1.2 Advantages and Types of Prestressing

This section covers the following topics.

- Definitions
- Advantages of Prestressing
- Limitations of Prestressing
- Types of Prestressing

1.2.1 Definitions

The terms commonly used in prestressed concrete are explained. The terms are placed in groups as per usage.

Forms of Prestressing Steel

Wires

Prestressing wire is a single unit made of steel.

Strands

Two, three or seven wires are wound to form a prestressing strand.

Tendon

A group of strands or wires are wound to form a prestressing tendon.

Cable

A group of tendons form a prestressing cable.

Bars

A tendon can be made up of a single steel bar. The diameter of a bar is much larger than that of a wire.

The different types of prestressing steel are further explained in Section 1.7, Prestressing Steel.

Nature of Concrete-Steel Interface

Bonded tendon

When there is adequate bond between the prestressing tendon and concrete, it is called a bonded tendon. Pre-tensioned and grouted post-tensioned tendons are bonded tendons.

Unbonded tendon

When there is no bond between the prestressing tendon and concrete, it is called unbonded tendon. When grout is not applied after post-tensioning, the tendon is an unbonded tendon.

Stages of Loading

The analysis of prestressed members can be different for the different stages of loading. The stages of loading are as follows.

1) Initial : It can be subdivided into two stages.
   a) During tensioning of steel
   b) At transfer of prestress to concrete.

2) Intermediate : This includes the loads during transportation of the prestressed members.

3) Final : It can be subdivided into two stages.
   a) At service, during operation.
   b) At ultimate, during extreme events.

1.2.2 Advantages of Prestressing

The prestressing of concrete has several advantages as compared to traditional reinforced concrete (RC) without prestressing. A fully prestressed concrete member is usually subjected to compression during service life. This rectifies several deficiencies of concrete.

The following text broadly mentions the advantages of a prestressed concrete member with an equivalent RC member. For each effect, the benefits are listed.

1) Section remains uncracked under service loads

- Reduction of steel corrosion
  - Increase in durability.
- Full section is utilised
  - Higher moment of inertia (higher stiffness)
  - Less deformations (improved serviceability).

- Increase in shear capacity.
- Suitable for use in pressure vessels, liquid retaining structures.
- Improved performance (resilience) under dynamic and fatigue loading.

2) High span-to-depth ratios

Larger spans possible with prestressing (bridges, buildings with large column-free spaces)

Typical values of span-to-depth ratios in slabs are given below.

Non-prestressed slab	28:1
Prestressed slab	45:1

For the same span, less depth compared to RC member.

- Reduction in self weight
- More aesthetic appeal due to slender sections
- More economical sections.

3) Suitable for precast construction

The advantages of precast construction are as follows.

- Rapid construction
- Better quality control
- Reduced maintenance
- Suitable for repetitive construction
- Multiple use of formwork
  - ⇒ Reduction of formwork
- Availability of standard shapes.

The following figure shows the common types of precast sections.

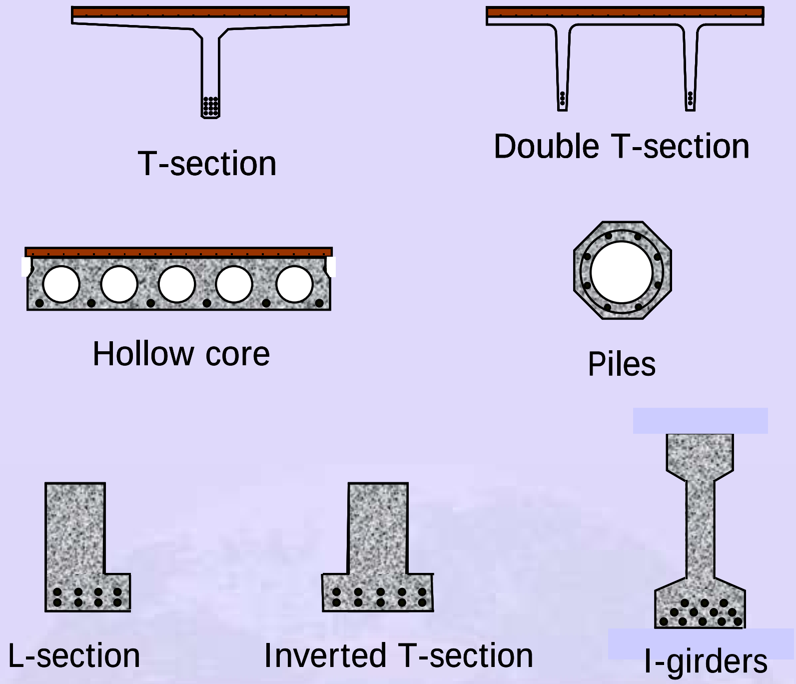

Figure 1-2.1 Typical precast members

1.2.3 Limitations of Prestressing

Although prestressing has advantages, some aspects need to be carefully addressed.

- Prestressing needs skilled technology. Hence, it is not as common as reinforced concrete.
- The use of high strength materials is costly.
- There is additional cost in auxiliary equipments.
- There is need for quality control and inspection.

1.2.4 Types of Prestressing

Prestressing of concrete can be classified in several ways. The following classifications are discussed.

Source of prestressing force

This classification is based on the method by which the prestressing force is generated. There are four sources of prestressing force: Mechanical, hydraulic, electrical and chemical.

External or internal prestressing

This classification is based on the location of the prestressing tendon with respect to the concrete section.

Pre-tensioning or post-tensioning

This is the most important classification and is based on the sequence of casting the concrete and applying tension to the tendons.

Linear or circular prestressing

This classification is based on the shape of the member prestressed.

Full, limited or partial prestressing

Based on the amount of prestressing force, three types of prestressing are defined.

Uniaxial, biaxial or multi-axial prestressing

As the names suggest, the classification is based on the directions of prestressing a member.

The individual types of prestressing are explained next.

Source of Prestressing Force

Hydraulic Prestressing

This is the simplest type of prestressing, producing large prestressing forces. The hydraulic jack used for the tensioning of tendons, comprises of calibrated pressure gauges which directly indicate the magnitude of force developed during the tensioning.

Mechanical Prestressing

In this type of prestressing, the devices includes weights with or without lever transmission, geared transmission in conjunction with pulley blocks, screw jacks with or without gear drives and wire-winding machines. This type of prestressing is adopted for mass scale production.

Electrical Prestressing

In this type of prestressing, the steel wires are electrically heated and anchored before placing concrete in the moulds. This type of prestressing is also known as thermo-electric prestressing.

External or Internal Prestressing

External Prestressing

When the prestressing is achieved by elements located outside the concrete, it is called external prestressing. The tendons can lie outside the member (for example in I-girders or walls) or inside the hollow space of a box girder. This technique is adopted in bridges and strengthening of buildings. In the following figure, the box girder of a bridge is prestressed with tendons that lie outside the concrete.

Figure 1-2.2 External prestressing of a box girder

(Reference: VSL International Ltd.)

Internal Prestressing

When the prestressing is achieved by elements located inside the concrete member (commonly, by embedded tendons), it is called internal prestressing. Most of the applications of prestressing are internal prestressing. In the following figure, concrete will be cast around the ducts for placing the tendons.

Figure 1-2.3 Internal prestressing of a box girder

(Courtesy: Cochin Port Trust, Kerala)

Pre-tensioning or Post-tensioning

Pre-tensioning

The tension is applied to the tendons before casting of the concrete. The pre-compression is transmitted from steel to concrete through bond over the transmission length near the ends. The following figure shows manufactured pre-tensioned electric poles.

Figure 1-2.4 Pre-tensioned electric poles

(Courtesy: The Concrete Products and Construction Company, COPCO, Chennai)

Post-tensioning

The tension is applied to the tendons (located in a duct) after hardening of the concrete. The pre-compression is transmitted from steel to concrete by the anchorage device (at the end blocks). The following figure shows a post-tensioned box girder of a bridge.

Figure 1-2.5 Post-tensioning of a box girder
(Courtesy: Cochin Port Trust, Kerala)

The details of pre-tensioning and post-tensioning are covered under Section 1.3, "Pre-tensioning Systems and Devices", and Section 1.4, "Post-tensioning Systems and Devices", respectively.

Linear or Circular Prestressing

Linear Prestressing

When the prestressed members are straight or flat, in the direction of prestressing, the prestressing is called linear prestressing. For example, prestressing of beams, piles, poles and slabs. The profile of the prestressing tendon may be curved. The following figure shows linearly prestressed railway sleepers.

Figure 1-2.6 Linearly prestressed railway sleepers

(Courtesy: The Concrete Products and Construction Company, COPCO, Chennai)

Circular Prestressing

When the prestressed members are curved, in the direction of prestressing, the prestressing is called circular prestressing. For example, circumferential prestressing of tanks, silos, pipes and similar structures. The following figure shows the containment structure for a nuclear reactor which is circularly prestressed.

Figure 1-2.7 Circularly prestressed containment structure, Kaiga Atomic Power Station, Karnataka

(Reference: Larsen & Toubro Ltd, ECC Division, *60 Landmark Years*)

Full, Limited or Partial Prestressing

Full Prestressing

When the level of prestressing is such that no tensile stress is allowed in concrete under service loads, it is called Full Prestressing (Type 1, as per **IS:1343 - 1980**).

Limited Prestressing

When the level of prestressing is such that the tensile stress under service loads is within the cracking stress of concrete, it is called Limited Prestressing (Type 2).

Partial Prestressing

When the level of prestressing is such that under tensile stresses due to service loads, the crack width is within the allowable limit, it is called Partial Prestressing (Type 3).

Uniaxial, Biaxial or Multiaxial Prestressing

Uniaxial Prestressing

When the prestressing tendons are parallel to one axis, it is called Uniaxial Prestressing. For example, longitudinal prestressing of beams.

Biaxial Prestressing

When there are prestressing tendons parallel to two axes, it is called Biaxial Prestressing. The following figure shows the biaxial prestressing of slabs.

Figure 1-2.8 Biaxial prestressing of a slab

(Courtesy: VSL India Pvt. Ltd., Chennai)

Multiaxial Prestressing

When the prestressing tendons are parallel to more than two axes, it is called Multiaxial Prestressing. For example, prestressing of domes.