Lecture - 07

Introduction to Prestressed Concrete

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Topics

- Introduction
- Principle of Prestressing
- Advantages of Prestressed Concrete
- Prestressing Steel
- High Strength Concrete used for Prestressed Construction
- Methods of Prestressing

Objectives

At the end of this lecture, students will be able to

- Explain Principle of Pre-stressing
- Classify methods of Pre-stressing

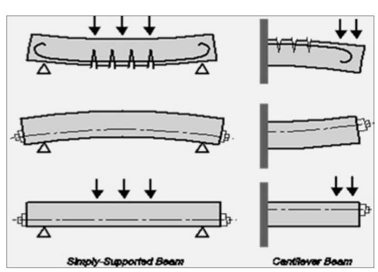
Introduction

- **Background**
  - Concrete is basically a compressive material, with its strength in tension being relatively low.
  - Prestressing applies a precompression force to the member that reduces or eliminates undesirable tensile stresses that would otherwise be present.

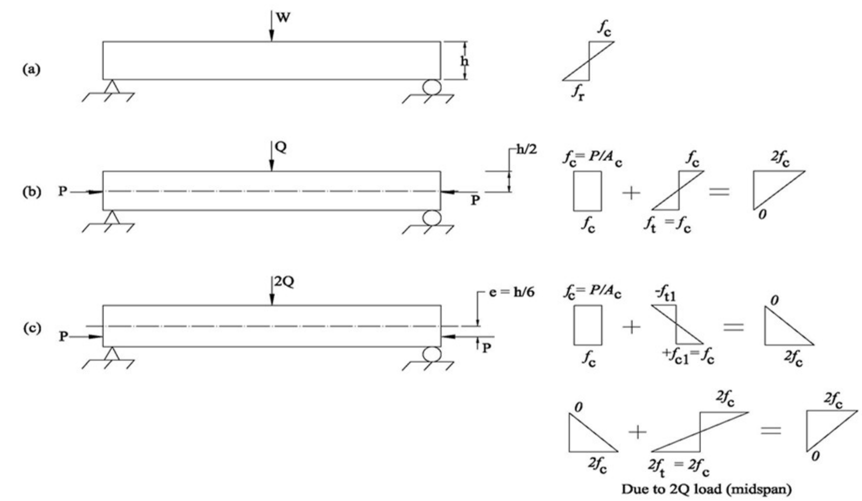
Reinforced concrete cracked under load.

Post-tensioned concrete before loading.

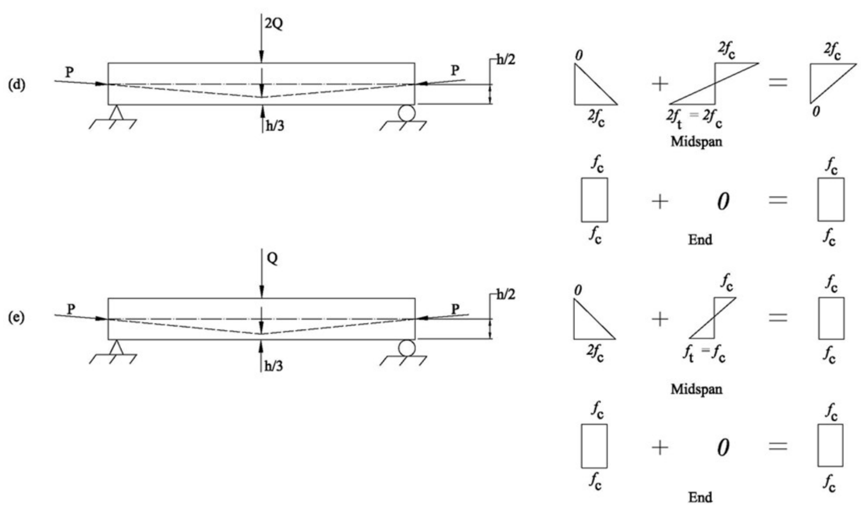
Post-tensioned concrete after loading.



Principle of Prestressing



Principle of Prestressing



Principle of Prestressing

- Some important conclusions can be drawn from previous simple examples:
  - Prestressing can control or even eliminate concrete tensile stress for specified loads.
  - Eccentric prestress is usually much more efficient than concentric prestress.
  - Variable eccentricity is usually preferable to constant eccentricity, from the viewpoints of both stress control and deflection control.

Advantages of Prestressing

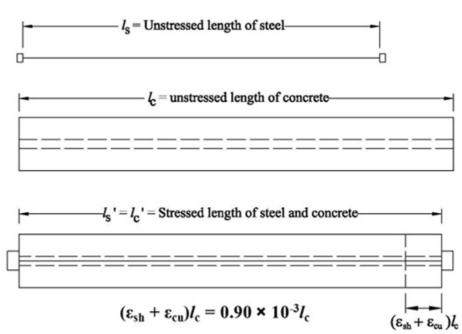
- Prestressing results in the overall improvement in performance of structural concrete used for ordinary loads and spans.
- Prestressing extends the range of application far beyond the limits for ordinary reinforced concrete, leading not only to much longer spans with economical member cross sections than previously thought possible, but permitting innovative new structural forms to be employed.

Advantages of Prestressing

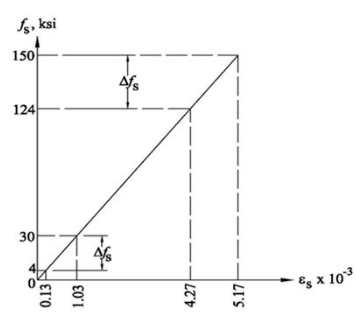
- Objectionable deflection and cracking, which would otherwise be associated with the use of non prestressed reinforced concrete members at high stress, are easily controlled by prestressing.

Prestressing Steel

- **Importance of High Strength Steel**



Effect of shrinkage and creep of concrete in reducing prestress force for axially prestressed beam



Stress variation with strain

Prestressing Steel

- **Importance of High Strength Steel**
  - The initial strain in the steel is:

    $\varepsilon_{si} = f_{si}/E_s = 30/29000 = 1.03 \times 10^{-3}$

  - And the steel elongation is:

    $\Delta_s = \varepsilon_{si} l_s = 1.03 \times 10^{-3} l_s$

  - The sum of shrinkage and creep strain in the concrete is about 0.90×10^{-3}, and the corresponding length change is:

    $(\varepsilon_{sh} + \varepsilon_{cu}) l_c = 0.90 \times 10^{-3} l_c$

Prestressing Steel

- **Importance of High Strength Steel**
  - Since l_s and l_c are nearly the same for f_{st} = 30 ksi, which means that the combined effects of shrinkage and creep of the concrete is almost a complete loss of the stress in steel.
  - The effective steel stress remaining after time-dependent effects would be $f_{se} = (1.03 – 0.90) \times 10^{-3} \times 29 \times 10^3 \approx 4$ ksi

Prestressing Steel

- **Importance of High Strength Steel**
  - For high strength steel at an initial stress of 150 ksi, the initial strain would be:

    ε_{si} = 150/29000 = 5.17 × 10^{-3}
  - $\varepsilon_{si} l_s$ = 5.17 × $10^{-3} l_s$
  - The effective steel stress f_{se} after losses due to shrinkage and creep would be f_{se} = (5.17 – 0.90) × 10^{-3} × 29 × 10^3 = 124 ksi
  - The loss is about 17 percent of the initial steel stress in this case compared with 87 percent loss when mild steel was used.

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Prestressing Steel

- **Types of High Strength Steel**
  - **Round wires**
    - Wires are normally bundled in groups of up to about 50 individual wires to produce prestressing tendons of the required strength.
  - **Stranded cable**
    - Stranded cable, more common than wire in U.S. practice, is fabricated with six wires wound around a seventh of slightly larger diameter.
  - **Alloy steel bars**
    - Available in the form of deformed bar similar to reinforcing bar

Prestressing Steel

- **Types of High Strength Steel**
  - **Sizes**

Steel	Diameter range, inch (mm)
Prestressing Wire	0.192 to 0.276 (5 to 7 mm)
Strand	0.250 to 0.600 (6 to 15 mm)
Alloy Steel Bars	0.750 to 1.375 (19 to 35 mm) (as plain round bars)
	0.625 to 1.250 (16 to 32 mm) (as deformed bars)

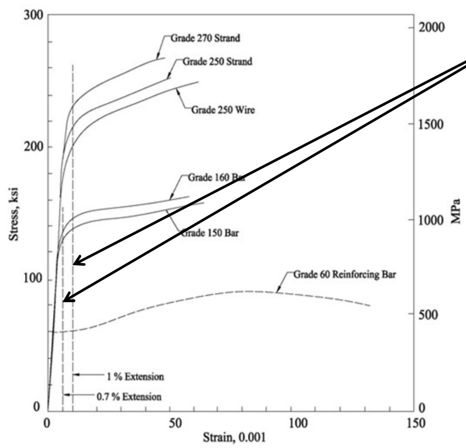
Prestressing Steel

- **Types of High Strength Steel**
  - **Tensile Yield Strength**

Steel	Grades (ksi)
Round wires	235, 240, 250
Strands (7-wired)	250, 270 300 (not recognized by ASTM A421)
Alloy steel bars	145 (regular grade, most common) 160 (special grade, may be ordered)

Prestressing Steel

- **Stress-Strain Curves**



The yield strength is somewhat arbitrarily defined as the stress at a total elongation of 1 percent for strand and wire and at 0.7 percent for alloy steel bars.

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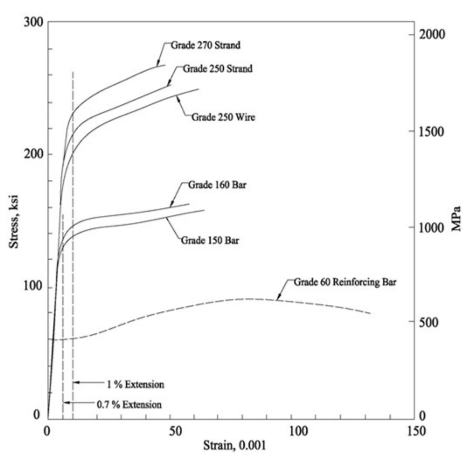
Prestressing Steel

- **Stress-Strain Curves**



The prestressing steels have significantly less ductility.

Prestressing Steel

- **Elastic Modulus for various High Strength Steels**

Steel	E_s *(psi)*
Un-bonded strand	26,000,000 psi
Bonded strand	≈ 27,000,000 psi
Smooth round wires	≈ 29,000,000 psi (same as for reinforcing bar)
Alloy steel bars	27,000,000 psi

Prestressing Steel

- **Relaxation**
  - When prestressing steel is stressed to the levels that are customary during initial tensioning and at service loads, it exhibits a property known as *relaxation.*
  - Relaxation is defined as the loss of stress in stressed material held at constant length.
  - The same basic phenomenon is known as creep when defined in terms of change in strain of a material under constant stress.

Prestressing Steel

- **Relaxation**
  - To be specific, if a length of prestressing steel is stressed to a sizable fraction of its yield strength f_{py} (say 80 to 90 percent) and held at a constant strain between fixed points such as the ends of a beam, the steel stress f_p will gradually decrease from its initial value f_{pi}.

Prestressing Steel

- **Relaxation**
  - A satisfactory estimate for ordinary stress relieved strand and wires can be obtained from eq. (1), which was derived from more than 400 relaxation tests of up to 9 years duration:

$$\frac{f_p}{f_{pi}} = 1 - \frac{\log t}{10}\left(\frac{f_p}{f_{py}} - 0.55\right) \text{....................(1)}$$

  Where, f_p= final stress after t hours, f_{pi} = initial stress, and f_{py} = nominal yield stress.

  - For low-relaxation strand, eq. (1) is replaced by:

$$\frac{f_p}{f_{pi}} = 1 - \frac{\log t}{45}\left(\frac{f_p}{f_{py}} - 0.55\right) \text{....................(2)}$$

High Strength Concrete Used for Prestressed Construction

- **Definition**
  - Although the exact definition is arbitrary, the term generally refers to concrete having uniaxial compressive strength in the range of about 8000 to 15,000 psi or higher.
  - Such concretes can be made using carefully selected but widely available cements, sands, and stone; certain admixtures including high-range water-reducing super plasticizers, fly ash, and silica fume; plus very careful quality control during production.

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High Strength Concrete Used for Prestressed Construction

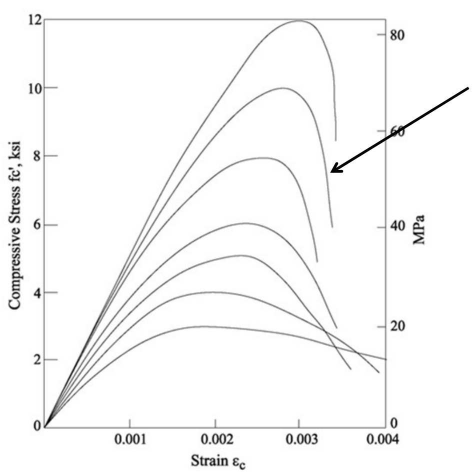
- **Advantages**
  - High strength concrete has a higher elastic modulus than the low strength concrete, so that loss of prestress force resulting from elastic shortening of the concrete is reduced.
  - Creep and shrinkage losses are also low.
  - High bearing stresses in the vicinity of tendon anchorages for post tensioned members are more easily accommodated.
  - In the case of pretensioned elements, higher bond strength results in a reduction in the development length required to transfer prestress force from the cables to the concrete.

High Strength Concrete Used for Prestressed Construction

- **Advantages**
  - Finally, concrete of higher compressive strength also has a higher tensile strength so that the formation of flexural and diagonal tension crack is delayed.

High Strength Concrete Used for Prestressed Construction

- **Stress-Strain Curves**



Typical set of compressive stress strain curve for normal density concrete, obtained from uniaxial compressive test performed at normal, moderate testing speeds on concretes that are 28 days old

High strength concrete are more brittle.

Methods of Prestressing

- Although many methods have been used to produce the desired state of precompression in concrete members, all pre-stressed concrete members can be placed in one of two categories:
  - Pre-tensioned,
  - Post-tensioned.

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Methods of Prestressing

- **Pre-tensioning (Procedure)**
  - The strands are tensioned over the full length of the casting bed at one time, after which a number of individual members are cast along the stressed tendon.
  - When the jacking force is released, the prestress force is transferred to each member by bond, and the strands are cut free between members.

Methods of Prestressing

- **Pre-tensioning (Procedure)**
  - In present practice anchorage and jacking abutments may be as much as 800 ft apart.
  - Cable depressors are often used with long-line prestressing, just as with individual members.

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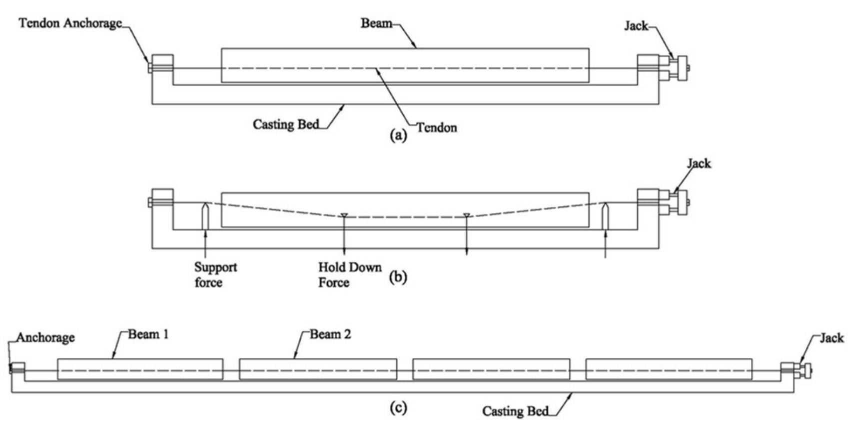
Methods of Prestressing

- **Pre-tensioning (Procedure)**



Methods of Prestressing

- **Pre-tensioning (Procedure)**

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Methods of Prestressing

- **Pre-tensioning (Advantages)**
  - Well suited to the mass production of beams using the long-line method of prestressing.
  - Pretensioning is a particularly economical method of prestressing, not only because the standardization of design permits reusable steel or fiberglass forms, but also because the simultaneous prestressing of many members at once results in great saving of labor. In addition, expensive end-anchorage hardware is eliminated.

Methods of Prestressing

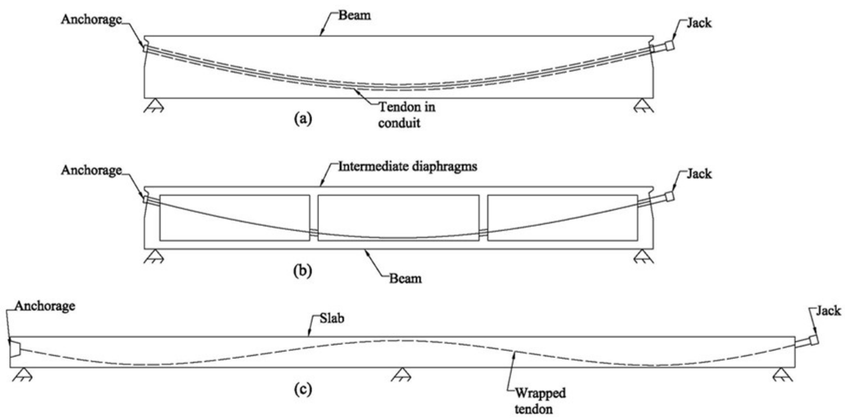
- **Post-tensioning (Procedure)**
  - Usually hollow conduits containing the unstressed tendons are placed in the beam forms, to the desired profile, before pouring the concrete.
  - The conduit is wired to auxiliary beam reinforcement (unstressed stirrups) to prevent accidental displacement, and the concrete is poured.
  - When it has gained sufficient strength, the concrete beam itself is used to provide the reaction for the stressing jack.

Methods of Prestressing

- **Post-tensioning (Procedure)**
  - With the tendon anchored by special fittings at the far end of the member, it is stretched, and then anchored at the jacking end by similar fittings, and the jack removed.
  - The tension is gauged by measuring both the jacking pressure and the elongation of the steel.
  - The tendons are normally tensioned one at a time, although each tendon may consist of many strands or wires.

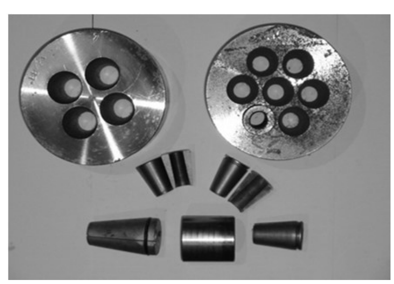
Methods of Prestressing

- **Post-tensioning (Procedure)**



Methods of Prestressing

- **Post-tensioning (Advantages)**
  - A significant advantage of all post-tensioning schemes is the ease with which the tendon eccentricity can be varied along the span to provide the desired counter moment.



Post tensioning under progress Conduit Anchor blocks and wedges

Prestressed Concrete Plant Video

Prestressed Concrete Video

Prestressed Concrete Video BRT Peshawar

Grouting of Prestressed Concrete Girder

References

- **Design of Concrete Structures 13 Ed. by Nilson, Darwin and Dolan.**

The End