1.3 Pre-tensioning Systems and Devices

This section covers the following topics.

- Introduction
- Stages of Pre-tensioning
- Advantages of Pre-tensioning
- Disadvantages of Pre-tensioning
- Devices
- Manufacturing of Pre-tensioned Railway Sleepers

1.3.1 Introduction

Prestressing systems have developed over the years and various companies have patented their products. Detailed information of the systems is given in the product catalogues and brochures published by companies. There are general guidelines of prestressing in **Section 12** of **IS:1343 - 1980**. The information given in this section is introductory in nature, with emphasis on the basic concepts of the systems.

The prestressing systems and devices are described for the two types of prestressing, pre-tensioning and post-tensioning, separately. This section covers pre-tensioning. Section 1.4, “Post-tensioning Systems and Devices”, covers post-tensioning. In pre-tensioning, the tension is applied to the tendons before casting of the concrete. The stages of pre-tensioning are described next.

1.3.2 Stages of Pre-tensioning

In pre-tensioning system, the high-strength steel tendons are pulled between two end abutments (also called bulkheads) prior to the casting of concrete. The abutments are fixed at the ends of a prestressing bed.

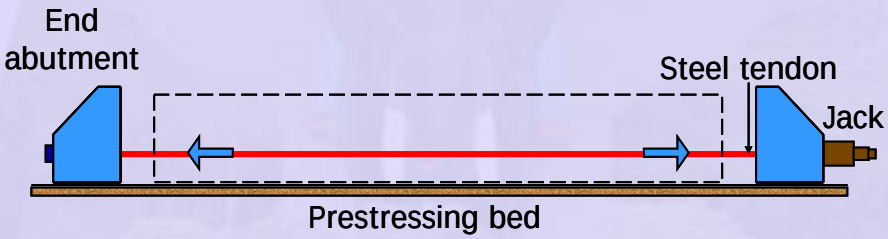
Once the concrete attains the desired strength for prestressing, the tendons are cut loose from the abutments.

The prestress is transferred to the concrete from the tendons, due to the bond between them. During the transfer of prestress, the member undergoes elastic shortening. If the tendons are located eccentrically, the member is likely to bend and deflect (camber). The various stages of the pre-tensioning operation are summarised as follows.

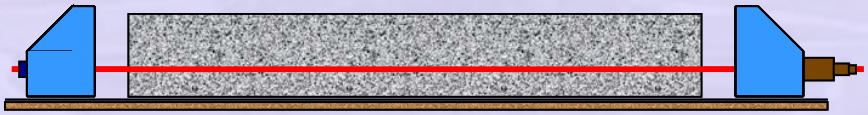
1) Anchoring of tendons against the end abutments
2) Placing of jacks
3) Applying tension to the tendons
4) Casting of concrete
5) Cutting of the tendons.

During the cutting of the tendons, the prestress is transferred to the concrete with elastic shortening and camber of the member.

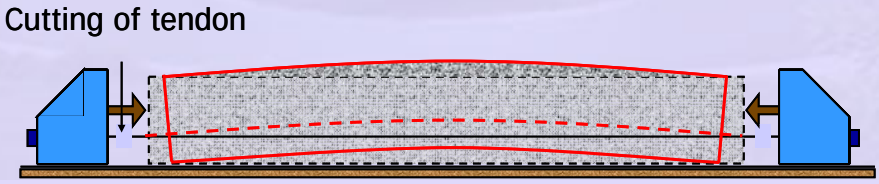
The stages are shown schematically in the following figures.



(a) Applying tension to tendons



(b) Casting of concrete



(c) Transferring of prestress

Figure1-3.1 Stages of pre-tensioning

1.3.3 Advantages of Pre-tensioning

The relative advantages of pre-tensioning as compared to post-tensioning are as follows.

- Pre-tensioning is suitable for precast members produced in bulk.

- In pre-tensioning large anchorage device is not present.

1.3.4 Disadvantages of Pre-tensioning

The relative disadvantages are as follows.

- A prestressing bed is required for the pre-tensioning operation.
- There is a waiting period in the prestressing bed, before the concrete attains sufficient strength.
- There should be good bond between concrete and steel over the transmission length.

1.3.5 Devices

The essential devices for pre-tensioning are as follows.

- Prestressing bed
- End abutments
- Shuttering / mould
- Jack
- Anchoring device
- Harping device (optional)

Prestressing Bed, End Abutments and Mould

The following figure shows the devices.

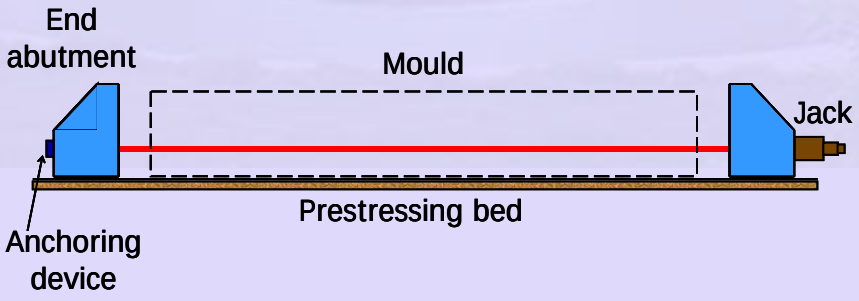


Figure1-3.2 Prestressing bed, end abutment and mould

An extension of the previous system is the **Hoyer system**. This system is generally used for mass production. The end abutments are kept sufficient distance apart, and several members are cast in a single line. The shuttering is provided at the sides and

between the members. This system is also called the **Long Line Method**. The following figure is a schematic representation of the Hoyer system

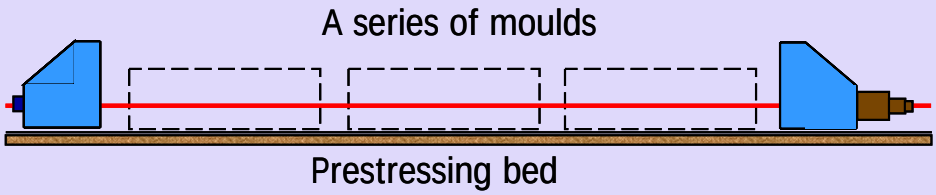


Figure 1-3.3 Schematic representation of Hoyer system

The end abutments have to be sufficiently stiff and have good foundations. This is usually an expensive proposition, particularly when large prestressing forces are required. The necessity of stiff and strong foundation can be bypassed by a simpler solution which can also be a cheaper option. It is possible to avoid transmitting the heavy loads to foundations, by adopting self-equilibrating systems. This is a common solution in load-testing. Typically, this is done by means of a 'tension frame'. The following figure shows the basic components of a tension frame. The jack and the specimen tend to push the end members. But the end members are kept in place by members under tension such as high strength steel rods.

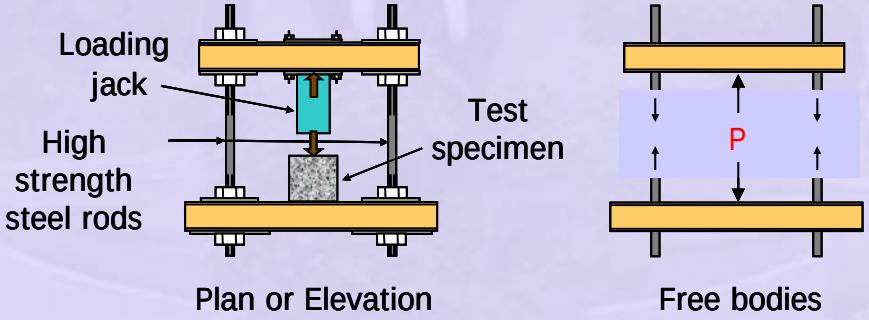


Figure 1-3.4 A tension frame

The frame that is generally adopted in a pre-tensioning system is called a **stress bench**. The concrete mould is placed within the frame and the tendons are stretched and anchored on the booms of the frame. The following figures show the components of a stress bench.

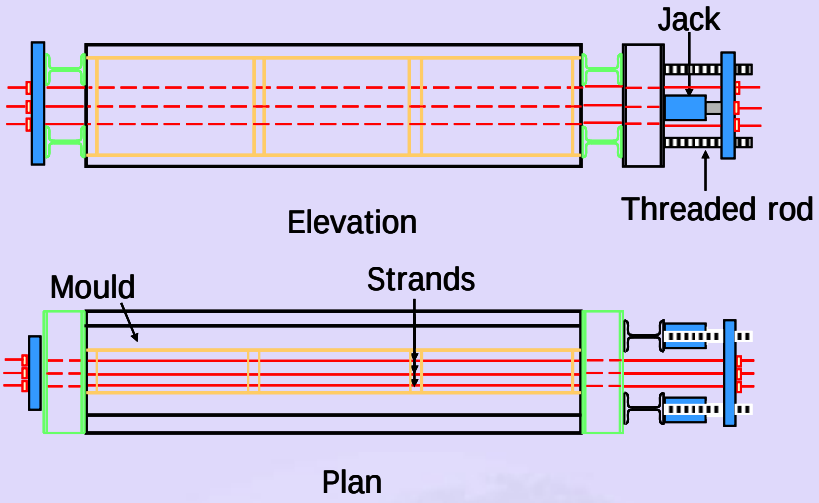


Figure 1-3.5 Stress bench – Self straining frame

The following figure shows the free body diagram by replacing the jacks with the applied forces.

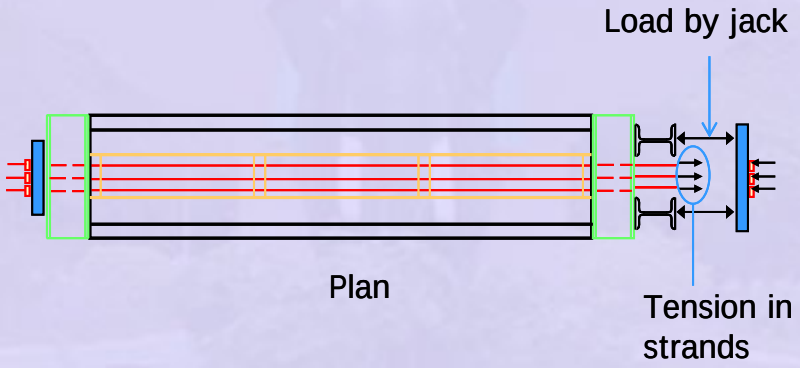


Figure 1-3.6 Free body diagram of stress bench

The following figure shows the stress bench after casting of the concrete.

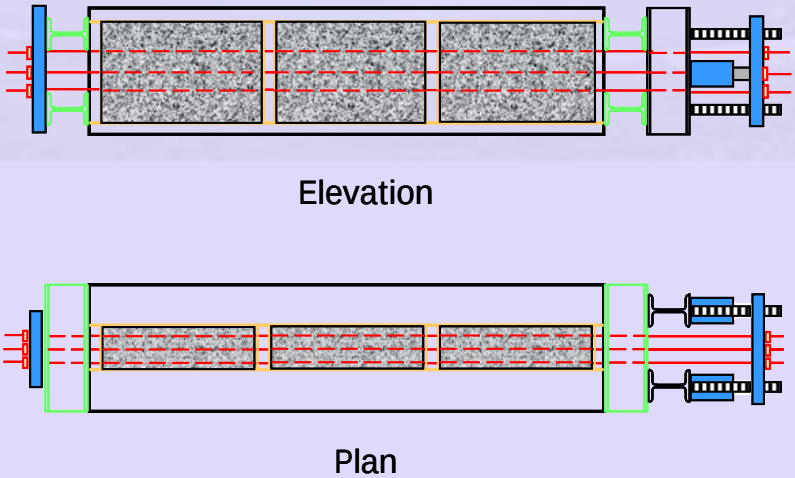


Figure 1-3.7 The stress bench after casting concrete

Jacks

The jacks are used to apply tension to the tendons. Hydraulic jacks are commonly used. These jacks work on oil pressure generated by a pump. The principle behind the design of jacks is Pascal's law. The load applied by a jack is measured by the pressure reading from a gauge attached to the oil inflow or by a separate load cell. The following figure shows a double acting hydraulic jack with a load cell.

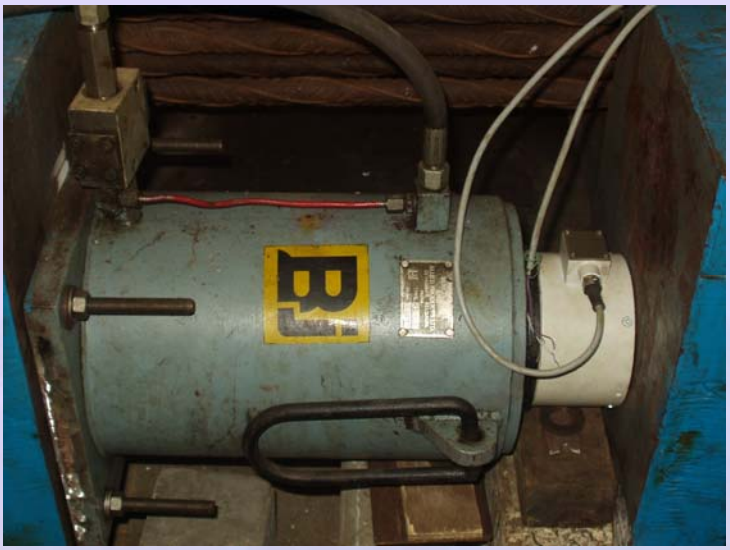


Figure 1-3.8 A double acting hydraulic jack with a load cell

Anchoring Devices

Anchoring devices are often made on the wedge and friction principle. In pre-tensioned members, the tendons are to be held in tension during the casting and hardening of concrete. Here simple and cheap quick-release grips are generally adopted. The following figure provides some examples of anchoring devices.

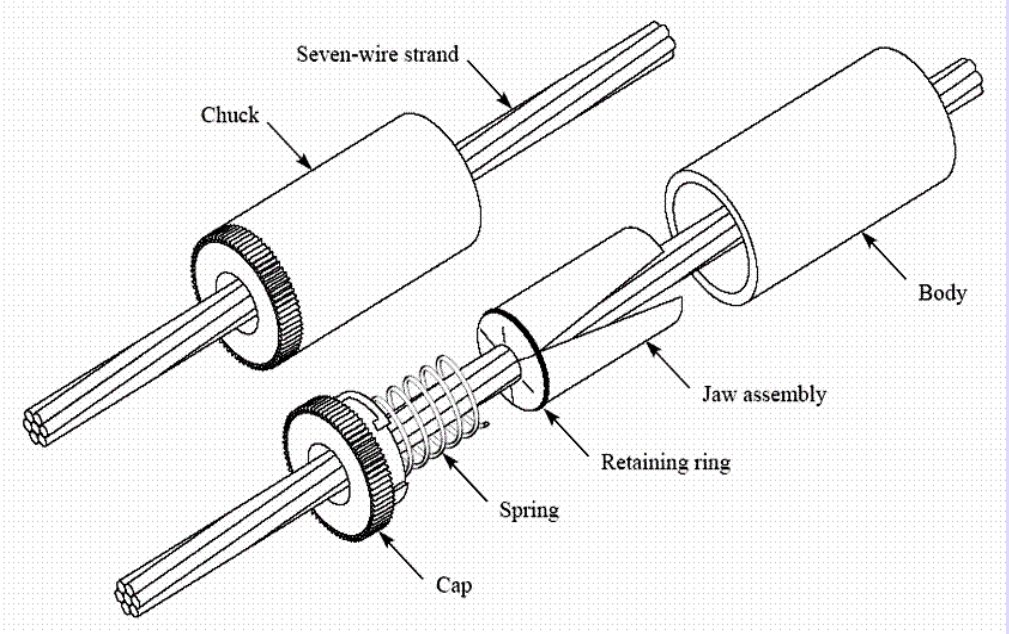


Figure 1-3.9 Chuck assembly for anchoring tendons

(Reference: Lin, T. Y. and Burns, N. H., *Design of Prestressed Concrete Structures*)

Harping Devices

The tendons are frequently bent, except in cases of slabs-on-grade, poles, piles etc. The tendons are bent (harped) in between the supports with a shallow sag as shown below.

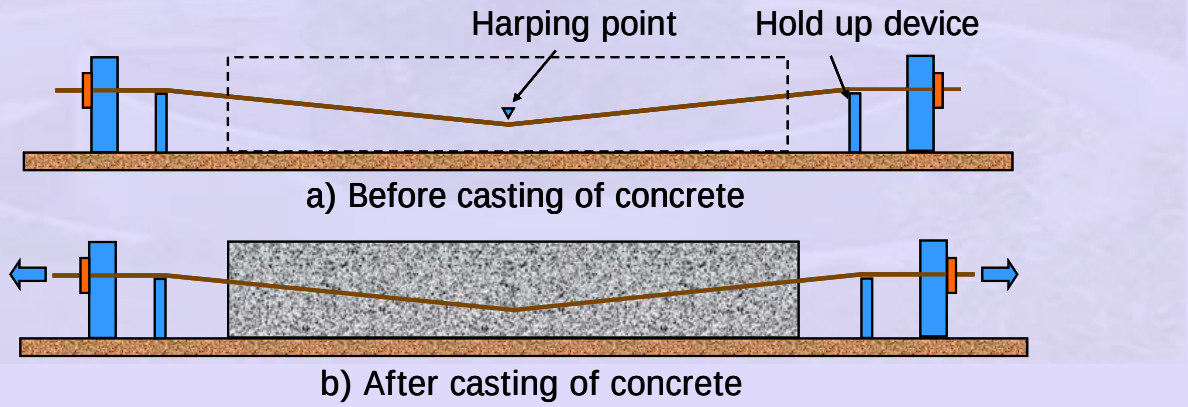


Figure 1-3.10 Harping of tendons

The tendons are harped using special hold-down devices as shown in the following figure.

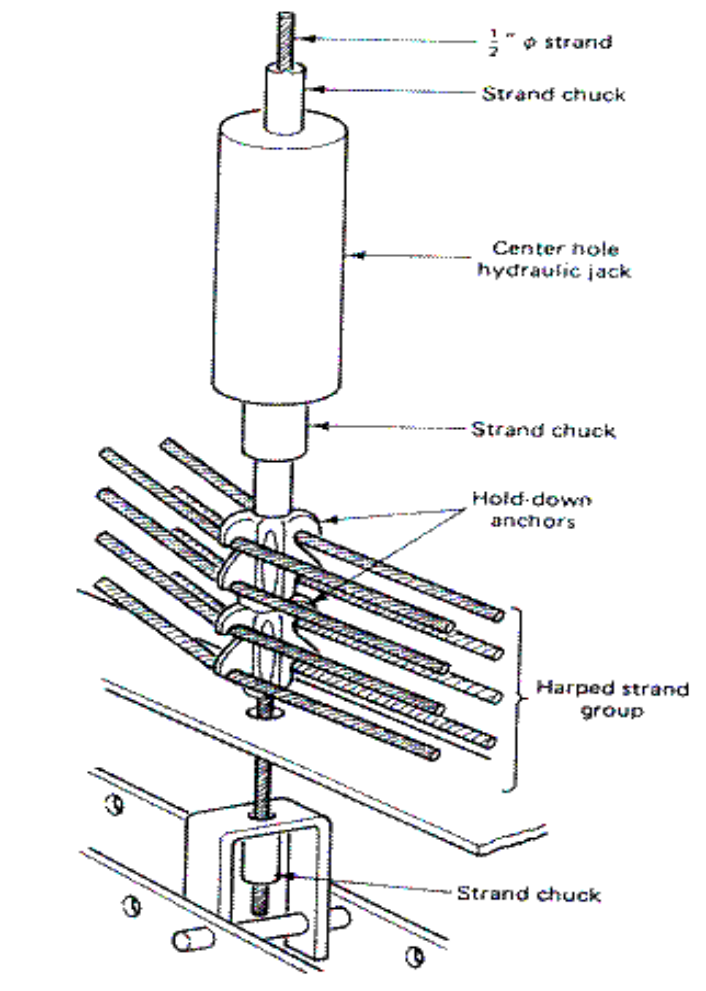


Figure 1-3.11 Hold-down anchor for harping of tendons

(Reference: Nawy, E. G., *Prestressed Concrete: A Fundamental Approach*)

1.3.6 Manufacturing of Pre-tensioned Railway Sleepers

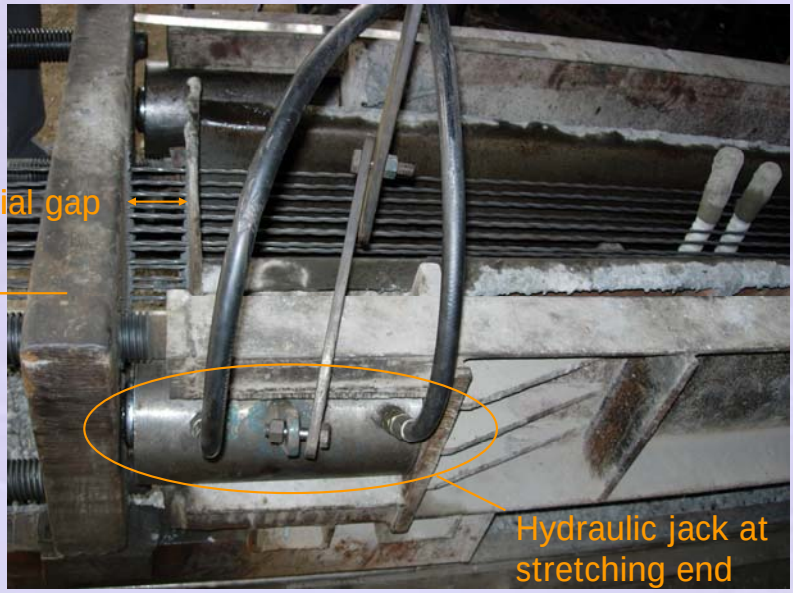
The following photos show the sequence of manufacturing of pre-tensioned railway sleepers (Courtesy: The Concrete Products and Construction Company, COPCO, Chennai). The steel strands are stretched in a stress bench that can be moved on rollers. The stress bench can hold four moulds in a line. The anchoring device holds the strands at one end of the stress bench. In the other end, two hydraulic jacks push a plate where the strands are anchored. The movement of the rams of the jacks and the oil pressure are monitored by a scale and gauges, respectively. Note that after the extension of the rams, the gap between the end plate and the adjacent mould has increased. This shows the stretching of the strands.

Meanwhile the coarse and fine aggregates are batched, mixed with cement, water and additives in a concrete mixer. The stress bench is moved beneath the concrete mixer. The concrete is poured through a hopper and the moulds are vibrated. After the finishing of the surface, the stress bench is placed in a steam curing chamber for a few hours till the concrete attains a minimum strength.

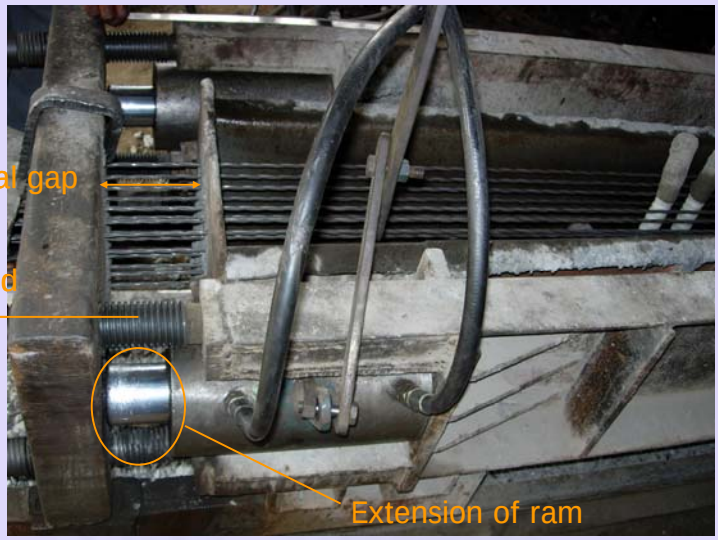
The stress bench is taken out from the chamber and the strands are cut. The sleepers are removed from the moulds and stacked for curing in water. After the complete curing, the sleepers are ready for dispatching.

(a) Travelling pre-tensioning stress bench

(b) Anchoring of strands



(c) Stretching of strands



(d) Stretching of strands

(e) Material storage

Automated batching by weight

(f) Batching of materials

(g) Pouring of concrete

(h) Concrete after vibration of mould

(i) Steam curing chamber

(j) Cutting of strands

(k) Demoulding of sleeper

(l) Stacking of sleeper

(m) Water curing

(n) Storage and dispatching of sleepers

Figure 1-3.12 Manufacturing of pre-tensioned railway sleepers