Reinforced Concrete Design – I

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Lecture 01

Introduction to Reinforced Concrete Design

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Topics Addressed

- General
- Properties of Concrete
- Properties of Steel
- Codes and the ACI Code
- Mechanics of Reinforced Concrete

Objectives

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

- Define Reinforced Concrete
- Define Design Loads as per ACI Code
- Compare Working Stress design method with Strength design method

General

- **Objective of the Course**
  - Humans need construction of civil structures such as buildings, bridges and dams etc. to fulfill their various needs.
  - An Engineering design would ensure that these structures are built safe and economical.

General

- **Objective of the Course**
  - Materials such as stones, bricks, timber, steel and concrete are generally used to construct these structures.
  - In this course, however, we will study some basic concepts of the design of Buildings (bridges, dams etc. will not be discussed) made of reinforced concrete.

General

- **Reinforced Concrete**
  - The concrete in which steel is used as reinforcement for enhancing primarily the tensile strength of concrete members.

General

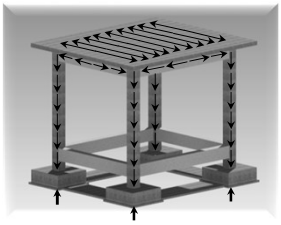
Multi Storey Building

General

- **Buildings**
  - Most common building types according to how the loads are transmitted to the ground
    - Frame System
    - Load bearing wall system
    - Mixed System

General

- **Buildings**
  - **Frame System**
    - A reinforced concrete frame building generally consist of slabs, beams and columns.
    - The loads from roof / floor slabs are transmitted to the foundation either directly through columns or through beams to the columns.



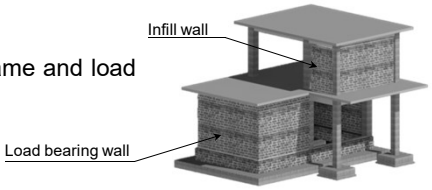
General

- **Buildings**
  - **Frame System**
    - The reinforced concrete design is carried out component by component such that slabs, beams and columns are separately designed.

General

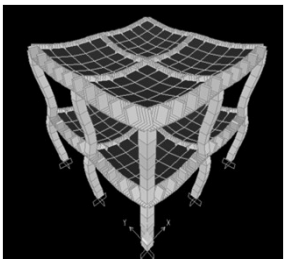
- **Buildings**
  - **Load Bearing Wall System**
    - In such buildings loads from roof slab are directly transmitted to foundation through walls.

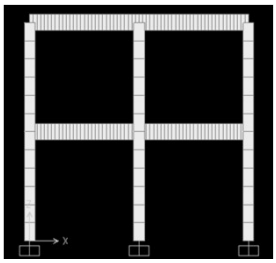
  - **Mixed System**
    - It is the combination of frame and load bearing wall systems.



General

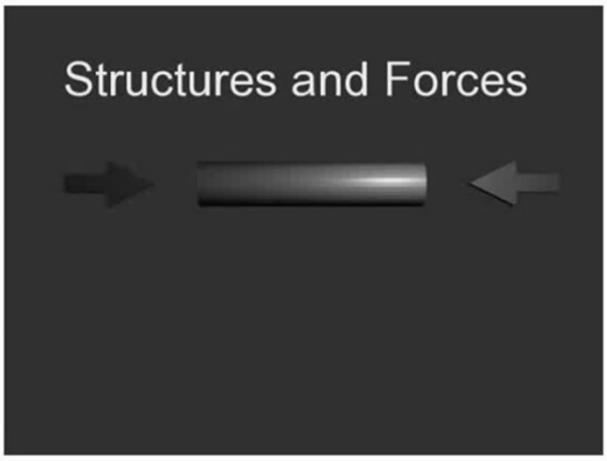
- **Loads Effects on the Building**
  - Loads on buildings induces one or more of the following effects (stresses).
    - Axial (Compressive and Tensile)
    - Flexure
    - Shear
    - Torsion





General

- **Loads Effects on the Building**



General

- **Structural Design**
  - The structure must be designed to withstand all these effects without undesirable consequences.
  - In order to learn the design of reinforced concrete buildings, following must be studied:
    - Properties of concrete and reinforcing steel,
    - Building codes used for design of reinforced concrete,
    - Mechanics of reinforced concrete.

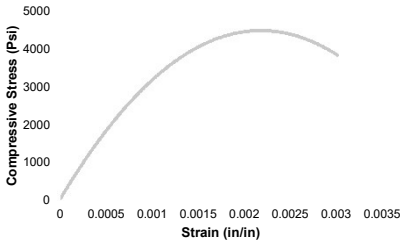
Properties of Concrete

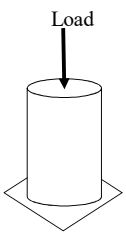
- **Compressive Strength**
  - The uniaxial compressive strength is measured by a compression test of a standard test cylinder. This test is used to monitor the concrete strength for quality control or acceptance purposes.
  - The specified compressive strength is measured by compression tests on 6 by 12 inches cylinders, tested after 28 days of moist curing (testing methods: ASTM Standards C31 and C39).

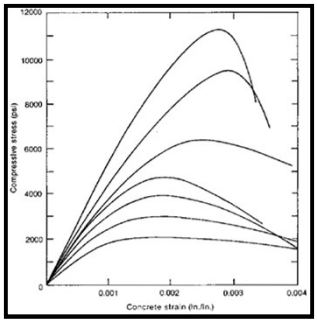
Properties of Concrete

- **Mechanical Properties**
  - Compressive Strength
    - Stress Strain Curve

Typical Stress Strain Curve for Concrete







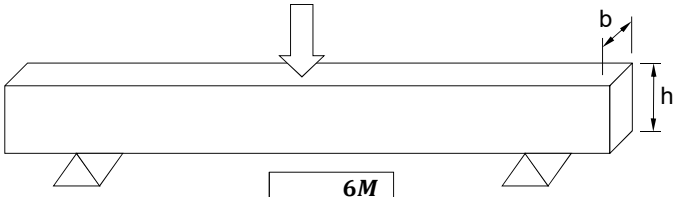
Typical concrete stress strain curves in compression

Properties of Concrete

- **Stress Strain Curve**

Properties of Concrete

- **Tensile Strength**
  - Varies between 8% to 15% of the compressive strength.
  - Modulus of Rupture (Flexural Test)
    - **ASTM C 293** – Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)
    - The beams are 6 in. x 6 in. x 30 in. long



$$f_r = \frac{6M}{bh^2}$$

Properties of Concrete

- **Relationship Between Compressive and Tensile Strengths**
  - Tensile strength increases with an increase in compressive strength.
  - Ratio of tensile strength to compressive strength decreases as the compression strength increases.

$$\boldsymbol{Tensile\ Strength} \propto \sqrt{\mathbf{f'_c}}$$

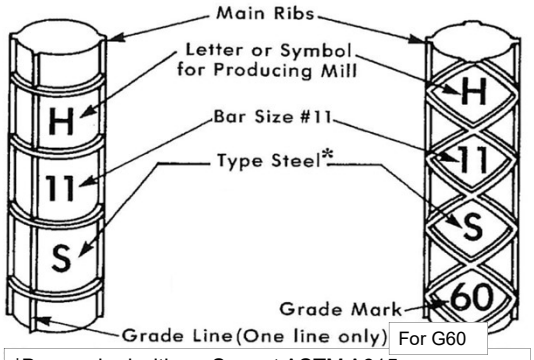
Types of Reinforcing Steel

- Deformed Bar Reinforcement
- Plain Reinforcement
- Prestressing Steel
- Structural Steel Shapes

Note: In the next slides only the properties of Deformed Bars will be discussed.

Properties of Reinforcing Steel

- **Shapes & Designations**



*Bar marked with an S meet ASTM A615

Properties of Reinforcing Steel

- **ASTM Specifications**
  - According to the ACI (American Concrete Institute) Code, the reinforcing bars used in reinforced concrete must conform to either of the following specifications.
    - **ASTM A 615: ASTM A 615** covers deformed carbon-steel reinforcing bars that are currently the most widely used type of steel bar in reinforced concrete construction. Bars of this type are marked with the letter "S" per the specification requirements.
    - **ASTM A 706: ASTM A 706** covers low-alloy steel deformed bars intended for applications where controlled tensile properties, restrictions on chemical composition to enhance weldability, or both, are required. Bars of this type are marked with the letter "W" per the specification requirements.

Properties of Reinforcing Steel

- **Physical Properties A615/A615M-16**

Bar Designation	Diameter (in.)	Area (in^2)	Weight (lb/ft)
#3	0.37	0.11	0.38
#4	0.50	0.20	0.67
#5	0.62	0.31	1.04
#6	0.75	0.44	1.50
#7	0.87	0.60	2.04
#8	1.00	0.79	2.67
#9	1.12	1.00	3.40
#10	1.25	1.27	4.30
#11	1.37	1.56	5.31
#14	1.75	2.25	7.65
#18	2.25	4.00	13.60

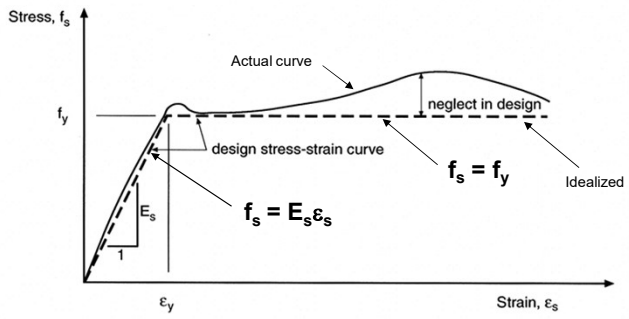
Properties of Reinforcing Steel

- **Strength**

Steel Grade	Minimum Yield Strength, f_y (ksi)	Ultimate Strength (ksi)
40	40	70
50	50	80
60	60	90
75	75	100

Properties of Reinforcing Steel

- **Typical Stress-Strain Curve**



Building Codes and the ACI Code

- **Introduction**
  - A code is a set of technical specifications and standards that controls the important details of design and construction. The purpose of code is to produce sound structures so that public will be protected from poor and inadequate design and construction.

Building Codes and the ACI Code

- **General Building Codes**
  - Cover all aspects of building design and construction from architecture to structural to mechanical and electrical. UBC, IBC and Euro-code are general building codes.
- **Seismic Codes**
  - Cover only seismic provisions of buildings such as SEAOC and NEHRP of USA, BCP-SP 07 of Pakistan.

Building Codes and the ACI Code

- **Material Specific Codes**
  - Cover design and construction of structures using a specific material or type of structure such as ACI, AISC, AASHTO etc.
- **Others such as ASCE**
  - Cover minimum design load requirement, Minimum Design Loads for Buildings and other Structures (ASCE 7-10).

Building Codes and the ACI Code

- **The ACI MCP**
  - ACI MCP (American Concrete Institute Manual of Concrete Practice) contains 150 ACI committee reports; revised every three years.
    - ACI 318: Building Code Requirements for Structural Concrete.
    - ACI 315: The ACI Detailing Manual.
    - ACI 349: Code Requirement for Nuclear Safety Related Concrete Structures.
    - Many others.

Building Codes and the ACI Code

- **The ACI 318 Code**
  - The American Concrete Institute "Building Code Requirements for Structural Concrete (ACI 318)", referred to as the ACI code, provides minimum requirements for structural concrete design or construction.
  - The term "structural concrete" is used to refer to all plain or reinforced concrete used for structural purposes.
    - Prestressed concrete is included under the definition of reinforced concrete.

Building Codes and the ACI Code

- **Design Loads in the ACI code**
  - **Load (ACI 318-19, 2.3)**
    - ACI 318-19 code define load as "*forces or other actions that result from the weight of all building materials, occupants, and their possessions, environmental effects, differential movement, and restrained dimensional changes; permanent loads are those loads in which variations over time are rare or of small magnitude; all other loads are variable loads".*

Building Codes and the ACI Code

- **Design Loads in the ACI code**
  - **Dead Load (ACI 318-19, 2.3)**
    - *(a) The weights of the members, supported structure, and permanent attachments or accessories that are likely to be present on a structure in service; or*
    - *(b) Loads meeting specific criteria found in the general building code; without load factors.*

Building Codes and the ACI Code

- **Design Loads in the ACI code**
  - **Live Load (ACI 318-19, 2.3)**
    - *(a) Load that is not permanently applied to a structure, but is likely to occur during the service life of the structure (excluding environmental loads); or*
    - *(b) Loads meeting specific criteria found in the general building code; without load factors.*
    - ACI specifies live load magnitudes for various occupancy or uses.
    - Minimum Uniformly Distributed Live Loads in the ACI code

Building Codes and the ACI Code

- **Design Loads in the ACI code**
  - **Other loads**
    - Include earthquake loads, wind loads, snow loads etc.

Building Codes and the ACI Code

- **Design Loads in the ACI code**
  - **Service loads (ACI 318-19, 2.3)**
    - *All loads, static or transitory, imposed on a structure or element thereof, during the operation of a facility, without load factors.*
  - **Factored loads (ACI 318-19, 2.3)**
    - *Load, multiplied by appropriate load factors.*

Building Codes and the ACI Code

- **Design Procedures:**
  - **Working Stress Design approach**
    - Capacity is reduced by half
    - Demand is kept the same
  - **ACI 318 Design approach: (ACI 318-19, 4.6)**
    - According to the ACI 318 Code, the RC Members shall be designed using the strength design method.
    - In the strength design method, the loads are amplified and the capacities are reduced.

Building Codes and the ACI Code

- **FOS in ACI Design procedure**
  - The factor of safety in strength design method is ensured by amplifying the applied loads on the structure and reducing the members capacities.
  - We know that, Capacity / Demand = FOS; FOS > 1.0
  - According to Strength Design Method;

    φ Capacity = γ Demand; where $\varphi < 1$, and $\gamma > 1$

    Capacity / Demand = γ / φ
  - FOS = γ / φ

Mechanics of Reinforced Concrete

- **Mechanics**
  - Mechanics is both quantitative and qualitative.
    - Qualitative mechanics deals with the nature of the effect of loads (stresses).
    - Quantitative mechanics deals with the formulation obtained using the established laws, for instance equilibrium.

Mechanics of Reinforced Concrete

- **Mechanics of Reinforced Concrete**
  - The formulation of design equations for axial, flexure, shear and torsional stresses is based on the mechanics of reinforced concrete and will be taught in these respective topics.
  - The mechanics of reinforced concrete for flexure will be discussed in detail in the next week lecture.

References

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