PRESTRESSED CONCRETE

LECTURE NOTES

Dr. B.L.P SWAMI

UNIT – I

INTRODUCTION TO PSC MATERIALS, METHODS OF PRESTRESSING, LOSSES IN PRESTRESSING.

PRESTRESSED CONCRETE.

UNIT-I.

Introduction : Basic Concepts, Materials, Permissible stresses — Systems of prestressing Losses of prestress in pretensioned and post tensioned members.

INTRODUCTION.

The idea of prestressing to counteract the stresses due to loads was put forward towards the end of ~~last~~ ~~eighteenth~~ nineteenth century and the beginning of twentieth century. This has led to the development of PSC and gradually PSC has become popular since 1940. A number of bridges were constructed with PSC from 1940 to 1960 in other countries. In India PSC has become popular since 1960. Bridges and other structures have been constructed. PSC is being put to use for several applications.

In the words of Guyon "There is probably no structural problem to which prestress cannot provide a solution". Prestress is more than a technique. It is a general principle.[4]

BASIC CONCEPTS OF PRESTRESSING.

P.S.C. is basic concrete in which internal stresses of a suitable magnitude and distribution are introduced so that the stresses resulting from external loads are counteracted to a desired degree. In concrete members the prestress is commonly introduced by tensioning the steel reinforcement. For PSC, high strength concrete and high tensile steel are employed.

NEED FOR HIGH STRENGTH CONCRETE.

It is necessary to offer high resistance in tension, shear, bond and bearing in addition to high comp. strength. It has high modulus of elasticity less shrinkage cracks and smaller ultimate creep strain.

NEED FOR HIGH STRENGTH STEEL.

It is necessary to use high strength (tensile) steel so that it is able to take high initial tensile stresses. Even after some losses in stress occur, the loss must be only a small percentage of the initial stress. The balance stress is transferred to concrete as compression and the member must perform effectively and efficiently.

ADVANTEGES OF P.S.C.

1) PSC members have lesser cross sectional dimensions compared to RCC members and hence there is savings in the use of materials.

2) No cracks occure in PSC under working loads as in the case of RCC where micro cracks occure in the tension zone.

3) Higher shear strength.

4) The structure of PSC is slender.

5) As high strength concrete is used in PSC, more durability is achieved.

6) High energy absorption.

7) Design dead loads are decreased because of slender sections.

8) Deflections are limited.

(Repeated) →

Advantages of PSC

1. There are savings in the materials used because of Smaller Sections Compared to RCC.
2. Cracks do not occur under working loads as in the case of RCC.
3. Higher shear strength and hence lesser shear reinf.
4. The sections are slender and hence lesser material used.
5. More ductile and hence can take more deflection.
6. High energy absorption.
7. More stronger in shrinkage and creep and higher durability.
8. Design dead loads are decreased and the design becomes economical.

NOTE: The above advantages are available with PSC compared to conventional R.C.C. Though the PSC sections are slender and utilise lesser material compared to RCC, the cost of high strength concrete, H.T. steel etc. are more. Special PSC equipment, machinery and devices are required. As such, material wise it may not be economical. However, due to lesser dead weight of the structure overall economy in the designs will be available.

Requirements for Concrete:

Characteristic strength.

(As per IS 1343-1980)

Concrete grade.	Characteristic Strength at 28 d. in N/mm^2 (on 15 cm cubes at 28 d).
M30	30
M35	35
M40	40
M45	45
M50	50
M55	55
M60.	60.

In PSC,
For post tensioning work, Min. is M30
for Pretensioning " Min is M40.

Min. Cement Content

It is from 300 to 360 kg/m^3 from durability considerations

Max. Cement Content.

530 kg/m^3 should not be exceeded in general from shrinkage considerations.

Concrete Mix

Should be designed by a standard method. Machine mixing of Concrete should be used.

Tensile Strength of Concrete: (7)

The flexural strength of concrete is given by

$f_{cr} = 0.7\sqrt{f_{ck}}$ N/mm² ; f_{ck} : Characteristic Comp. strength

Elastic deformation.

(Nearly for M20)

$E_c = 5000\sqrt{f_{ck}}$ N/mm² $= 25,491$ N/mm² $= 2.5 \times 10^4$ N/mm² $= 0.25 \times 10^5$

Where,

E_c : Short term Young's modulus (7d to 28d) in N/mm²

In design $E_s = 2 \times 10^5$ N/mm², $m = 13$

$E_c = \frac{2 \times 10^5}{13} = 0.15 \times 10^5$ N/mm²

Shrinkage.

Shrinkage mainly depends upon the water content and to a lesser extent on cement content.

Shrinkage strain = 0.0003 (for pretensioning)

" $= \frac{0.0002}{\log_{10}(t+2)}$ for post tensioning

Where 't': age of concrete at transfer.

Creep of Concrete.

$f_{cr} = \frac{stress}{E_t} \times \phi$

E_t : At the time of loading

Creep coefficient = Ult. creep strain / Elastic strain.

Creep of concrete depends on age.

Age of loading — Creep strain and max. ratio a

Age	Creep coeff.
7d	2.2
28d	1.6
1 year	1.1

Durability

* Min. cement content should be maintained.

(19/2/23)

Prestressing Steel. (H.T. Steel) (IS 1343 - 1980)

→ Prestressing steel shall be any of the following.

1) Plain hard drawn steel wire conforming to IS 1785 - 1966. (Part I and II)
2) Cold drawn indented wire conforming to IS 6003 - 1975
3) High tensile steel bar conforming to IS - 2090 - 1962.
4) Uncoated stress relieved strands - IS 6006 - 1970.

Modulus of elasticity.

May be adopted as follows.

Type	Modulus of elasticity N/mm^2
1) Plain cold drawn wires	210
2) High tensile steel bars	200
3) Strands	195

The characteristic strengths may be adopted as follows.

a)

Dia. of HT wire in mm	Characteristic strength, N/mm^2
3	1900
4	1750
5	1600
7	1500
8	1400

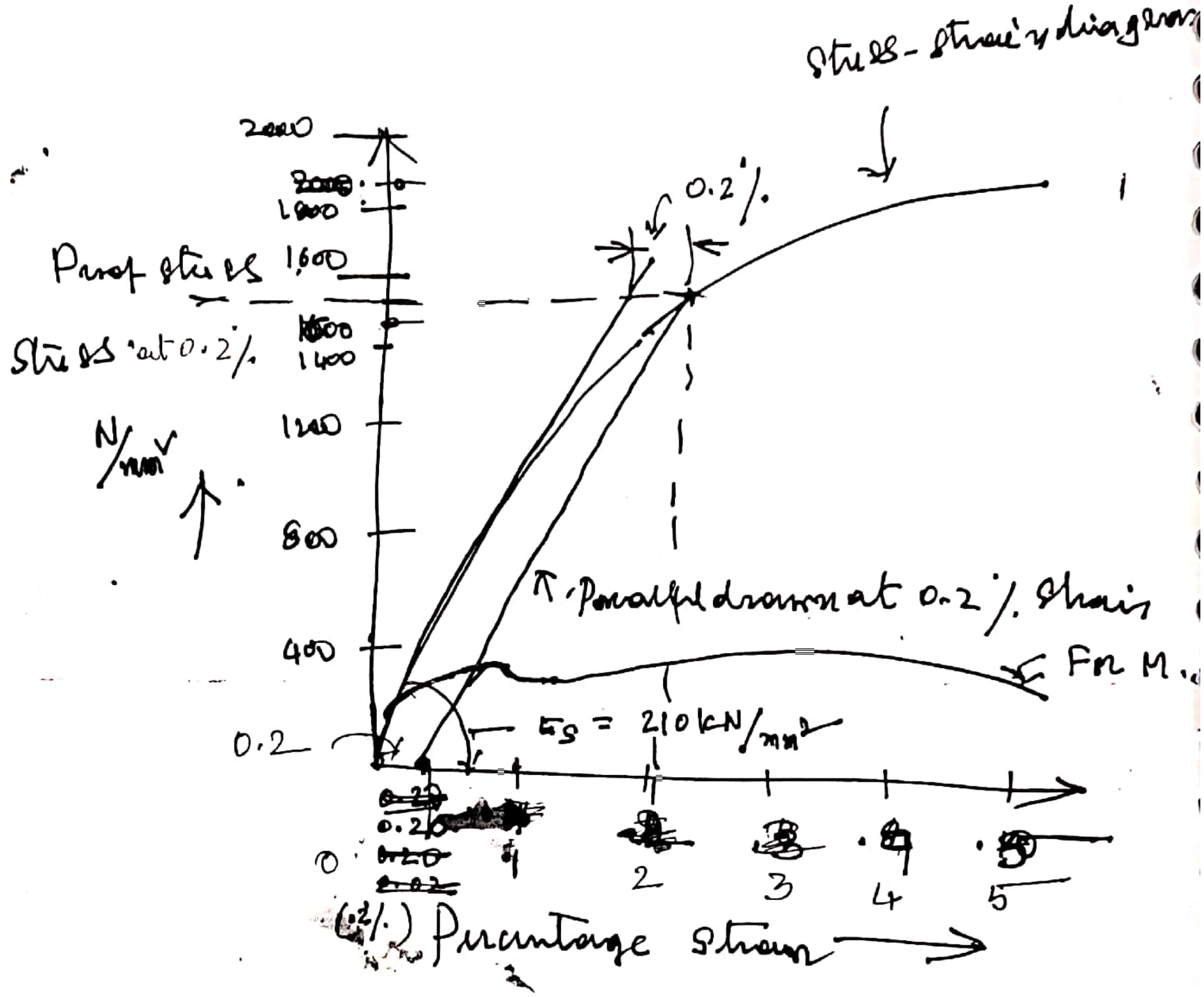
b) High tensile bars

Dia. mm	Characteristic strength N/mm^2
10 to - 40 mm	1000

For HT Steel.

~~Yield stress at a~~ 0.2% proof stress is considered

Min. Percentage ~~Min.~~ Elongation at rupture = 20%.



Permissible Stresses. (As per IS 1343).

1) At the time of initial tensioning —— 80% of UL

2) After allowing for all losses —— 45 to 50% of UL

Min. Cover to Reinf:

clear cover of 20 mm for pretension[illegible] and [illegible] mm for post tensioning. For exposure, increase the cover [illegible] should be provided.

PRESTRESSING SYSTEMS. [UNIT I (Cont'd)]

Introduction. (General)

Precompression is imparted to concrete by tensioning the prestressing steel. The most widely used method for prestressing of structural concrete elements is by longitudinal tensioning of steel by different tensioning devices. Prestressing is done with the help of hydraulic jacks. For circular structures such as water tanks, silos etc. circular prestressing is carried out. Prestress in concrete can be developed by chemical prestressing using expansive cements.

Broad classification.

a) Externally and internally prestressed member.

In the external prestressing, the ends of the member are directly compressed by the jacks without the necessity of tendons. In the internal prestressing, tendons are prestressed by jacks and the force is transferred to concrete.

b) Linear & Circular Prestressing

By providing tendons in the form of circular hoops, prestressing is done in the case of circular structures like tanks, silos, pipes etc.

c). Pre-

c) Pretensioning and Post tensioning.

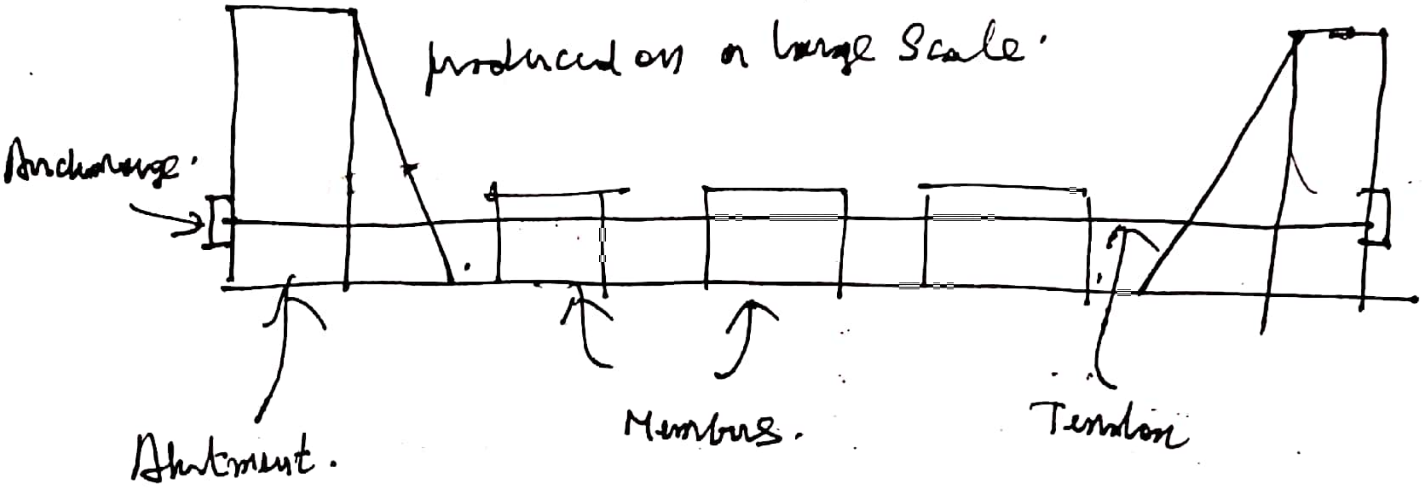
In pretensioning the tendon is securely held to one abutment and the other end is pulled by hydraulic jacks. After the required prestressing force is applied, then this end is also secured to the abutment, concrete is poured, cured and hardened and then the ends are released to allow for stress transfer.

In Post tensioning.

The beam is first cast after leaving the ducts inside. The tendon is passed inside after concrete is hardened. One end of the tendon is fixed and anchored to the end of the member. The other end is pulled by a jack which is butting against the other end of the member. The jack pulls the tendon and simultaneously compresses the concrete. After reaching the desired level of prestress, this end is also properly anchored to the end of the member. To avoid excessive bearing stresses which may damage the ends of the member distribution plates are provided at the ends.

Pretensioning by Hoyer System.

In the hoyer system, prestressed members such as electric poles, sleepers etc. are produced on a large scale.



POST TENSIONING SYSTEMS.

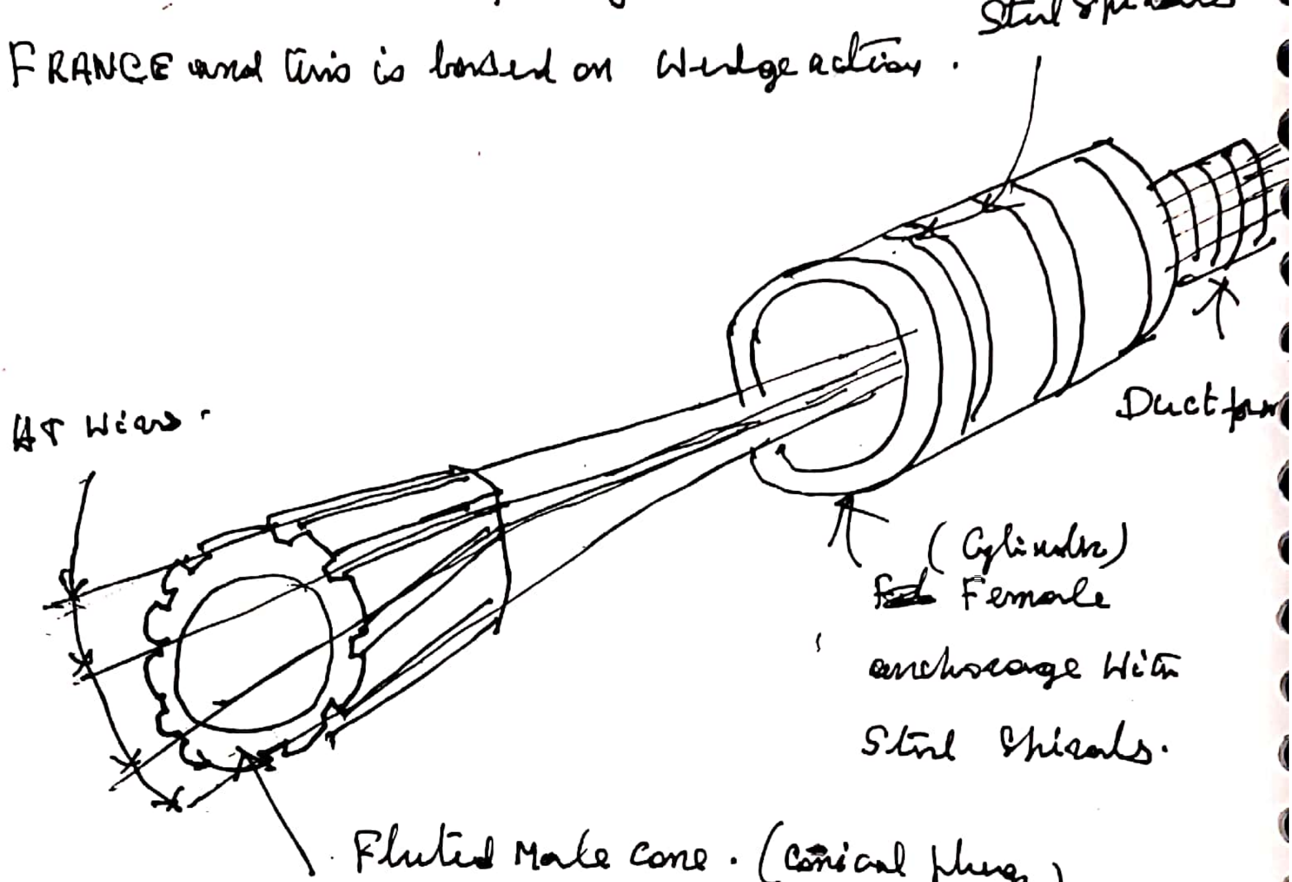
The various systems of post tensioning differ only in the manner of arrangement of wires, in the process of jacking and in the anchorage devices.

The most commonly patented prestressing systems are based on the following principles of anchoring the tendons.

1. Wedge action producing a frictional grip on the wires.
2. Direct bearing from rivet or bolt heads formed at the end of the wires.
3. Looping the wires around the concrete.

1) FREYSSINET SYSTEM.

This is one of the foremost systems developed in FRANCE and this is based on Wedge action.



FREYSSINET SYSTEM.

In this System, H.T. wires of 5 to 8 mm dia and about 12 NOS are grouped together into cables with spiral spring inside. The spiral spring separates the wires and maintains proper clearance between the wires to facilitate grouting which will be done later. It further assists to transfer the reaction to Concrete. The Whole thing is enclosed in a thin metal steel Cover.

The HT wires are passed through the duct frame, ~~cylinder anchorage and the conical plug~~.

The cylinder anchorage is made of good quality concrete with corrugations on the outside. It has a central conical hole and is provided with heavy hoop reinf.

After keeping the cylinder in proper position, the conical plug is pushed inside after tensioning the wires. The central hole passing axially through the plug permits cement grout to be injected through it. This provides additional restraint against slipping of wires.

<u>Advantages</u> : 1) Securing the wires is not expensive.

2) The desired stretching force is obtained quickly.

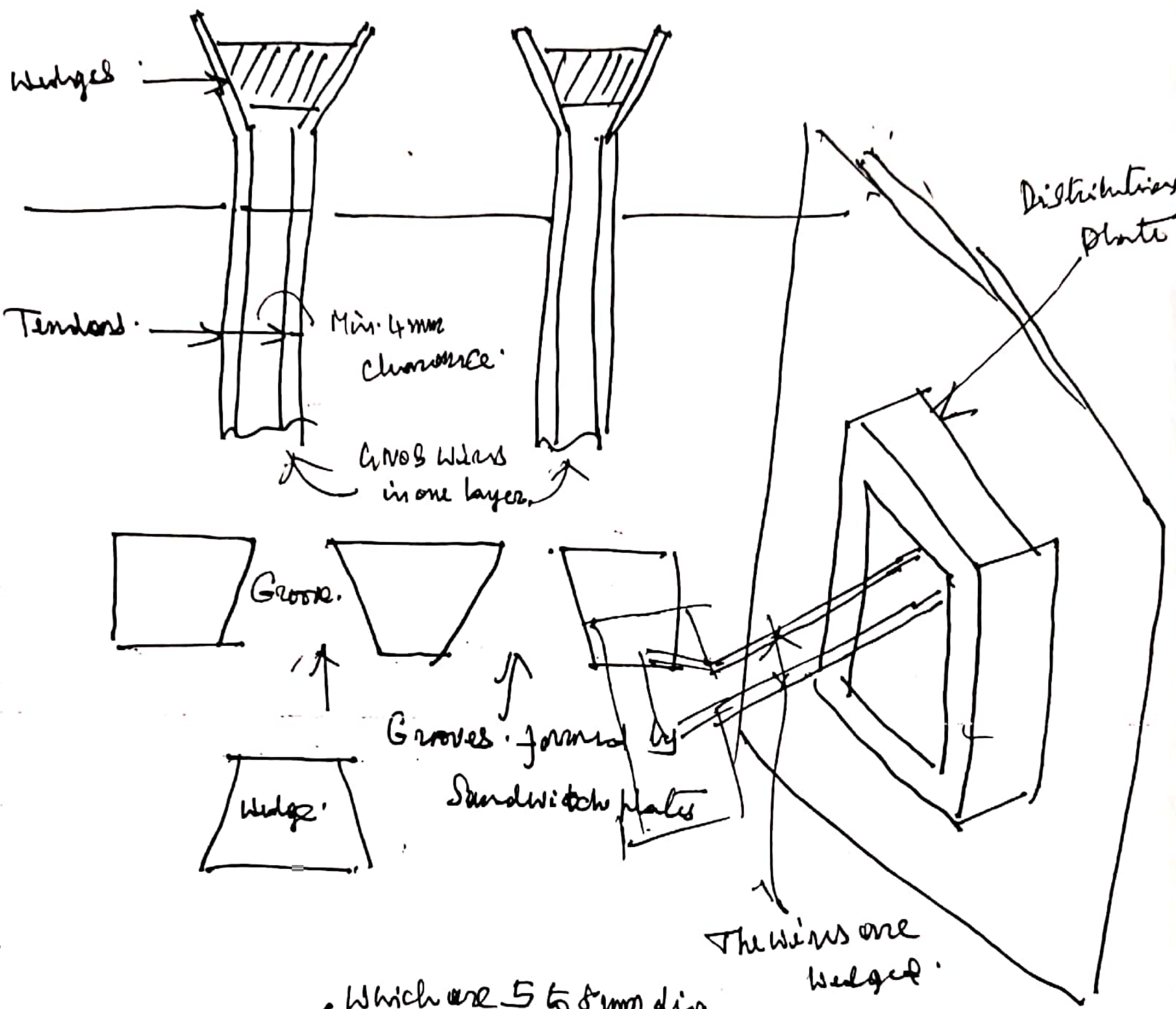
3) The plugs are left in the concrete and they do not project beyond the ends of the member.

<u>Disadvantages</u> : 1) In this method all the wires are stretched together. Hence, the stress produced in the wires may not be uniform.

2) The greatest stretching force is 25 to 50t only which may not be sufficient sometimes.

3) The jacks used are heavy and expensive.

MAGNEL BLAYTON SYSTEM.

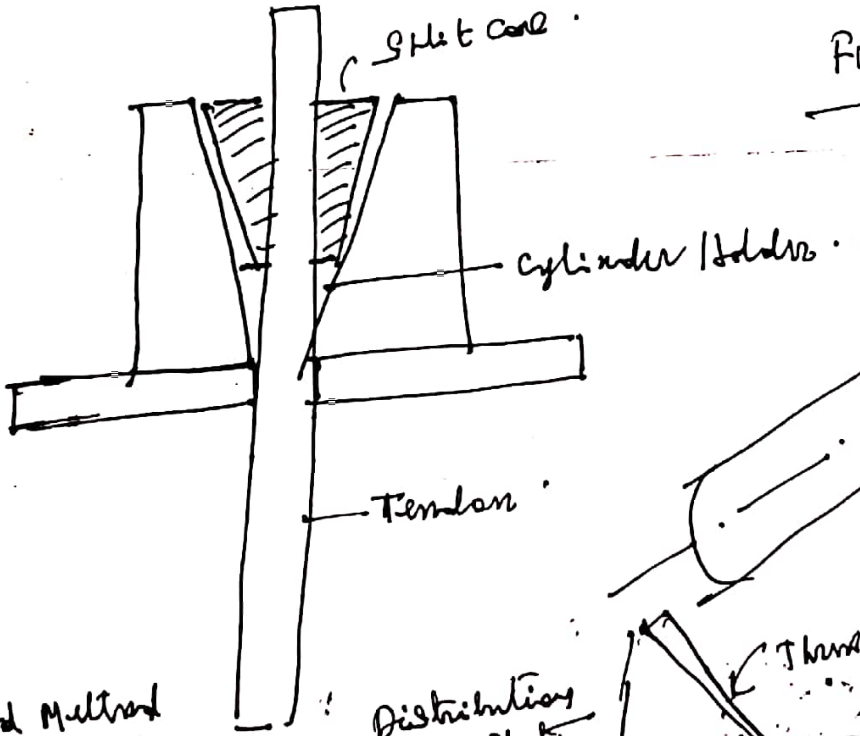


The wires (which are 5 to 8 mm dia) are arranged 4 Nos in one layer and upto 16 layers can be accommodated in the duct. The wires are separated by a clearance of 4 mm by using the spacers, and the same pattern is maintained throughout the length of the cable. The wires are anchored by wedging after tensioning two at a time into Sandwich plates.

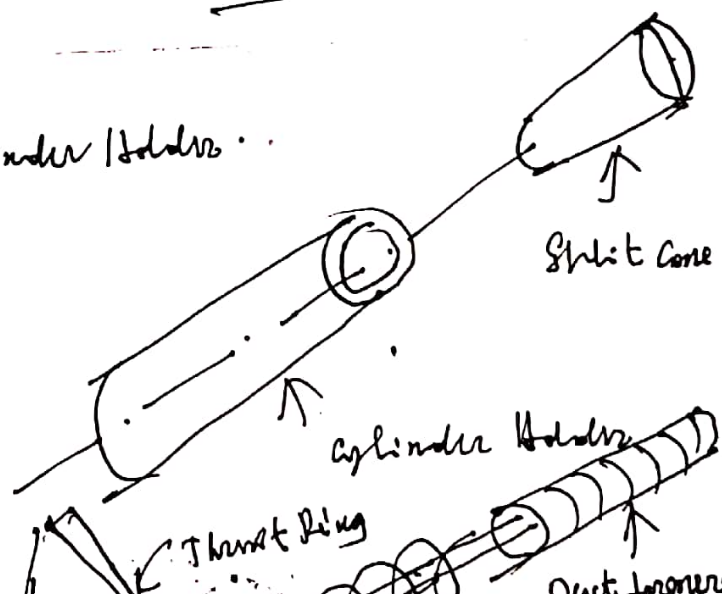
The Wires are taken two in each groove, then tightened. Then a steel wedge is driven between the tightened wires to anchor them against the plate.

One anchorage unit consists of one to 8 sandwich plates. The anchorage plate set is arranged against a distribution plate. The wires are tightened two at a time by jacking,

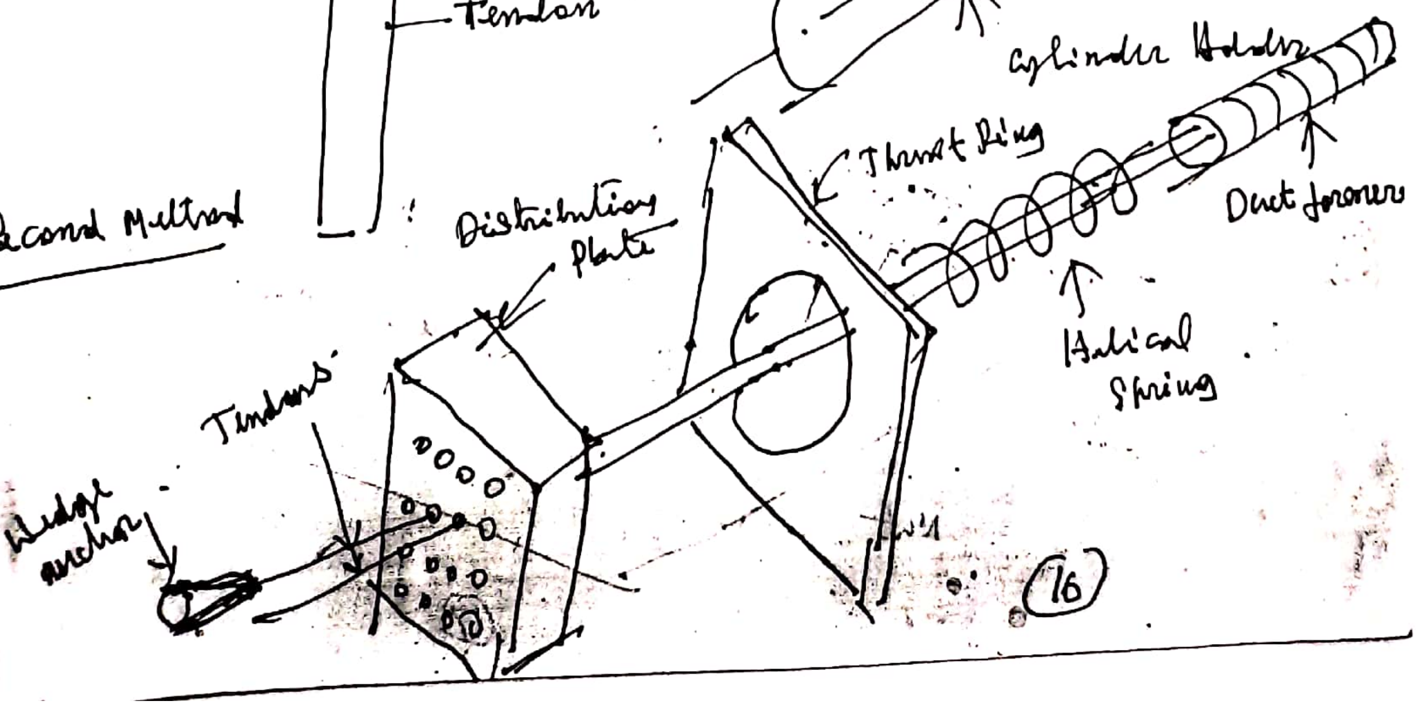
GIFFORD UDALL SYSTEM.



First Method

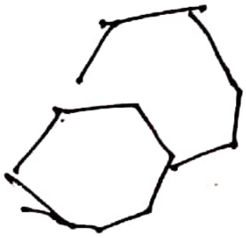


Second Method

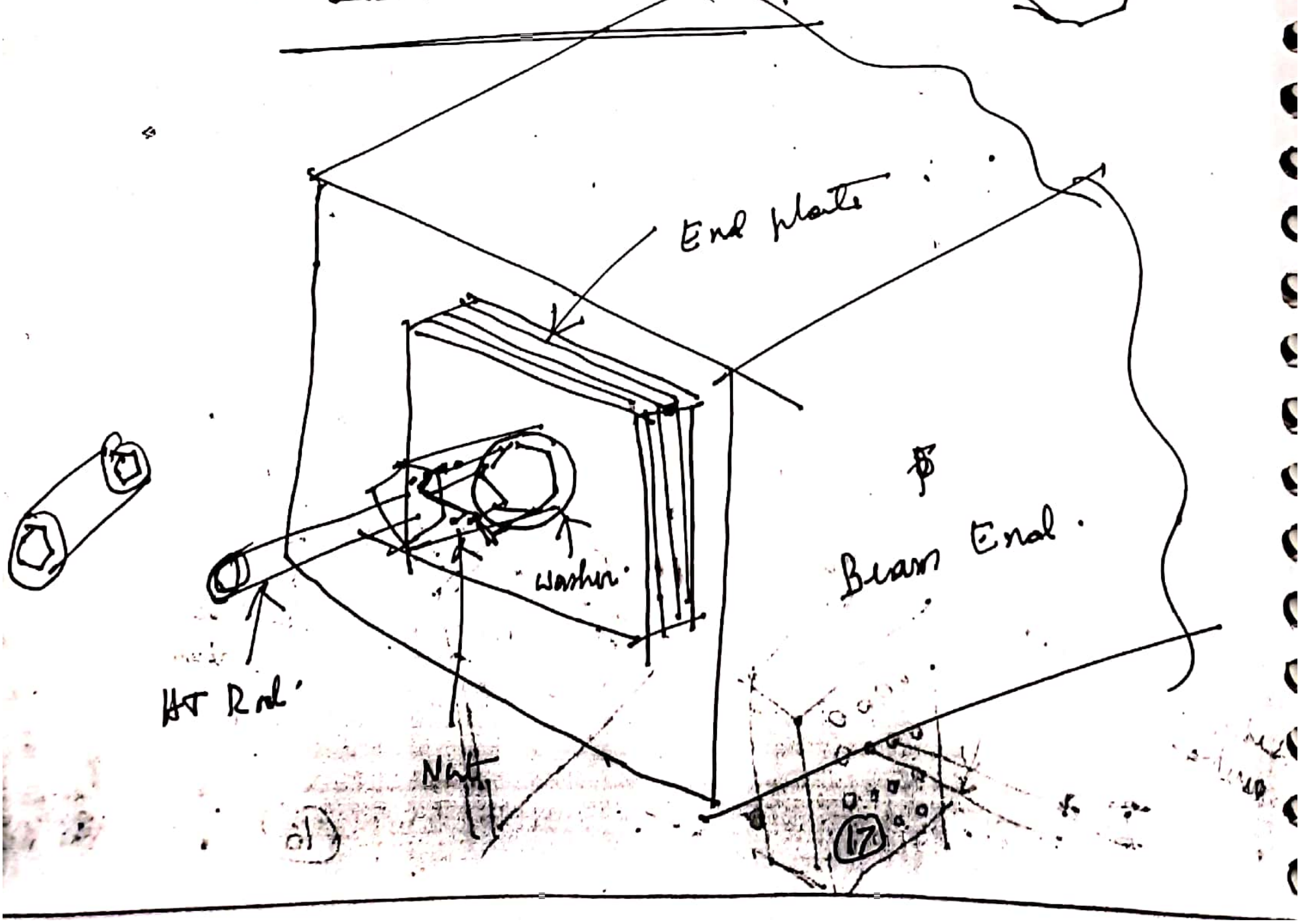


In the Gifford Udall Systems, special anchorages known as 'Udall grips' are used for anchoring the wires after prestressing. The other details like distribution plate, thrust ring, Helical spring, duct former etc. are provided as usual.

In the first method split cone wedges are fixed into cylinder holders. In the second method, Conical wedges are fixed directly into the distribution plate provided with holes.



Lee McCall System



In Lee McCall System, high tensile alloy steel bars (Silica-Manganese Steel) are used as tendons. These bars are used in 22, 25, 28, 30 mm etc. diameters. They are available in lengths up to 20 m. By providing special threaded nuts the bars are anchored. The nuts bear against a distribution plate and thus the prestress is transferred by direct end bearing on the bars.

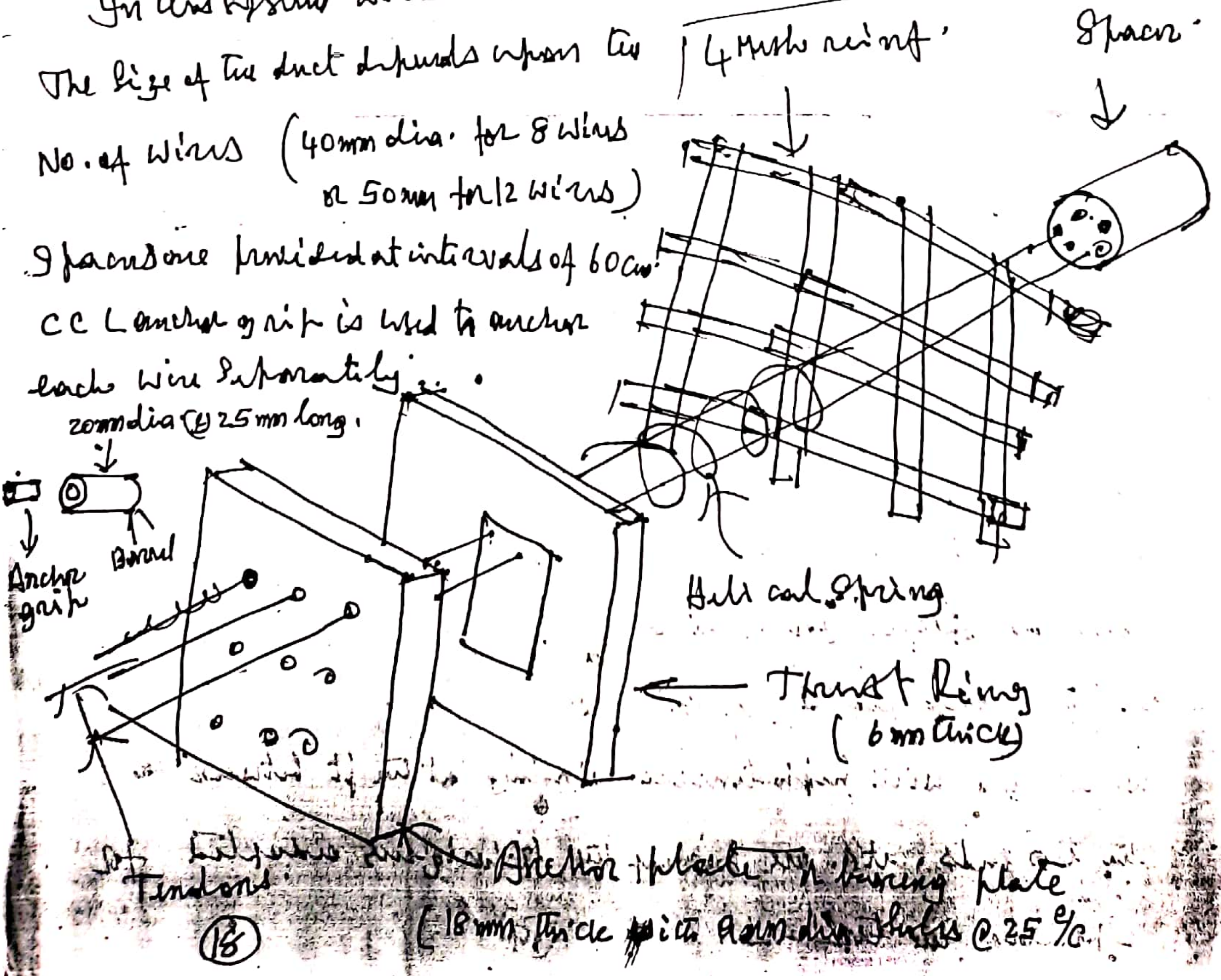
CCL Standard System

In this system wires are tensioned individually.

The size of the duct depends upon the No. of wires (40 mm dia. for 8 wires or 50 mm for 12 wires)

Spacers are provided at intervals of 60 cm.

CCL anchor grip is used to anchor each wire separately.



Steel wedges which fit over the wires are accommodated in a steel barrel having a tapered hole. The barrels are 20 mm dia. and 25 mm long. The wedges bear against a drilled anchor plate through which the wires are passed. The anchor plate bears against a thrust ring, which is cast into the concrete. The thrust ring is of M.S 6 mm thick is rectangular with a central rectangular hole. To prevent local bursting effect a helix is provided behind the thrust ring. A vertical mesh is also provided behind the helix for this purpose. The bearing plate is 18 mm thick with 9 mm. dia. holes provided at a spacing of 25 mm centres in parallel rows to accommodate the wires.

Splices for Tendons

- Couplers with screws for H.T bars
- Torpedo splices for H.T wires
- Using clamp plates for H.T. wires
- Wrapping with high tensile winding at the jt between the two ends, e.g. are some of the techniques adopted for splicing the tendons.

THERMO ELECTRIC PRESTRESSING.

The tendons or bars are heated to 300-400°C within 3 to 5 min. They undergo an elongation of 0.4 to 0.5%. The bars are thus cooled and the shortening is prevented by means of fixed anchors. The cooling period is 12 to 15 Min. This method was adopted in USSR. Successfully.

CHEMICAL PRESTRESSING.

By using expanding cements (75% OPC + 15% High alumina cement + 10% Gypsum cement) is made to expand and thus develops tensile stresses in steel, cements ~~placed~~ in turn comp. stress is developed in. This method is not suitable when high degree of prestress is required.

Applications of Post tensioning

1) Post tensioning is mostly preferred for the construction of circular prestressing, Nuclear ~~in~~ site structures, long span bridge structures, monuments etc.
2) It has the advantage of varying the profile to counteract the B.M. effectively.
3) Preferred for long span box girder segmental construction