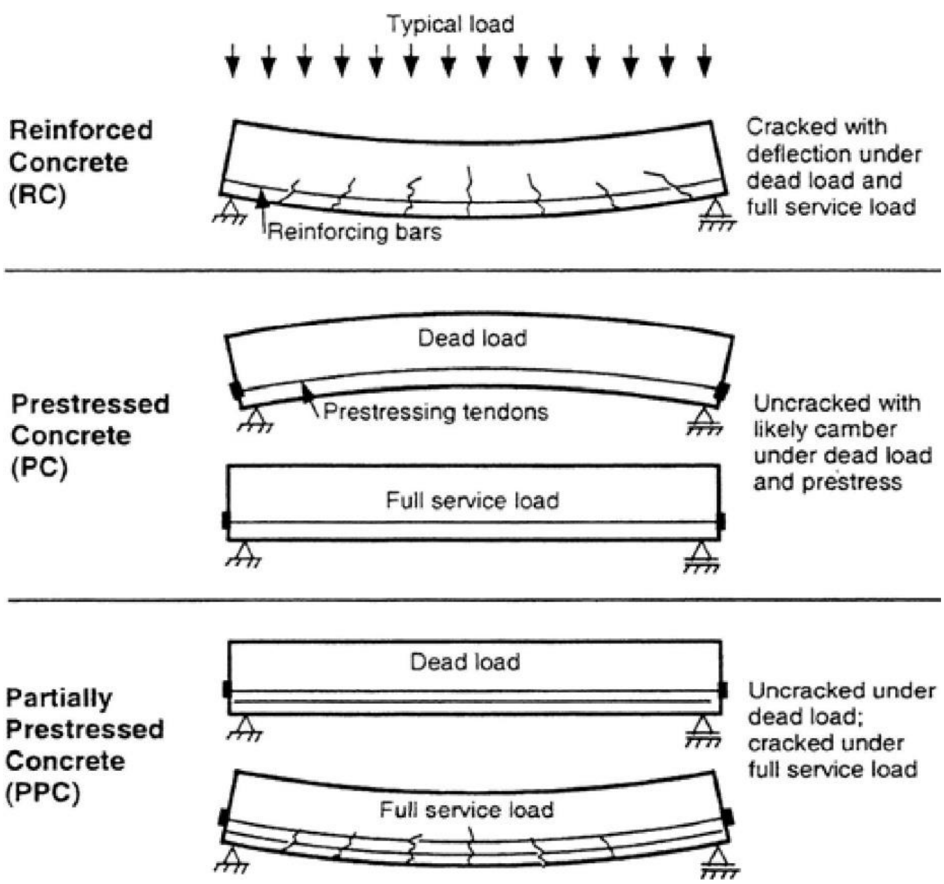
What is Prestressing?

It is imposition of internal stresses into a structure in opposite action of stresses caused by service or working loads. So, in concrete structures, prestressing provides a pre-compressive axial force to eliminate or greatly reduce internal tensile stresses along service time of the structure. In concrete bridges, the prestressing leads to considerable advantages such as smaller sections, longer spans, minimum deflections and more durability due less or free from cracks. However, the disadvantages of prestressing are cost of some special equipment, expert supervision to ensure closer quality control in manufacture and losses in initial prestressing forces.

Full and Partial Prestressing

Generally, prestressing tendon is used to obtain full prestressed concrete (PC) structures. Sometimes, prestressing tendon may be used in combination with conventional reinforcing steel to obtain partial prestressed concrete (PPC), which in between full prestressed concrete (PC) and reinforced concrete (RC). Partial prestressed concrete (PPC) allows some tension and cracking under full service load while ensuring sufficient ultimate strength. Therefore, it is used to control camber and deflection, increase ductility and save costs.



Differences between Prestressed and Partially Prestressed Concrete in Comparison with Conventional Reinforced Concrete

Methods of Prestressing

There are two methods of prestressing:

- ***Pretensioning***: Apply prestress to steel tendons ***before*** casting concrete.
- ***Posttensioning***: Apply prestress to steel tendons ***after*** casting concrete.

Pretensioning

It is the most common for precast sections and mass production and can be done through:

(a) Tendons are stressed.
(b) Concrete is cast around the stressed tendons.
(c) Prestress is transferred from the external anchorages to the concrete.

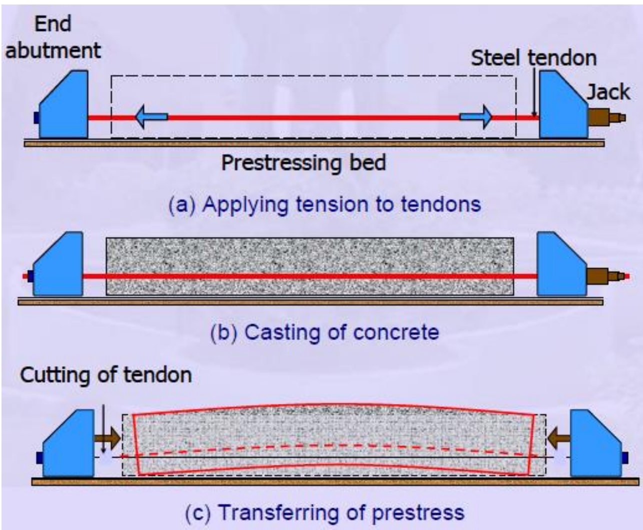
In pre-tensioned members, the tendon is directly bonded to the concrete cast around it. Therefore, the tendon force is transferred to the concrete through the bond along a transmission length extended from the ends of the member. Sometimes, it is necessary to deboned the tendon from the concrete or harp the tendon up to keep the stresses at ends within allowable limits.

Posttensioning

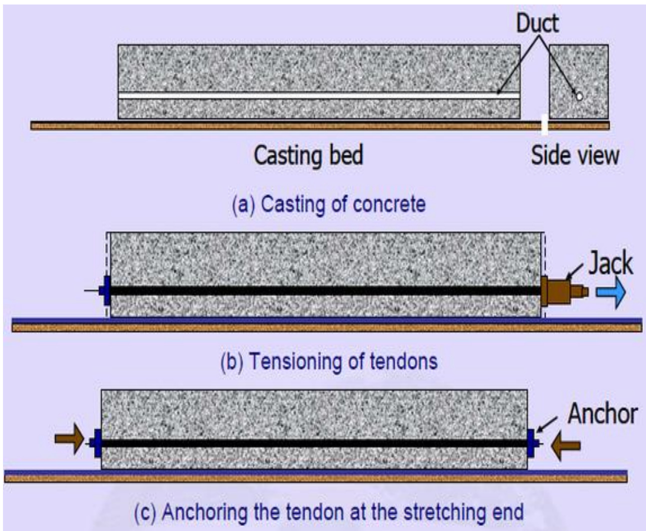
In this method, the concrete is already set but usually has ducts through which the tendons are passed, prestressing can be implemented through:

(a) Concrete is cast.
(b) Tendons are passed into ducts and then stressed.
(c) Prestress is transferred from the external anchorages to the concrete.

The prestress force is transformed from tendons to concrete through bearing stress on anchorage areas at ends of member. In some cases, grouting materials are poured into ducts after posttensioning accomplishment in order to provide indirect bond between tendon and its surrounding concrete. Lately, the prestress force can be transformed through both bearing and bonding. Nowadays, new types of ducts can be slipped out of concrete to enable grouting to provide direct bond between tendons and concrete.



Stages of Pretensioning



Stages of Posttensioning

Losses of Prestress

From the time the prestress is applied (before losses), the prestress force gradually reduces over time to an equilibrium level (after losses). The sources of these losses depend on the method of prestressing are:

- Elastic shortening of concrete
- Shrinkage and creep of concrete
- Relaxation or creep of prestressing steel
- Slippage at end anchorage system in posttensioning
- Friction along ducts in posttensioning.

AASHTO specifications state that losses due to elastic shortening, friction and anchorage set are instantaneous (short-term losses), whereas losses due to shrinkage, creep and relaxation are time-dependent (long-term losses). The total losses of prestress can be determined as:

- $\Delta f_{pT} = \Delta f_{pES} + \Delta f_{pLT}$ [Pretensioned members]
  $= \Delta f_{pF} + \Delta f_{pA} + \Delta f_{pES} + \Delta f_{pLT}$ [Posttensioned members]

where:

Δf_{pT}: total loss
Δf_{pF}: loss due to friction
Δf_{pA}: loss due anchorage set
Δf_{pES}: loss due to elastic shortening
Δf_{pLT}: loss due to long-term shrinkage, creep and relaxation of steel.

The total losses of prestress can be estimated as a percentage of the initial prestress. Lump-sum values of losses were used in the early development of prestressed concrete, but it is obsolete todays. Where accuracy is required, it is so necessary to estimate each component of losses separately and then find out its summation.

It becomes evident that because of losses, the final effective prestress force (P_e) is less than the initial applying prestress force (P_i). After losses depletion, the residual prestress force can be estimated as:

- $P_e = P_i - \Delta f_{pT}.A_{ps}$ [accurate]
  $= R.P_i$ [approximate]
- $R = 1 - losses$

where:

A_{ps}: total area of prestress steel
R: reduction factor.

In structural design, the initial prestress force (P_i) is calculated depending on the tensile strength of the prestressing steel, whist the effective prestress force (P_e) is determined according to the actual service loads.