# Lecture 08

# Introduction to Prestressed Concrete

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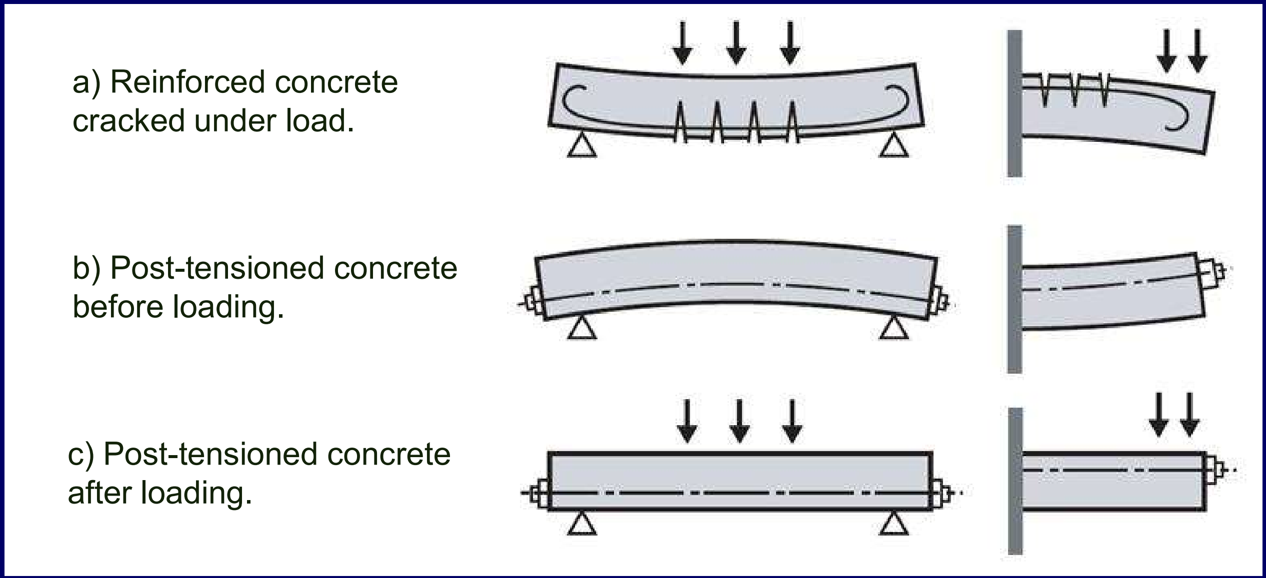
# Learning Outcomes

- **At the end of this lecture, students will be able to;**
  - ***Explain*** piciple of Pre-stressing
  - ***Classify*** methods of Pre-stressing
  - ***Describe*** the advantages of prestressed concrete

# 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.



# Introduction

## ❑ Principle of Prestressing

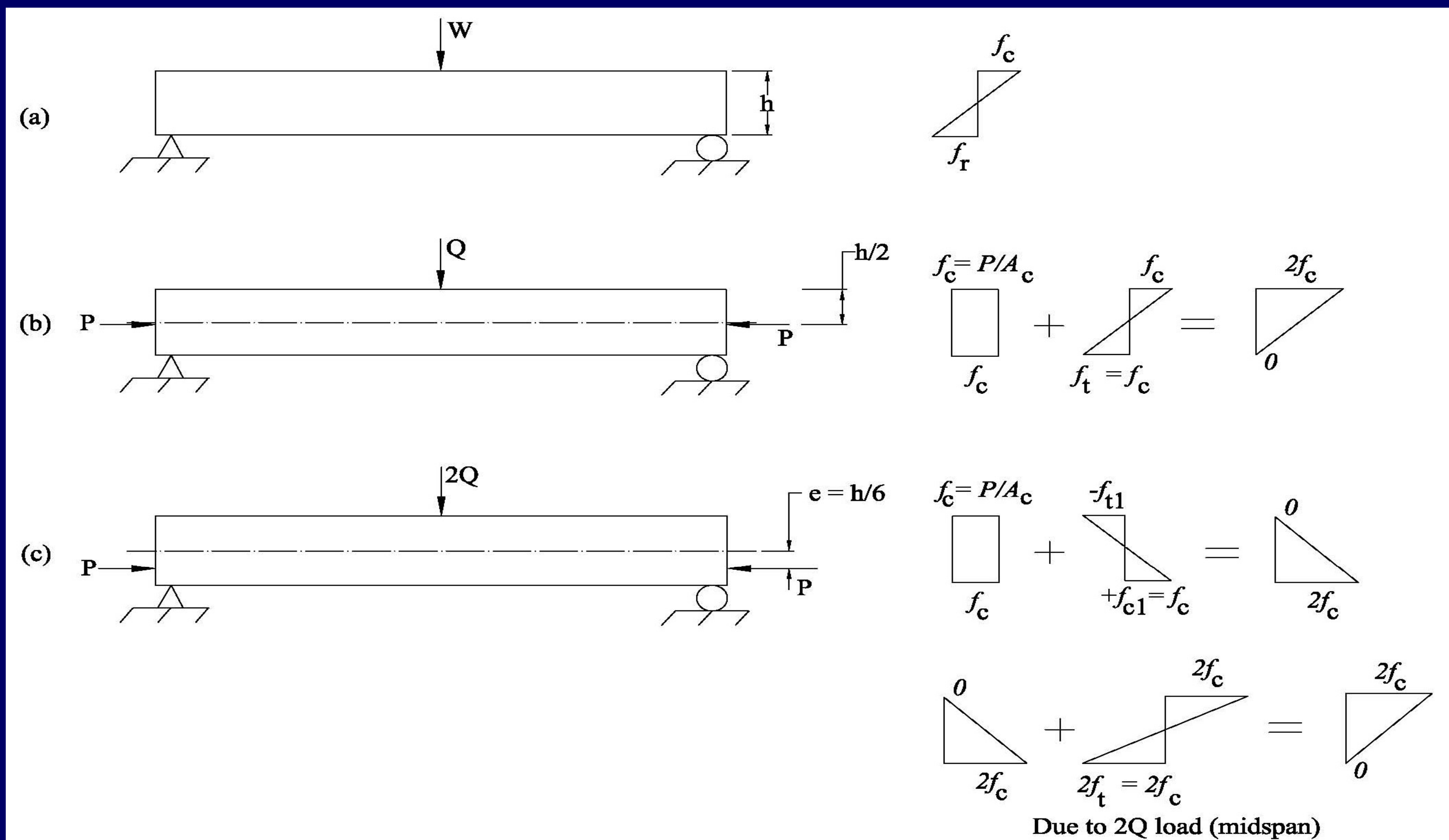
- The principle underlying prestressed concrete is that;

  *Compressive stresses induced in a concrete member by pre-compression before loading can partially or completely eliminate the tensile stresses induced after loading.*

- This statement has been elaborated in subsequent slides

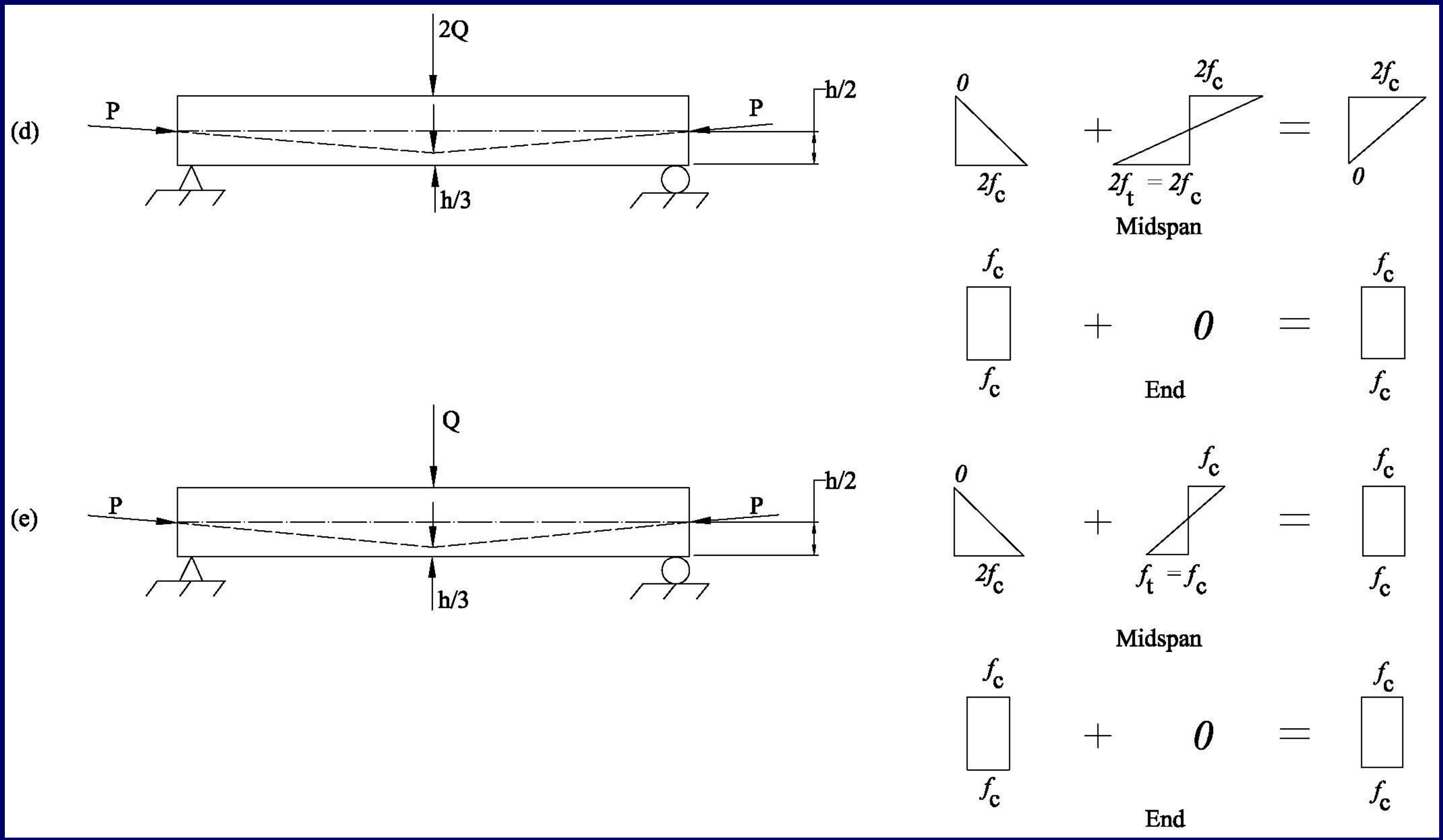
# Introduction

## ❑ Principle of Prestressing



# Introduction

## ❑ Principle of Prestressing



# Introduction

## 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.

# Introduction

## ❑ Advantages and Disadvantages of Prestressed Concrete

| Advantages | Disadvantages |
|---|---|
| • Economical for long-span structures. | • Less economical for short spans. |
| • Fast construction. | • Sufficient space required for precast works. |
| • Smooth and pleasant crack free surface. | • Highly skilled manpower and supervision required. |
| • Increased sustainability against sudden impact. | • Higher grades of concrete and steel needed. |
| • Higher durability than the conventional reinforced concrete. | • Limited use in higher seismic zones. |
| • Conveniently used in the construction of long span bridges and warehouses etc. | • Limited use in high rise buildings. |

# Introduction

## ❑ 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:

    1. Pre-tensioned,
    2. Post-tensioned.

- Please attentively watch the video clips on the next slide in order to better comprehend these techniques.

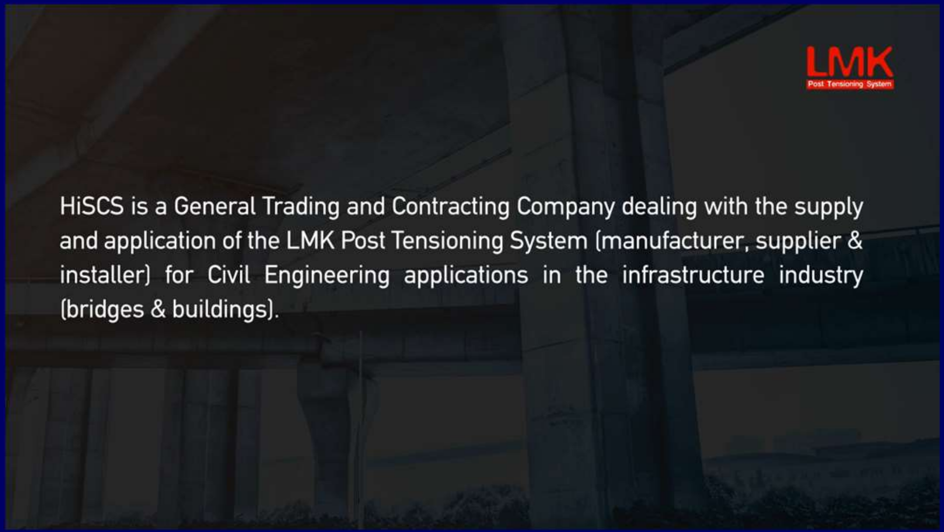
# Introduction

- **Methods of Prestressing**

Pre-tensioning

# Introduction

## ❑ Methods of Prestressing




Post-tensioning

Post-tensioned Concrete Girder at BRT Peshawar

# Introduction

## ❑ Methods of Prestressing

### 1. Pre-tensioning

#### ❑ Advantages

- Well suited to the mass production of beams using the long-line method of prestressing.
- Pre-tensioning 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.

# Introduction

## ❑ Methods of prestressing

### 2. 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

# Material Properties

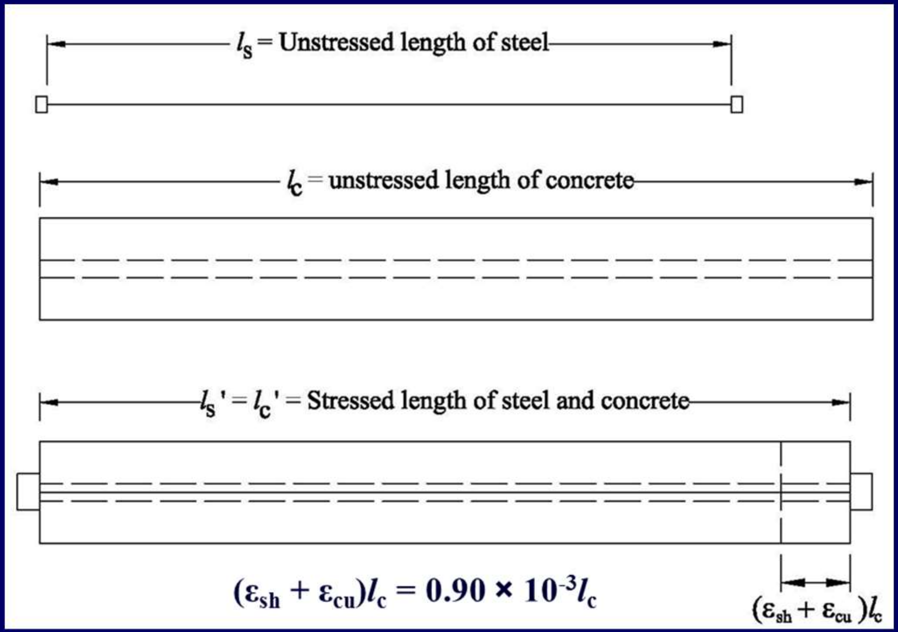
## 1. High strength Concrete

- 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.
- 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.

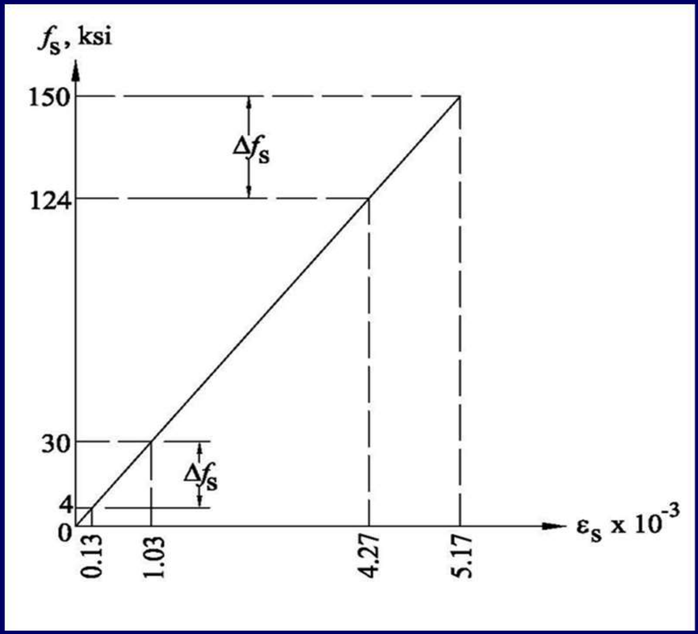
# Material Properties

## 2. Prestressing Steel

### ❖ Importance




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




Stress variation with strain

# Material Properties

## 2. Prestressing Steel

### ❖ Importance

- 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 $0.90 \times 10^{-3}$, and the corresponding length change is:

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

# Material Properties

## 2. Prestressing steel

### ❖ Importance

- 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

# Material Properties

## 2. Prestressing Steel

### ❖ Importance

- For high strength steel at an initial stress of 150 ksi, the initial strain would be:

  $\varepsilon_{si} = 150/29000 = 5.17 \times 10^{-3}$

  $\varepsilon_{si} l_s = 5.17 \times 10^{-3} l_s$

- The effective steel stress $f_{se}$ after losses due to shrinkage and creep would be $f_{se} = (5.17 - 0.90) \times 10^{-3} \times 29 \times 10^{3} = 124$ 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.

# Material Properties

## 2. Prestressing Steel

### ❖ Types of Prestressing Steel

#### i. Round wires

- Wires are normally bundled in groups of up to about 50 individual wires to produce prestressing tendons of the required strength.

#### ii. 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.

# Material Properties

## 2. Prestressing 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) |

# Material Properties

## 2. Prestressing steel

### ❖ Strength

| Yield Tensile strength | |
|---|---|
| **Steel** | **Grades (ksi)** |
| Round wires | 235, 240, 250 |
| Strands (7-wired) | 250, 270<br>300 (not recognized by ASTM A421) |

| Elastic Modulus | |
|---|---|
| **Steel** | **$E_s$ (psi)** |
| Un-bonded strand | 26,000,000 psi |
| Bonded strand | ≈ 27,000,000 psi |
| Smooth round wires | ≈ 29,000,000 psi<br>(same as for reinforcing bar) |

# Material Properties

## 2. 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.

# Material Properties

## 2. 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 $f_{pi}$

# Material Properties

## 2. 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:

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

Where;

$f_p$ = final stress after $t$ hours,

$f_{pi}$ = Initial stress, and

$f_{py}$ = Nominal yield stress.

# Material Properties

2. **Prestressing steel**

❖ **Relaxation**

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

$$\frac{f_p}{f_{pi}} = 1 - \frac{logt}{45}\left(\frac{f_p}{f_{py}} - 0.55\right) ---(2)$$

# Example 8.1

- **Example 7.1**
  - A high strength prestressing steel having nominal yield strength of 250ksi is subjected to an initial stress of 200ksi.

  ***Determine*** the time in hours at which the stress is 90% of the initial stress.

# Example 8.1

## Solution

- **Given Data**

$f_{py} = 250ksi$

$f_{pi} = 200ksi$

$f_p = 0.9f_{pi}$

- **Required Data**

$Time, t = ?$

# Example 8.1

## ❑ Solution

From the relaxation equation, we have

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

By substituting the relevant values, we get

$$\frac{0.9(200)}{200} = 1 - \frac{log t}{10}\left(\frac{0.9(200)}{250} - 0.55\right)$$

$$\Rightarrow \frac{log t}{10} = \frac{1 - 0.9}{0.17}$$

$$t = 762698.59\ hours \approx 87\ years$$

# The End

In terms of knowledge, stay hungry, in terms of talent, stay foolish; because if you think you are perfect, you shut the door of knowledge and never can create something new.

**Best of luck for your future!**

# References

- Design of Concrete Structures 14th / 15th edition by Nilson, Darwin and Dolan.
- Building Code Requirements for Structural Concrete (ACI 318-19)