DESIGN OF REINFORCED CONCRETE STRUCTURES

Course Code: EG722CE

Credit Hour: 4-1.5-1.5

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- 1.2 Method of reinforcement and reinforcement of concrete by steel bars
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Practical and Laboratory Works:

a) Beam test in bending
b) Beam test in shear
c) Beam test in combined bending and shear
d) Practical work on making skeleton of steel bars for beam column connection
e) Practical work on making skeleton of steel bars for one way and two way slab

Course Works:

Course work on integrated design of a building structure

Reference Books:

1. "Reinforced Concrete Limit State Design", A. K. Jain,, Roorkee, Nem Chand and Bros
2. " Limit State Design" Dr. Ram Chandra, Standard Book House
3. " Reinforced Concrete Design" S.N.Sinha, Tata MacGraw-Hill Publishing Company
4. "Design of Concrete Structures" J.N.Bandhyopadhay, Prentice-Hall

Design of Reinforced Concrete Structures

COURSE DESCRIPTOR

Course code: EG722CE

Credit hours: 4-1.5-1.5

Course objective: Make students capable to design ordinary reinforced concrete structures, build foundation for design of complex concrete structures

Chapter 1: Reinforced Concrete Structures and Design Methods

- **Lecture hours: 5**
- **Tutorial hours: 0**
- **Instructional objectives:**
  Introduce reinforced concrete structures and their design process and design methods.
- **Instructional requirements to the topic:**

1.1 Rationale of Reinforcement of Cement Concrete

Describe the limitation of plain cement concrete as a structural material. Explain the weak properties of plain cement concrete and state the need of reinforcement to address these properties.

1.2 Method of Reinforcement and Reinforcement of Concrete by Steel Bars

Discuss about the different method of reinforcement. Introduce the reinforcement by steel bars and state its advantages. Describe the different types of steel bars used in reinforcing concrete including mild steel bars, high strength deformed bars and thermo mechanically treated bars with respect to their strength and ductility. Inform about the steel bars with their trade name available in the market.

1.3 Introduction to Reinforced Concrete Structures

Discuss about the reinforced concrete structures used in civil engineering. Illustrate the basic forms of structures used.

1.4 Design Methods of Reinforced Concrete Structures

Name the different design methods used to design the RC structures. Explain the basic principle of Woking Stress Design Method and Limit State Design Method and describe merits and demerits of these methods. State the superiority of the Limit State Method.

1.5 Design Process and Basis for Design

State the objective of design and explain design process. Describe each stage of design process i.e. structural planning, preliminary design, idealization/modelling of structures and loads, analysis of structures and design and detailing of structures. Introduce with the design codes used in the design of RC structures.

Chapter 2: Working Stress Method of Design

- **Lecture hours: 7**
- **Tutorial hours: 1.5**
- **Instructional objectives:**
  Introduce working stress design method and give basic concept of design of reinforced concrete beam by working stress method.
- **Instructional requirements to the topic:**

2.1 Basic Assumptions in Working Stress Design

Describe the basic assumptions in the design of RC structures subjected to direct axial load and bending by working stress design method. Define modular ratio and give reason for the value of modular ratio = $280/3\sigma_{cb}$.

2.2 Working Load and Permissible Stresses in Concrete and Steel

Define working load. Explain how the working loads are calculated. Define permissible stresses of concrete and steel. Show the value of permissible stresses applied in different type of steel bars and different grade of concrete. Discuss about the value of permissible stresses applied for different load combinations.

2.3 Behaviour of Beam under Loading

Illustrate the behaviour of beam with its deformed shape and bending stress and strain distribution across the depth of beam section. Explain compression, balanced and tension failure of beam.

2.4 RC sections of beam

Give the concept of different RC sections of beam. Introduce singly reinforced, doubly reinforced rectangular and flanged section. Define under reinforced, over reinforced and balanced sections of beam and differentiate these sections with respect to their depth of neutral axis, moment resisting capacity and permissible stresses in concrete and steel

2.5 Design of Singly Reinforced rectangular beam

Explain the method of design of singly reinforced rectangular section of beam in bending and shear. Derive the mathematical expression for depth of neutral axis, moment resisting capacity offered by beam with respect to concrete and tension steel and area of tension steel. Give the concept of checking and design nature of design problems. Solve the problems of these types. Give the tutorials on the design of singly reinforced rectangular beam.

Chapter 3: Limit State Method of Design

- **Lecture hours: 12**
- **Tutorial hours: 4.5**
- **Instructional objectives:**

  Introduce limit state design method. Describe different limit states, their theories and principles used in design of reinforced concrete structures

- **Instructional requirements to the topic:**

3.1 Safety and Serviceability Requirements and Different Limit States of Structure

Describe safety and serviceability requirement of structures. Define limit state. List different limit states considered in the limit state design.

3.2 Design Strength of Materials and Design Load

Define characteristic strength of material. Discuss the method of determining characteristic strength for concrete and steel. Define partial safety factor for material. State the factors to be considered, while deciding the value of partial safety factor for material. Give the value of partial safety factor for concrete and steel. Define design strength and state the significance of design strength in limit state design.

Define characteristic load. Discuss the method of determining characteristic load. Define partial safety factor for load. State the factors to be considered, while deciding the value of partial safety factor for load. Give the value of partial safety factor for different loads and load combination. Define design load and state the significance of design load in limit state design.

3.3 Idealized Stress-Strain Diagram for Concrete and Steel

Describe stress strain relationship of concrete under loading. Illustrate stress-strain diagram and explain characteristic parameter of stress strain diagram. Show idealised stress strain diagram for concrete used in the design.

Describe stress strain relationship of mild steel bars and high strength deformed bars under loading. Illustrate stress-strain diagrams and explain characteristic parameter of stress strain diagrams. Show idealised stress strain diagram for mild steel bars and high strength deformed bars.

3.4 Limit State of Collapse

3.4.1 Limit state of collapse in flexure

Define limit state of collapse in flexure. State and explain the basic assumptions in the design of flexure member at limit state of collapse. Show the bending stress distribution (stress block) across the depth of beam. Describe stress block diagram. Derive $C = 0.36 f_{ck} b x_u$, the mathematical expression for compressive force offered by concrete in compression in rectangular beam at limit state of collapse. Define under reinforced, over reinforced and balanced section and explain different mode of failure of beam.

Differentiate these sections with respect to moment resisting capacity of the section, depth of neutral axis and stresses developed in steel bar and concrete.

3.4.2 Limit state of collapse in shear

Define limit state of collapse in shear. Explain behaviour of RC beam under shear and bending. Describe different type of shear failure and state the relation between shear span effective depth ratio and shear failure. Show shear stress distribution in RC beam. Define nominal shear stress. Give the maximum value of nominal shear stress. List the component of shear strength RC beam. Name the two parameters on which design shear stress of concrete depends.
Explain three types of shear reinforcement i.e. vertical stirrups, inclined stirrups and bent-up bars. Describe the method of design of shear reinforcement. Explain why the minimum shear reinforcement is provided. Give design steps for the design of shear reinforcement.

3.4.3 Limit state of collapse in torsion

Define limit state of collapse in torsion. Discuss about the type of torsional moment and necessity to consider in design. Explain the behaviour of RC beam under torsion. Define torsional stiffness of RC beam, equivalent shear force and equivalent bending moment. Describe the simplified approach of design of RC beam subjected to torsion, bending moment and shear force, i.e. the calculation of longitudinal and transverse reinforcement. Give reinforcement requirement to beam subjected to torsion, bending moment and shear force.

3.4.4 Limit state of collapse in compression

Define limit state of collapse in compression. State and explain the basic assumptions in the design of compression member subjected to axial compressive load and axial compressive load and bending moment at limit state of collapse. Show the bending stress and strain distribution across the depth of column. Discuss about the approach of design of compression member. Describe the design method for compression member subjected to axial compressive load and for compression member subjected to axial compressive load and bending moment.

3.5 Limit State of Serviceability

3.5.1 Limit state of serviceability in deflection

Define limit state of serviceability in deflection. List the method of controlling deflection for flexure member. Discuss the theoretical method in brief. Explain the method of sufficient stiffness to control deflection. Show the deflection is the function of span effective depth ratio of flexure member. Describe application of the expression l/d = $\alpha\beta\gamma\delta\lambda$ to control deflection.

3.5.2 Limit state of serviceability in cracking

Define limit state of serviceability in cracking. List the method of controlling cracks for flexure member. Discuss the theoretical method in brief. Explain the method of simple detailing rule to control cracking.

Chapter 4: Design of Structural Members by the Limit State Method

- **Lecture hours: 22**
- **Tutorial hours:**
- **Instructional objectives:**
  Make capable enough to design main structural members of reinforced concrete structures by Limit State Design.
- **Instructional requirements to the topic:**

4.1 Design of beam

4.1.1 Design of beam of rectangular section

Define singly reinforced rectangular section of beam. Describe analysis method of singly reinforced rectangular section. Derive mathematical expression for depth of neutral axis, moment resisting capacity and area of tension steel for singly reinforced rectangular section.

Define doubly reinforced rectangular section of beam. Describe analysis method of doubly reinforced rectangular section. Derive mathematical expression for depth of neutral axis, moment resisting capacity and area of tension and compression steel for doubly reinforced rectangular section.

Describe the design method of rectangular section for cases i) when cross sectional dimensions of beam are known and ii) when cross sectional dimensions of beam are not known including the method of proportioning the size of rectangular beam. Solve the design problems on both cases.

4.1.2 Design of beam of flanged section

Define singly reinforced flanged section of beam including effective width of flanged beam. Explain the method of determining effective width of flanged beam. Describe analysis method of singly reinforced flanged section. Derive mathematical expression for depth of neutral axis, moment resisting capacity and area of tension steel for singly reinforced flanged section.

Define doubly reinforced flanged section of beam. Describe analysis method of doubly reinforced flanged section. Derive mathematical expression for depth of neutral axis, moment resisting capacity and area of tension and compression steel for doubly reinforced flanged section.

Describe the design method of flanged section for cases i) when cross sectional dimensions of beam are known and ii) when cross sectional dimensions of beam are not known including the method of proportioning the size of flanged b eam. Solve the design problems on both cases.

4.2 Design of slab

4.2.1 Design of one-way slab

Classify RC slab in relation to their structure, support conditions, bending behaviour. Explain Grashoff - Rankine theory of load distribution on slab and define one-way and two-way bending of slab. Describe analysis method of one-way slab and explain design steps of one-way solid slab i.e. preliminary design, analysis, design in bending, check for shear, check for deflection, reinforcement detailing including curtailment of

reinforcement and check for development of main reinforcement. Solve the design problems on one way solid slab.

4.2.2 Design of two-way slab

Discuss the behaviour of two-way slab. Classify two-way slab in relation to their restrain and support condition. Name the type of restrained slab in relation to their continuity or discontinuity of edges. Discuss about the methods of analysis of slab. Explain IS code method of analysis of two-way slab and explain design steps of restrained two-way solid slab i.e. preliminary design, analysis, design in bending, check for shear, check for deflection, provide/check reinforcement detailing including curtailment of reinforcement and development length checking of main reinforcement and providing of torsion reinforcement. Solve the design problems on two-way solid slab.

4.3 Design of column

4.3.1 Design of short column

Classify the column in relation to their bracing, slenderness and loading. Define effective length and describe buckling behaviour of column. Define short and long column. Describe analysis and design method of axially loaded short column. Define accidental eccentricity and its significance. Explain analysis and design of uni-axially loaded short column by using interaction diagram method. Describe Bresler's load contour and explain analysis and design of bi-axially loaded short column by Bresler's load contour.

4.3.2 Design of long column

Describe analysis and design of long column for different loading conditions. Give the value of additional moment to be considered in the design of long column. Explain analysis and design method of braced column. Give the method of determining resultant bending moment taken in design of column.

4.4 Design of footing

4.4.1 Design of spread footing

Describe bending behaviour of spread footing. Show soil upward pressure on footing and critical sections of footing. Explain design of spread footing. List design steps and describe each step including determination of breadth of footing, determination of soil upward pressure, determination of bending moment, shear force at the critical section of footing, determination of depth of footing, check of depth for one way shear, determination of area of steel and their distribution and reinforcement detailing.

4.4.2 Design of isolated footing

Describe bending behaviour of isolated footing. Show soil upward pressure on footing and critical sections of footing. Explain design of isolated footing. List design steps and describe each step including determination of size of square and rectangular footing, determination of soil upward pressure, determination of bending moment, shear force at the critical sections of footing, determination of depth of footing, check of dep th for one way and two way shear, determination of area of steel and their distribution along width and length of footing, check for bearing stress and reinforcement detailing.

4.4.3 Design of combined footing

List the type of combined footing. Describe bending behaviour of combined footing. Show soil upward pressure on footing and critical sections of footing. Explain design of combined footing of rectangular shape. List design steps and describe each step

including determination of size of combined footing, determination of soil upward pressure, determination of bending moment, shear force at the critical sections of footing, determination of depth of footing, check of depth for one way and two way shear, determination of area of steel and their distribution along width and length of footing and reinforcement detailing.

4.4.4 Design of mat footing

Discuss the design method of mat footing. Give concept of design

4.5 Design of stairs

Discuss about the different types of stairs. Review geometric design of stairs. Show the effective span for stairs spanning horizontally and longitudinally. Explain load calculation on stairs. Describe design method for doglegged, quarter turn, open well and straight stairs. List the design steps and describe each step including determination of thickness of stair slab, determination of loads on stair, determination of bending moment, shear force at the critical section of stair, design in bending, determination of area of steel and their distribution, check for shear, and reinforcement detailing.

Chapter 5: Reinforcement Detailing

- **Lecture hours: 10**
- **Tutorial hours: 3**
- **Instructional objectives:**

  Give knowledge on normal/ductile detailing rules of reinforcement of structural members required in the design of reinforced concrete structures

- **Instructional requirements to the topic:**

5.1 Detailing of reinforcement in beam, slab, column, footing, staircase

Describe codal provision of concrete cover to reinforcing bars used in beam, slab, column, footing and staircase.

Explain provision of code for tension reinforcement, compression reinforcement, side face reinforcement, shear reinforcement and reinforcement requirement for torsion in beam.

Describe codal provision of minimum steel requirement and spacing and diameter requirement of reinforcing bars in slab.

Explain reinforcement detailing requirement in column, footing and staircase.

5.2 Development length of reinforcing bars

Define bond stress developed in steel bars embedded in concrete and development length of bars required for desired bond stress. Explain components of development length and derive expression of development length. $L_d \leq 1.3M_l/V_u + l_d$

5.3 Curtailment of reinforcing bars

Define curtailment of reinforcing bars. Explain general condition of curtailment, curtailment provision of reinforcing bars for positive and negative bending moment in flexure member. Show the curtailment of reinforcing bars in simply supported beam subjected to uniformly distributed load.

5.4 Splices

Define splicing of reinforcing bars. Describe codal provision of splicing of reinforcing bars.

5.5 Ductile detailing of reinforced concrete structures

Explain rationale of ductile detailing of reinforced concrete structures. Describe general provision, provision of longitudinal and transverse reinforcement of ductile detailing of flexure and compression member. Show beam-column and column-footing joint detailing of reinforcement.

Chapter 6: Prestressed Concrete Structures

- **Lecture hours: 4**
- **Tutorial hours: 1**
- **Instructional objectives:**

  Introduce Prestressed Concrete and give basic concept of design of Prestressed Concrete Structures

- **Instructional requirements to the topic:**

6.1 Introduction to Prestressed Concrete Structures

Define Prestressed Concrete. Explain use of Prestressed Concrete in structures.

6.2 Materials requirement of Prestressed Concrete

Describe concrete and steel requirement for prestressed concrete. Explain properties of prestressing wire and strand.

6.3 Prestressing system

Describe pre-tensioning and post-tensioning system of prestressing conrete. Explain linear and curvilinear prestressing of structural members. Introduce anchoring of prestressing cables.

6.4 Method of analysis and design

Explain basic concept used in the analysis and design of Prestressed Concrete Structures.

Practical and Laboratory Works:

a) Beam test in bending
b) Beam test in shear
c) Beam test in combined bending and shear
d) Practical work on making skeleton of steel bars for beam column connection
e) Practical work on making skeleton of steel bars for one way and two way slab

Course Works:

Course work on integrated design of beam, column, slab and footing of a building structure