KUPPAM ENGINEERING COLLEGE

DEPARTMENT OF CIVIL ENGINEERING

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PRESTRESSED CONCRETE STRUCTURE

UNIT -1

INTRODUCTION

A BRIEF HISTORY

In 1886, P.H. Jackson, an engineer of San Francisco obtained patents for tightening steel tie rods in artificial stones and concrete arches to serve as floor slabs

 Around 1888.C.E.W.Doehring of Germany independently secured a patent for concrete reinforced with metal that had tensile stress applied to it before the slab was loaded.

 Ever since the development of reinforced concrete by Hennebique at the end of 19th century, it was recognized that steel and concrete could be more effectively combined if the steel was pre-tensioned, putting the concrete into compression.

 Cracking could be reduced, if not prevented altogether, which will increase stiffness and improve durability In 1908, C.R. Steiner of U.S.A suggested the possibility of retightening the reinforcing rods after some shrinkage and creep of concrete had taken place.

GENERAL PRINCIPLES OF PRESTRESSING

- Prestressing is the intentional creation of permanent stress in a structure or assembly, for improving its behavior and strength under various service conditions.
- In ordinary reinforced concrete, consisting of concrete and mild steel as basic components, the compressive stresses are born by concrete while tensile stresses are born entirely by steel. The concrete only acts as a binding material; it does not take part in resisting the external forces.
- In prestressed concrete, compression is induced prior to loading in the zones where external loads would normally cause tensile stresses.
- In the case of long beams, where large shear forces exist, the beam sizes have to be large to limit the diagonal tensile stresses under certain limits. Prestress decrease diagonal tensile stresses. This has led to adopt modified I-section and T-section in which there is substantial reduction in web area.

- In order to get the maximum advantage of a prestressed concrete member, it is necessary to use not only high strength concrete but also high tensile steel wires.
- Concrete used for prestressed work should have cube strength of 35 N/mm^2 for post-tensioned system and 45N/m m^2 for pretensioned system.
- In the design of a prestressed concrete member, the estimated loss of prestress due to shrinkage of concrete and creep of concrete and steel is at the order of nearly 200 N/mm^2

Need of Prestressing

- To offset the deficiency of tensile strength in concrete, steel reinforcement is provided near the bottom of simple beams to carry the tensile stresses.

PRETENSIONING & POST TENSIONING METHOD

(89) What is Prestressed Concrete? || Types of Prestressed Concrete || Types of Concrete #3 - YouTube

PRETENSIONING METHOD

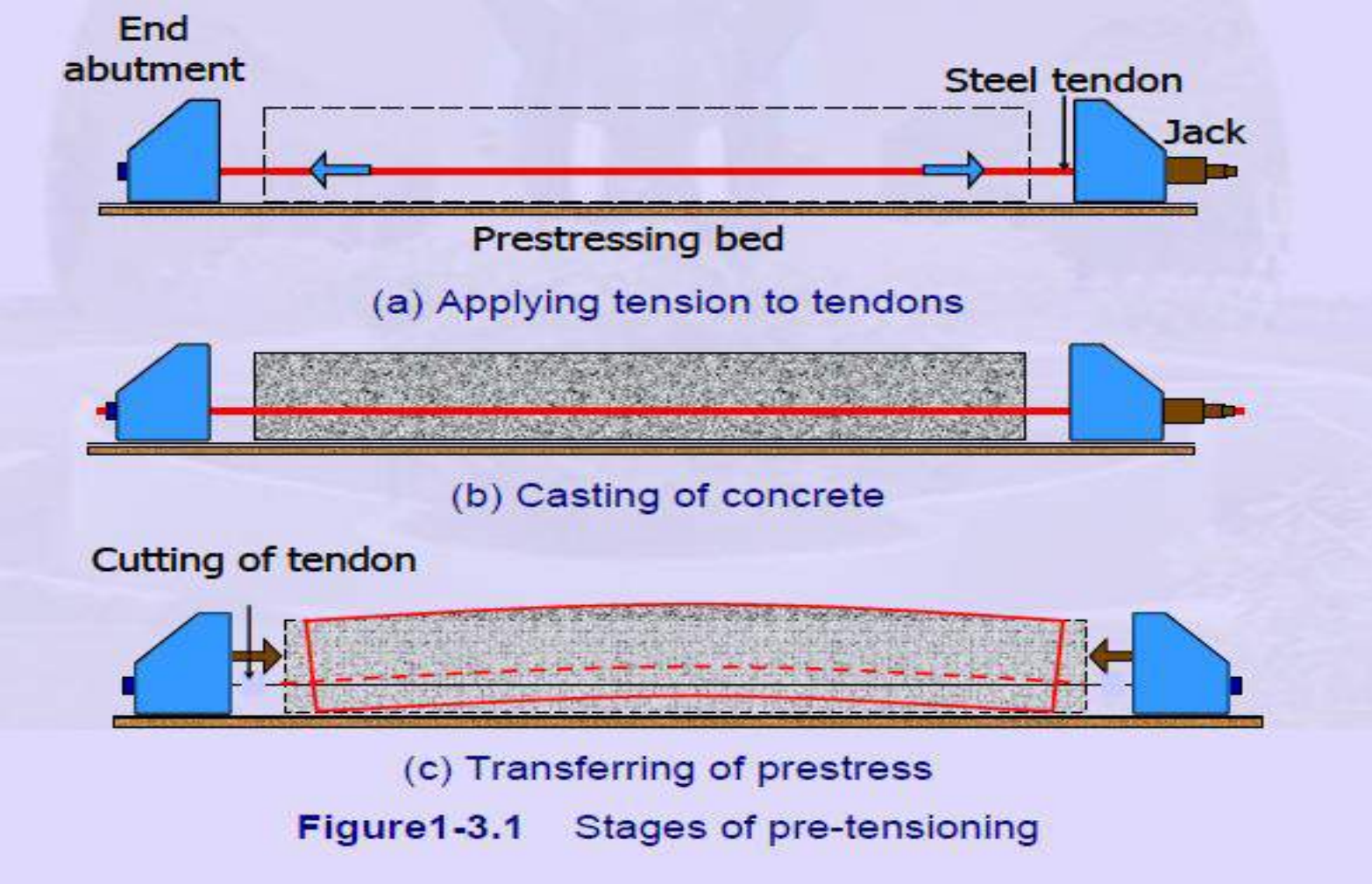


Figure1-3.1 Stages of pre-tensioning

A method of prestressing concrete in which tendons are tensioned before the concrete is placed.

PROCESS:

- Pre tensioning is one method of applying prestress.
- Tendons either pass through a single mould or a line of moulds for multiple members arranged end to end and can be attached at one end to fixed anchorage.
- The tendons are then tensioned from the fixed anchorage between an external independent anchorage to give the required tensile force in the tendon.
- The tendons are then held in place while the concrete is poured.
- When the concrete has hardened sufficiently the ends of the tendons are slowly released from the anchorages. The tendons are restrained from gaining their original length by the development of bond stresses between the concrete and the tendon, and it is these bond stresses that transfer the compressive stress to the concrete.
- The tendons are then finally trimmed off.

POST TENSIONING METHOD

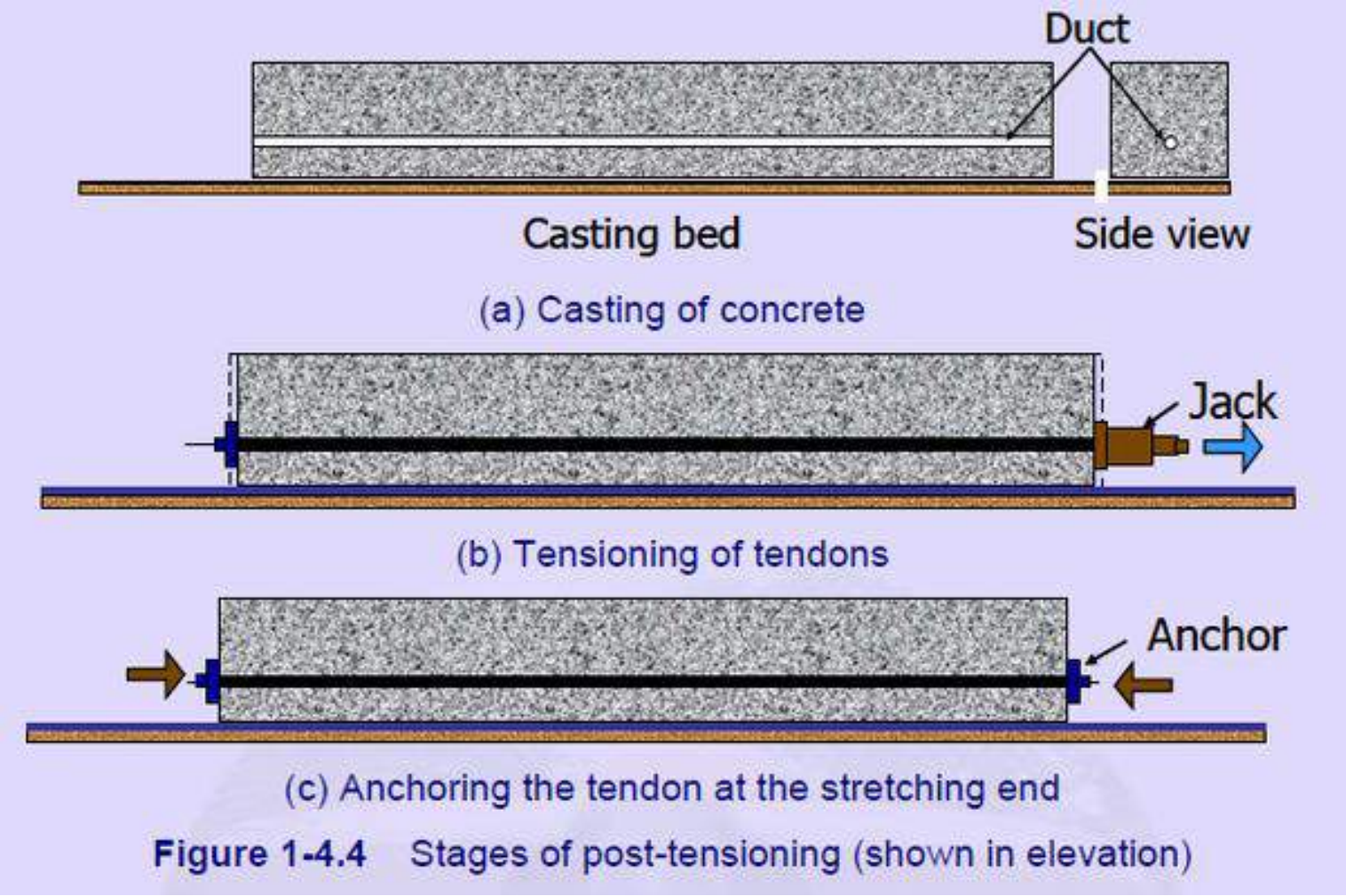


Figure 1-4.4 Stages of post-tensioning (shown in elevation)

A method of prestressing concrete in which tendons are tensioned after the concrete is placed.

PROCESS

- Post-Tensioning is another method of applying prestress to a concrete member.
- The tendon is placed in the correct position in the formwork with the dead-end anchorage and live end anchorage, through which the tendon passes.
- The concrete is then poured and left to harden.
- When the concrete has gained sufficient strength a jack is attached to the live end anchorage and the tendon stressed to the required force. The operation is to be carefully done as any error could impair the structural integrity of the member.
- The tension force in the tendon is transferred to the concrete as a compressive force by the reactions at the anchorages. The jack is then removed.

ADVANTAGES OF PRESTRESSED CONCRETE

- Longer span length increases untroubled floor space and parking facilities.
- Thinner slabs, that are important for high rise building as with the same amount of cost, it can construct more slabs than traditional thicker slabs.
- As the span length is larger, fewer joints are needed than traditional RC structures.
- Because of fewer joints, maintenance cost also becomes reduced during the design life as joints are the major locus of weakness in a concrete building.
- Long-term Durability.
- Better finishing of placed concrete.
- It requires a smaller amount of construction materials.
- It resists stresses are higher than normal RCC structures and is free from cracks.

DISADVANTAGES OF CONCRETE

- It requires high strength concrete and high tensile strength steel wires.
- The main disadvantage is construction requires additional special equipment like jacks, anchorage, etc.
- It requires highly skilled workers under skilled supervision.
- Construction cost is little higher than RCC structures.

MATERIALS USED IN PRESTRESSED CONCRETE

1) Steel
2) Concrete

HIGH TENSILE STEEL

Ordinary mild steel and deformed bars used in R.C.C. are not used in PSC (Prestressed concrete) because their yield strength is not very high.

In the PSC, loss of prestress (about 20%) occurs due to many factors. If mild steel or HYSD bars are used then very little prestress will be left after the losses and will be of no use for us. Therefore, high tensile strength steel is used for prestressing.

In addition to the high strength, the steel used in prestresing must have a higher ultimate elongation. Various forms of steel used for prestressing are as follows:

1. Tendons
2. Wire strands or cables
3. Bars

- **TENDONS**

Tendons are high strength tensile wires available in various diameter from 1.5mm to 8mm. Table gives the ultimate tensile strength of steel wires used for prestressing.

Diameter of wire (mm)	Ultimate tensile strength (N/mm^2)
1.5	2350
2.0	2200
3.0	1900
4.0	1750
5.0	1600
7.0	1500
8.0	1500

Wire Strands or Cables

- A strand or cable is made of a bundle of wires spun together. The overall diameter of a cable or stand is from 7 to 17mm. They are used for post-tensioning systems.

Bars

- High tensile steel bars of diameter 10mm or more are also used in prestressed concrete.

HIGH STRENGTH CONCRETE

- Since high tensile steel is used in PSC, the concrete used should also be of good quality and high strength.
- Therefore, IS code recommends a minimum mix of M40 for pretensioned system and M30 for post tensioned system.
- These mixes have high strength and a high value of modulus of elasticity of concrete which results in less deflection.
- The concrete used in PSC should be well compacted.

High strength concrete is used in PSC for following reasons:

1.Use of high strength concrete results in smaller sections.

2.High strength concrete offers high resistance in tension, shear, bond and bearing.

3.Less loss of prestress occurs with high strength concrete.

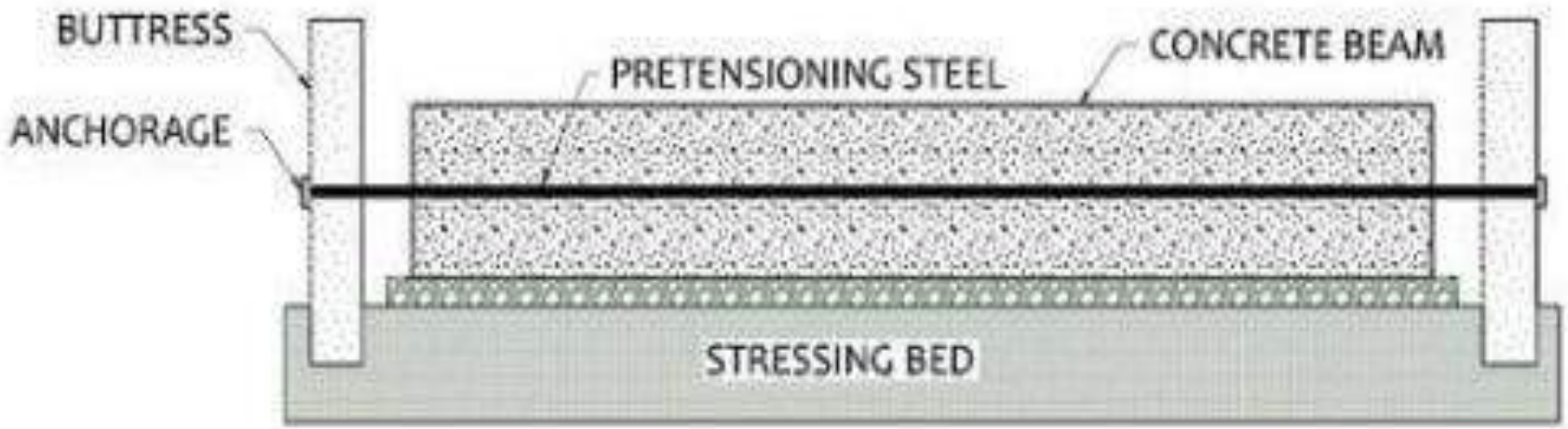
NECESSITY OF HIGH TENSILE STEEL AND HIGH STRENGTH CONCRETE

- High strength concrete is necessary for prestress concrete as the material offers highly resistance in tension, shear bond and bearing.
- In the zone of anchorage the bearing stresses being hired, high strength concrete is invariably preferred to minimizing the cost.
- High strength concrete is less liable to shrinkage cracks and has lighter modulus of elasticity and smaller ultimate creep strain resulting in a smaller loss of prestress in steel.
- The use of high strength concrete results in a reduction in a cross sectional dimensions of prestress concrete structural element with a reduced dead weight of the material longer span become technically and economically practicable.
- Tensile strength of high tensile steel is in the range of 1400 to 2000 N/mm^2 and if initially stress upto 1400 N/mm^2 their will be still large stress in the high tensile reinforcement after making deduction for loss of prestress. Therefore high tensile steel is made for prestress concrete.

METHODS AND SYSTEMS OF PRESTRESSING

In concrete structures, prestress is introduced by stretching steel wire and anchoring them against concrete. Therefore, the prestressing systems should comprise essentially a method of stretching the steel and a method of anchoring it to the concrete. Different systems are adopted for pre-tensioning and post tensioning.

A system of prestressing means the actual process adopted in making a prestressed beam. It involves the process of tensioning the tendons and securing them firmly to the concrete.



PRETENSIONED CONCRETE

POSTTENSIONED CONCRETE

PRE-TENSIONING SYSTEM

It involves pulling the tendon between abutments which are anchored firmly against the ends of stressing bed.

- The tendons are cut off at each end after the concrete hardens
- Now the prestress is transferred to the concrete.

Pre-tensioning Methods

a. Hoyer system or long line method

b. Shorer system

Hoyer system or long line method

Hoyer system or long line method is often adopted in pre-tensioning. Two bulk heads or abutments independently anchored to the ground are provided several meters apart, say, 100m. Wires are stretched between the bulkheads. Moulds are placed enclosing the wires. The concrete is now poured so that a number of beams can be produced in one line.

After the concrete has hardened, the wires are released from bulkheads and are cut off. The prestress is transferred through the bond between tendons and concrete.

Advantages

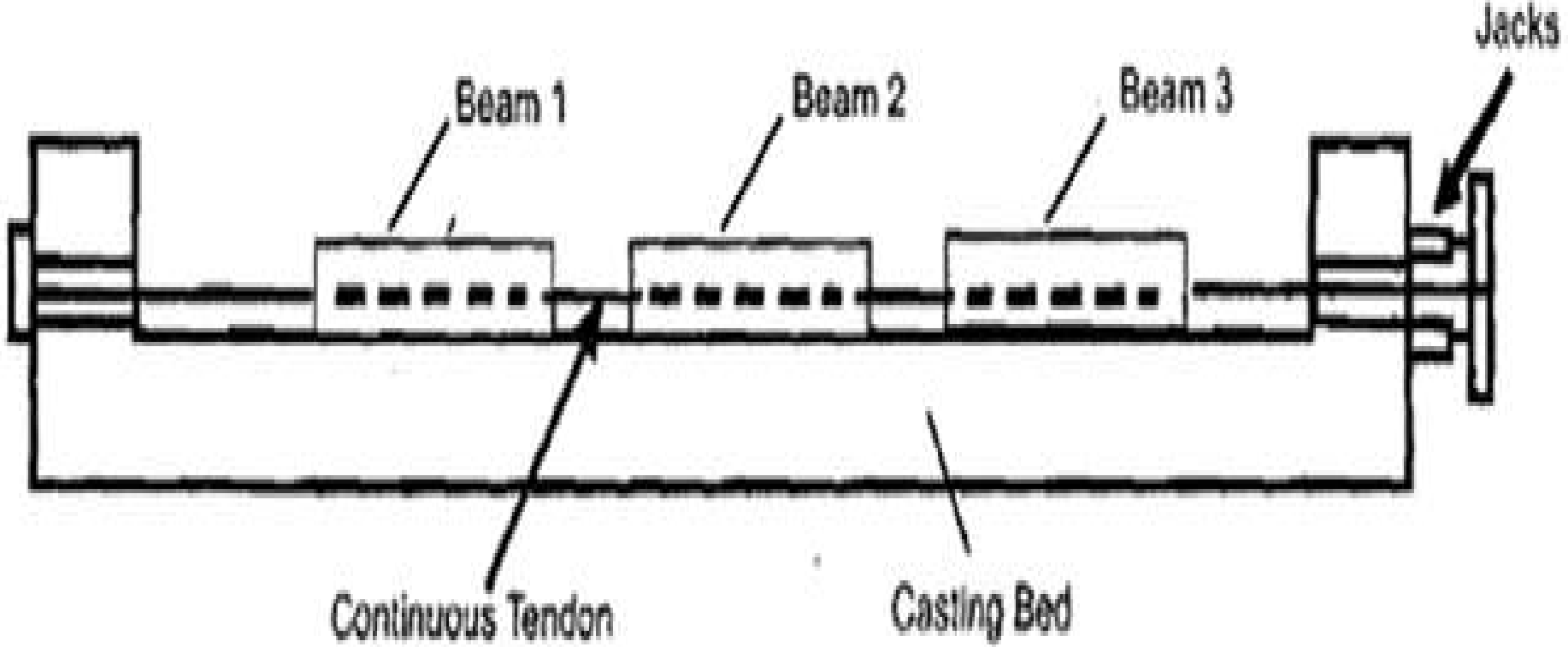
For large scale production.

Economical and is used in almost all pre-tensioning factories.

Disadvantages

Uneconomical for larger spans.

The end abutments should be very strong and are provided only in pre-cast factories.



Hoyer's Long Line System of Pre-tensioning

POST-TENSIONING SYSTEM

- A metal tube or a flexible hose following intended profile is placed inside the mould and concrete is laid. Flexible hose is then removed leaving a duct inside the member. Steel cable is inserted in the duct.
- The cable is anchored at one end of the member and stretched using a hydraulic jack at the other end. After stretching the cable is anchored at the other end also. Therefore post tensioning system consists of end anchorages and jacks.

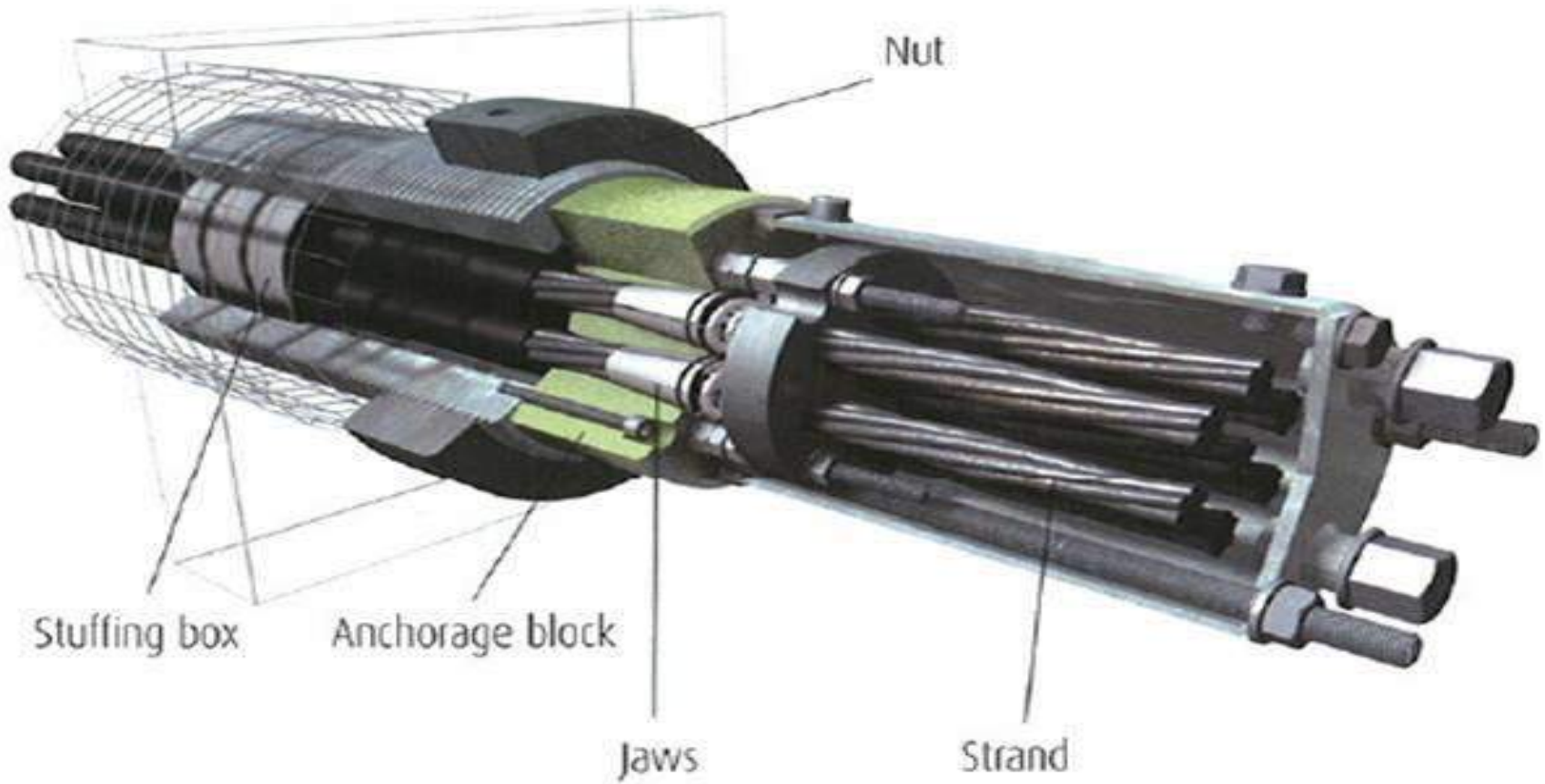
The popular post-tensioning systems are the following:

1. Freyssinet system
2. Magnel Blaton system
3. Gifford-Udall system
4. Lee-McCall system

Freyssinet system

- Freyssinet system was introduced by the French Engineer Freyssinet and it was the first method to be introduced.
- **High strength steel wires of 5mm or 7mm diameter, numbering 8 or 12 or 16 or 24 are grouped into a cable with a helical spring inside.**
- Spring keeps proper spacing for the wire. Cable is inserted in the duct.
- Anchorage device consists of a concrete cylinder with a concentric conical hole and corrugations on its surface, and a conical plug carrying grooves on its surface.
- Steel wires are carried along these grooves at the ends. Concrete cylinder is heavily reinforced.
- Members are fabricated with the cylinder placed in position. Wires are pulled by Freyssinet double acting jacks which can pull through suitable grooves all the wires in the cable at a time.
- One end of the wires is anchored and the other end is pulled till the wires are stretched to the required length. An inner piston in the jack then pushes the plug into the cylinder to grip the wires.

Lower partially prefabricated anchorage (RAB type)



Magnel Blaton system

- In Freyssinet system several wires are stretched at a time. In Magnel Blaton system, two wires are stretched at a time. This method was introduced by a famous engineer, Prof. Magnel of Belgium.
- In this system, the anchorage device consists of sandwich plate having grooves to hold the wires and wedges which are also grooved. Each plate carries eight wires.
- Between the two ends the spacing of the wires is maintained by spacers. Wires of 5mm or 7mm are adopted. Cables consists of wires in multiples of 8 wires. Cables with as much as 64 wires are also used under special conditions.
- A specially devised jack pulls two wires at a time and anchors them. The wires with the sandwich plate using tapered wedge is shown in figure.

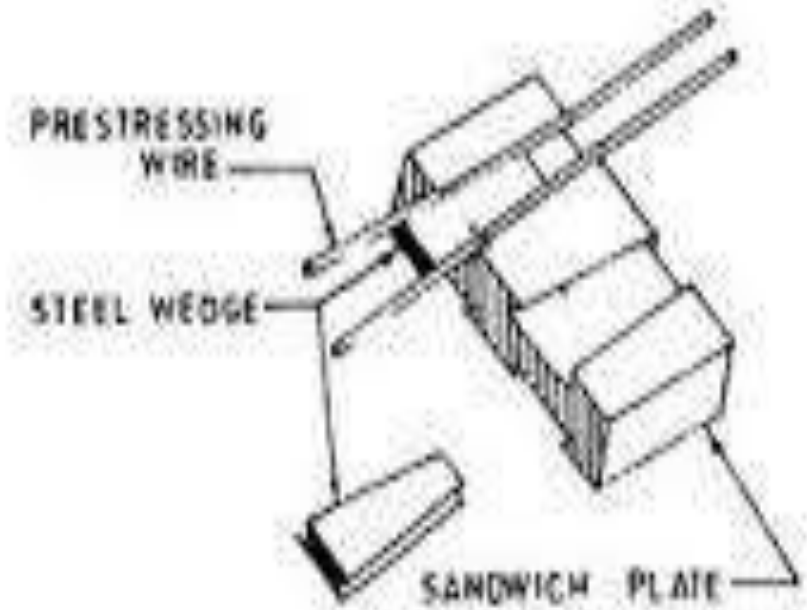


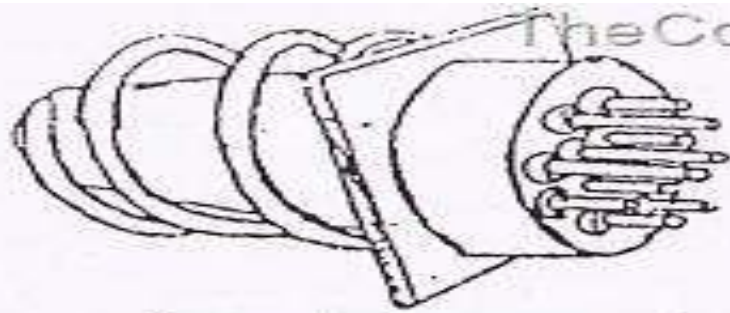
FIG.16·3 ANCHORAGE FOR MAGNEL-BLATON SYSTEM

Gifford Udall System

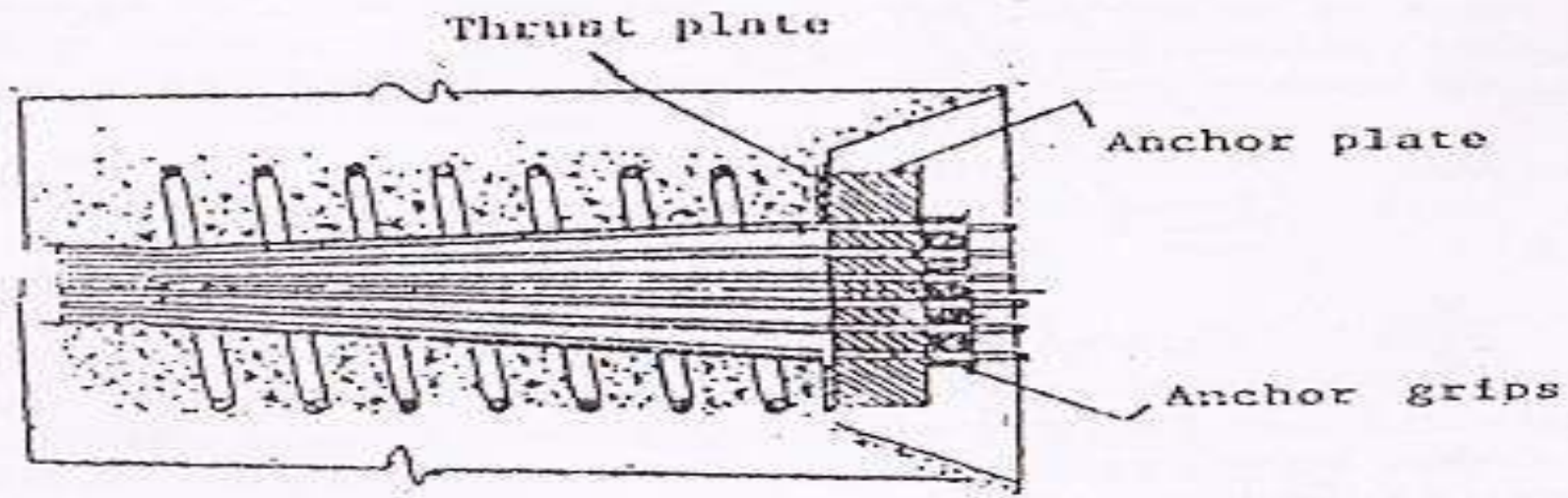
- This system originated in Great Britain, is widely used in India. This is a single wire system. Each wire is stressed independently using a double acting jack. Any number of wires can be grouped together to form a cable in this system. There are two types of anchorage device in this system.

  a) Tube anchorages
  b) Plate anchorages

- Tube anchorage consists of a bearing plate, anchor wedges and anchor grips. Anchor plate may be square or circular and have **8 or 12** tapered holes to accommodate the individual prestressing wires. These wires are locked into the tapered holes by means of anchor wedges.
- In addition, grout entry hole is also provided in the bearing plate for grouting. Anchor wedges are split cone wedges carrying serrations on its flat surface.
- There is a tube unit which is a fabricated steel component incorporating a thrust plate, a steel tube with a surrounding helix. This unit is attached to the end shutters and form an efficient cast-in component of the anchorage.

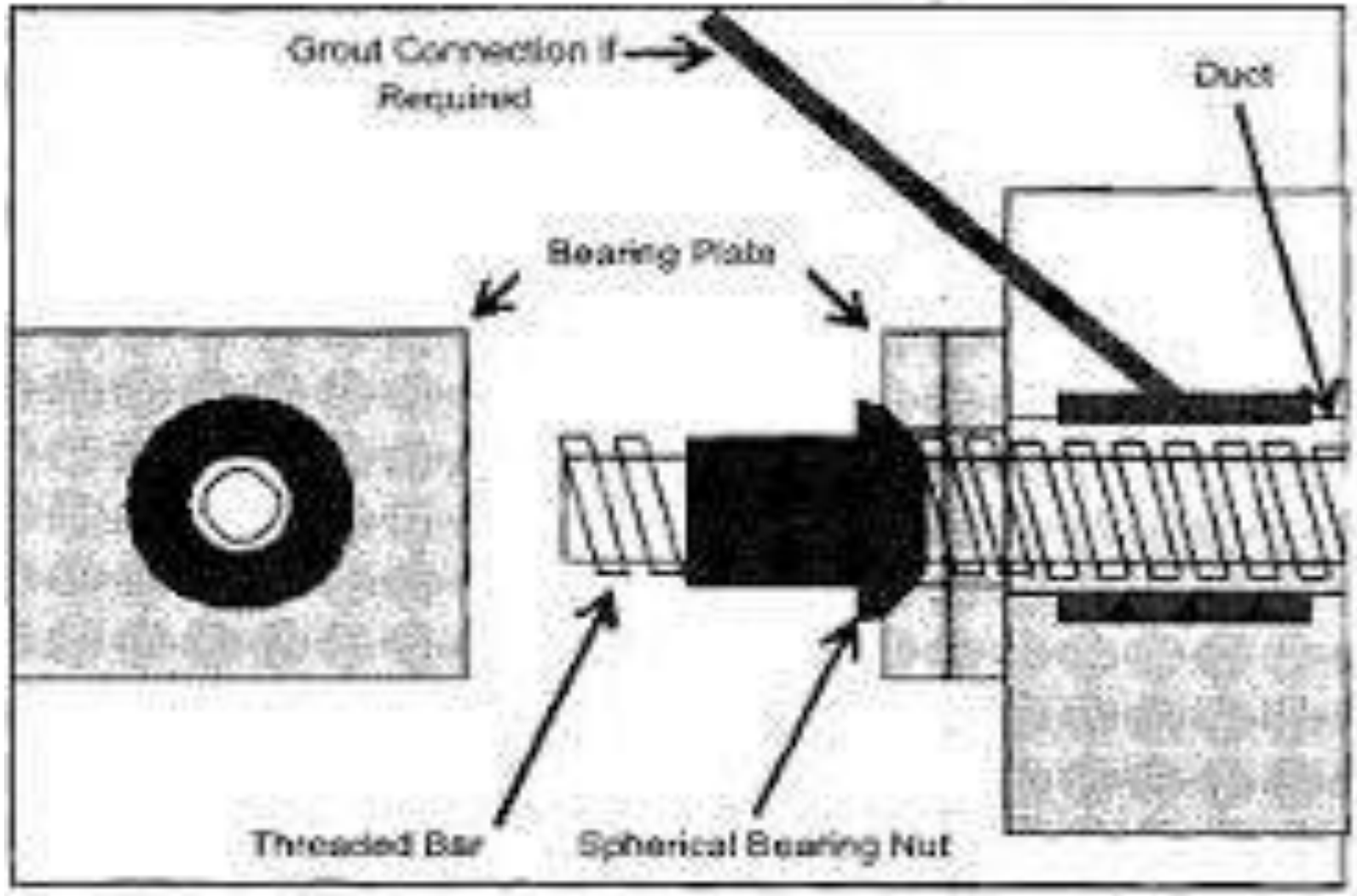


Tube Anchorages



Lee McCall System

- This method is used to prestress steel bars.
- The diameter of the bar is between 12 and 28mm bars provided with threads at the ends are inserted in the performed ducts.
- After stretching the bars to the required length, they are tightened using nuts against bearing plates provided at the end sections of the member.


Grout Connection if Required
Duct
Bearing Plate
Threaded Bar
Spherical Bearing Nut

Lee-McCall systems