Reinforced Concrete Design – I

(CE 320)

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Course Contents

Mid Term Course	
Lecture No.	**Topic**
1	Introduction to Reinforced Concrete Design
2	Design of Singly Reinforced Beam for Flexure
3	Design of Doubly Reinforced Beam for Flexure
4	Design of T-Beam and L-Beam Section for Flexure (Single and Two Span Beam)
5	Design and Detailing for Bond, Anchorage, Development Length, Laps and Splices

Course Contents

Final Term Course	
Lecture No.	**Topic**
6	Design of Reinforced Beam for Shear
7	Design of Reinforced Concrete Slabs
8	Design of Reinforced Concrete Column.
9	Design of Isolated Column Footing
10	Serviceability Criteria of the ACI Code for Deflection and Crack Width

Grading Policy

- **Midterm** = 25 %
- **Final Term** = 50 %
- **Session Performance** = 25 %
  - Assignments = 10 % *(4 Assignments)*
  - Quizzes = 15 % *(4 Quizzes)*

Lectures Availability

- All lectures and related material will be available on the website:

www.drqaisarali.com

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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

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

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

General

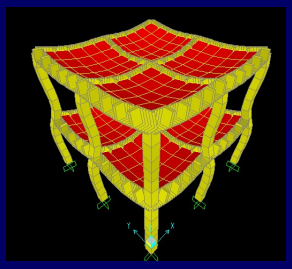
- **Buildings**
  - **Frame System**
    - A reinforced concrete frame building generally consist of slabs, beams and columns.
    - The loads from roof/floor slabs are transmitted to the foundation either directly through columns or through beams to the columns.
    - The reinforced concrete design is done component by component such that slabs beams and columns are separately designed.

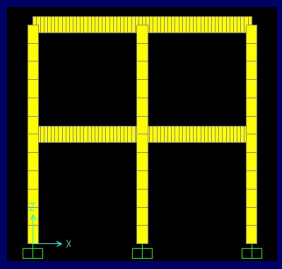
General

- **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

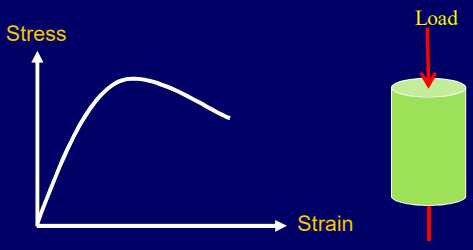
- **Structural Design**
  - The structure must be designed to withstand all these effects without undesirable consequences.
  - In order to learn the design of reinforced concrete buildings, following must be studied:
    - Properties of concrete and reinforcing steel,
    - Building codes used for design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

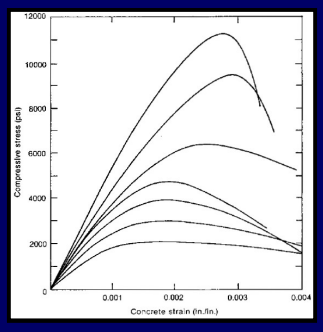
Properties of Concrete

- **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 concrete stress strain curves in compression

Properties of Concrete

- **Tensile Strength**
  - Varies between 8% and 15% of the compressive strength.
  - The type of test that is used to determine the tensile strength has a strong effect on the value that is obtained.
  - Two types of tests are widely used:
    - Modulus of Rupture (Flexural Test)
    - Split Cylinder Test

Properties of Concrete

- **Tensile Strength**
  - Modulus of Rupture (Flexural Test)
    - ASTM C 78 – Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
    - 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

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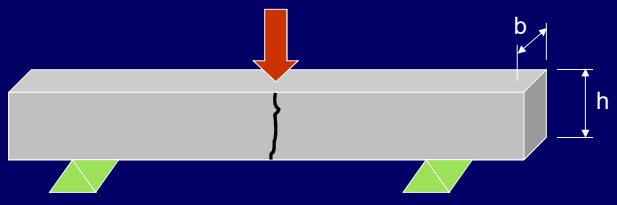
Properties of Concrete

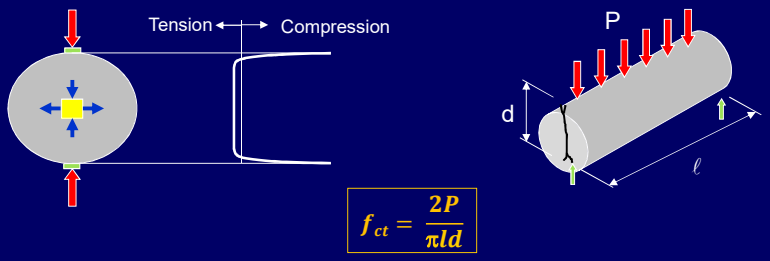
- **Tensile Strength**
  - Modulus of Rupture (Flexural Test)



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

Properties of Concrete

- **Tensile Strength**
  - Split Cylinder Test: The requirements of ASTM C 496 are used to conduct a split cylinder test on 6 in. x 12 in. cylinder.



$$f_{ct} = \frac{2P}{\pi l d}$$

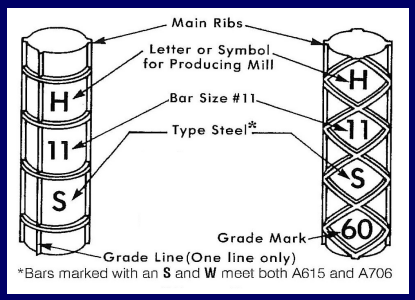
Properties of Concrete

- **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.

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

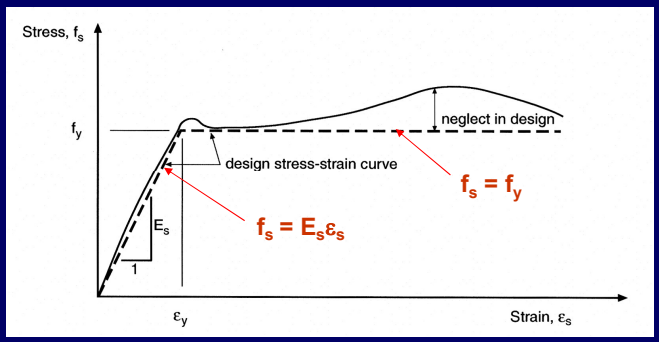
Properties of Concrete

- **ASTM Specifications**
  - **ASTM A 615,** Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.



Properties of Concrete

- **General Stress-Strain Curve**



Properties of Reinforcing Steels

- Strength & Stress-Strain Curve for different Steel Grades

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

Properties of Reinforcing Steels

- Physical Properties of Reinforcing Steel Bars

Bar Designation	Diameter (in.)	Area (in^2)	Weight (lb/ft)
#3	0.375	0.11	0.376
#4	0.500	0.20	0.668
#5	0.625	0.31	1.043
#6	0.750	0.44	1.502
#7	0.875	0.60	2.044
#8	1.000	0.79	2.670
#9	1.128	1.00	3.400
#10	1.270	1.27	4.303
#11	1.410	1.56	5.313
#14	1.693	2.25	7.650
#18	2.257	4.00	13.600

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 (ASCE7-02).

Building Codes and the ACI Code

- **The ACI 318 Code**
  - The American Concrete Institute "Building Code Requirements for Structural Concrete (ACI 318-14)," 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

- **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

- **Design Loads in the ACI code**
  - ACI 318 building code recommends the design loads specified by ASCE7.
  - These loads include dead loads, live loads and others.

Building Codes and the ACI Code

- **Design Loads in the ACI code**
  - **Dead Loads**
    - These loads do not change in time and space.
  - **Live Loads**
    - Chiefly consists of occupancy loads in the building.
    - ASCE7 specifies live load magnitudes for various occupancy or uses.
  - **Other loads**
    - include earthquake loads, wind loads, snow loads etc.

Building Codes and the ACI Code

- **Minimum Uniformly Distributed Live Loads in the ACI code**

Occupancy or Use	Live Load, psf[a]	Occupancy or Use	Live Load, psf[a]
Offices	50	Schools	
Corridors above first floor	80	Classrooms	40
Penal institutions		Corridors above first floor	80
Cell blocks	40	First-floor corridors	100
Corridors	100	Sidewalks, vehicular driveways, and yards subject to trucking[d]	250
Residential		Stadiums and arenas	
Dwellings (one and two-family)		Bleachers[c]	100
Uninhabitable attics without storage	10	Fixed seats (fastened to floor)[c]	60
Uninhabitable attics with storage	20	Stairs and exit ways	100
Habitable attics and sleeping areas	30	One and two-family residences only	40
All other areas except stairs and balconies	40	Storage areas above ceilings	20
Hotels and multifamily houses		Storage warehouses (shall be designed for	
Private rooms and corridors serving them	40	heavier loads if required for anticipated storage)	
Public rooms and corridors serving them	100	Light	125
Reviewing stands, grandstands, and bleachers[c]		Heavy	250
Roofs		Stores	
Ordinary flat, pitched, and curved roofs	20	Retail	
Roofs used for promenade purposes	60	First floor	100
Roofs used for roof gardens or assembly purpose	100	Upper floors	73
Roofs used for other special purposes[f]		Wholesale, all floors	125
Awnings and canopies		Walkways and elevated platforms	60
Fabric construction supported by a lightweight rigid skeleton structure[g]	5	(other than exitways)	
All other construction	20	Yards and terraces, pedestrians	100

Building Codes and the ACI Code

- **FOS in ACI Design procedure**
  - The factor of safety in design is ensured by amplifying the applied loads on the structure and reducing the material strength.
  - 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 (stress).
  - 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 318-14)