing Plate) properly machined, cleaned and protected from corrosion?	Are the Grips of Dead End Anchorage; seating evenly and adequately on the Anchor Plate?
Are the Grips free from Corrosion? Are the Back relief provided uniformly?	Is excessive sheathing/duct stripped & trimmed at Dead End (Fix) Anchorage?
Are the Grips of uniform length and serrations of consistent quality?	Is the plastic sheathing of sufficient and uniform thickness?
Are the ducts manufactured from quality steel strip and specified strip thickness?	Is the quality & texture of the filling grease is consistent?
Are the Seam Joints intact, watertight & uniform?	Is the grease applied evenly all over and packed?
Does the bare prestressing steels appear to be new and are free from corrosion?	Does the strand appear to be new and free from corrosion, when sheathing & grease are removed?
Are they adequately protected in store?	Are the Anchors properly machined with smooth Taper Holes for Grips?
Are the Anchors properly machined with smooth Taper Holes for Grips?	Are the Grips of uniform length and serrations of consistent quality?
-	Are the Grips free from Corrosion? Are the Back relief provided uniformly?
Are all Test Reports and Certificate available for the Prestressing Steel and all the components of Anchorage, as required by the specification	Are all Test Reports and Certificate available for the Prestressing Steel and all the components of Anchorage, as required by the specification

AT TENDON INSTALLATION STAGE:

For BONDED TENDONS	For UN-BONDED TENDONS
Are the high & low points of the Sheathing duct at the correct elevation?	Are the high & low points of the Tendons, at the correct elevation?
Are duct profiles smooth and correctly shaped (parabolic, circular or straight) between reference points?	Are the tendon profiles smooth and correctly shaped (parabolic, circular or straight) between reference points?
Are all duct joints properly matched and sealed with adhesive tape?	Do the tendons have excessive horizontal wobble?
Are there any holes in the entire length of the duct, and if so, have they been repaired to prevent concrete ingress?	Are there any holes in the entire length of the sheathing, and if so, have they been repaired?
Are there any kinks in the entire length of the duct, which may prevent the installation of prestressing steel?	Does the chairs or Support-bar system are adequate and confirm to the design requirement?
Is the Cable Supports are adequately tied to prevent displacement or floating of the duct during concreting?	Are the Stressing Anchors secured and fastened with the appropriate pocket former?
Are the Guides firmly secured and fastened with the End Block shuttering?	Is bursting reinforcement installed behind the anchorages are adequate and satisfying the design requirement?
Is bursting reinforcement installed behind the anchorages are adequate and satisfying the design requirement?	-
Has the method of concrete placement been reviewed as to its effect on duct stability during placement?	Has the method of concrete placement been reviewed as to its effect on duct stability during placement?
Has the conventional steels placement been reviewed?	Has the conventional steels placement been reviewed?

AT TENDON STRESSING STAGE:

For BONDED TENDONS	For UN-BONDED TENDONS
Are the Bearing Plates holes & Grips, free from rust dirt and grease? If not, clean them.	Are the Stressing Anchors holes & Grips, free from rust dirt and foreign particle? If not, clean them.
Has the elongation datum been marked for the initial and final reading? Are they logically and clearly located?	Has a consistent dimension been used, as the elongation datum mark on the strand?
Is the stressing equipments well maintained, and are all the calibration charts & reports available?	Is the stressing equipments well maintained, and are all the calibration charts & reports available?
Is the Operating Technician, trained and careful enough about the equipment and consistent from tendon to tendons?	Are the tendons stressed slowly enough to allow the strands to overcome as much friction as possible prior to locking?
Are the Bearing Plate and Grips seating properly after stressing?	Are Grips seated evenly, properly under pressure?
After elongation approval, is the tendon tails properly cut well inside and cleaned to fix Grout Cap for grouting?	After elongation approval, is the tendon tails properly cleaned and greased well inside & secured with Grout Cap?
Are the stressing pockets properly cleaned and prepared to allow good grout bond during and after patching?	-

SAFETY PRECAUTION DURING POST-TENSIONING OPERATION

During Prestressing operation, a huge forces are been induced into the tendons by the Jacking Equipments. These jacking equipments are working under tremendous hydraulic pressure, and thus a careful and competent workmanship can avoid accidents and damage to the equipment.

Some essential precautions are being listed here, to be adhered to:

- Stressing operation should be carried out by the trained and experienced personnel, under a competent engineer or supervisor.
- The equipments, especially the high pressure hose pipes, and the end fittings should be in perfect conditions. Damaged hose pipes must be replaced immediately. Any lack of decision in this regard may cause a serious accident.
- Protection caps must be placed over the Hose pipes nipples and the end fittings of the equipments. Always avoid putting the gausses or cotton waste into the nipple hole, as this may cause a severe ingress of dust & dirt into the hydraulic system.
- Jacking equipments and power-packs shall never be lifted, using hose pipes as a lifting devise.
- Stressing shall be done according to the specified data provided by the designer. In no case the pressure should be exceeded beyond 5% of the allowable limit.
- During stressing, nobody should be allowed to stand behind or underneath the Jacking unit, since failure of a tendon can cause a sever injuries or even death.
- In the stressing site; which are close to public traffic areas, A strong protective shield should be erected and the jack must be secured by ropes or chain pulley block to prevent failed strands from shooting out.

- The Prestressing steel (i.e. bars, wires or strands) should be stored carefully to ensure that they are not damaged in any way and should be checked for rust or corrosion before use.
- Care should be taken while handling and unwinding of prestressing steel coils, as they may ‘whip-back’ with force, if not securely bound.
- All the technicians should wear hand gloves and other safety harnesses while working at overhanging/raised stressing platform. Technicians are prone to fall down from a height in such cases.
- Ensure that unauthorized people should not gather in and around Stressing Site as sight seeing location. Erect a safety warning sign around.
- Wear safety helmets at site during stressing operation.
- Do not permit welding operation near H.T. Prestressing steel. Molten sparks arises from welding, if falls on the tendons, will change its mechanical properties and promotes the possibilities of premature failure. The damages caused by inadvertent heating, from welding, may not be detectable by visual inspection.
- Do not use Acetylene gas Torch heating apparatus to cut or trim the strand before stressing. Only abrasive cutting wheels should be used.
- Prestressing steel should not be used for providing earthing to the electrically operated equipments. An electric spark, when jumps through the prestressing steel, may effect or alter the molecular structure and a loss of strength may occur.
- Lightening conductors should be routed clear of tendons and the Anchorages etc.