DESIGN OF RC STRUCTURES

Subject Code: CV0501

RC – Reinforced Concrete

NO. OF HOURS OF LECTURES PER WEEK – 04

NO. OF HOURS OF TUTORIALS PER WEEK – 02

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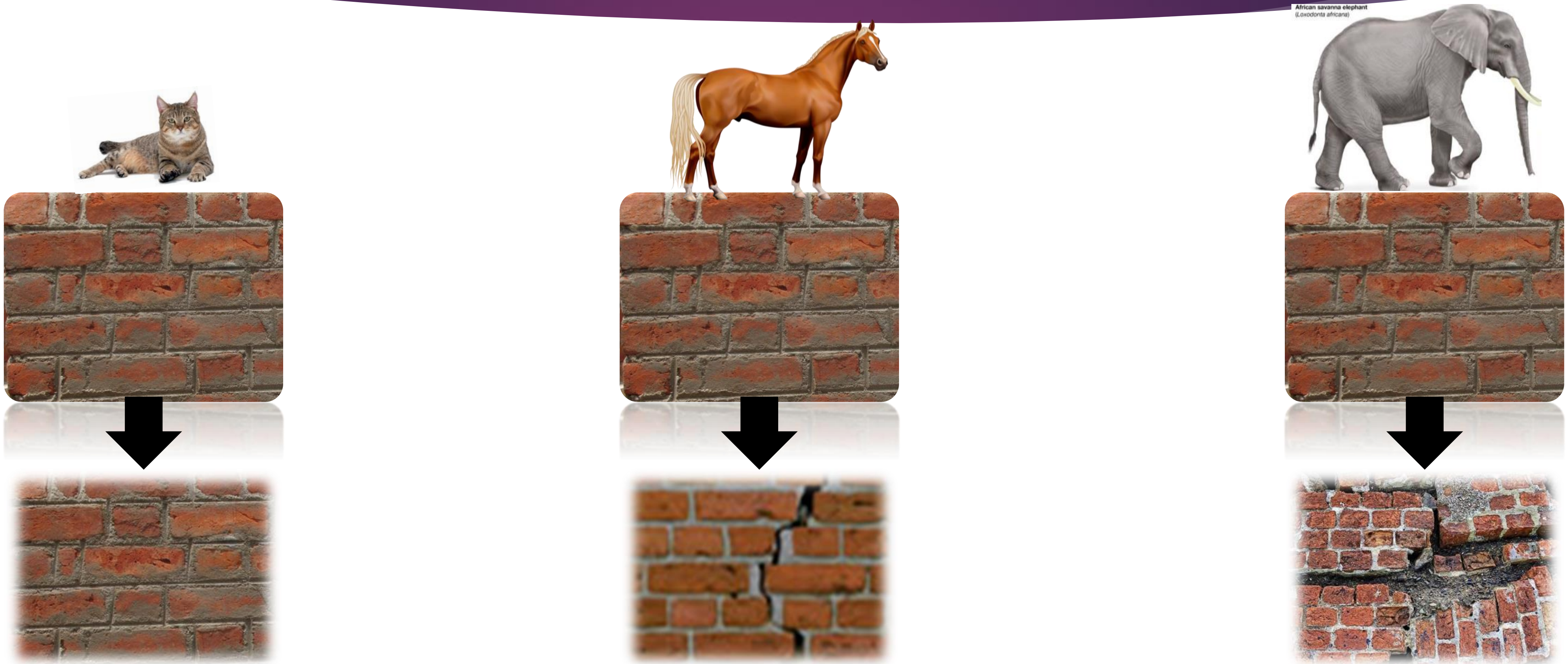
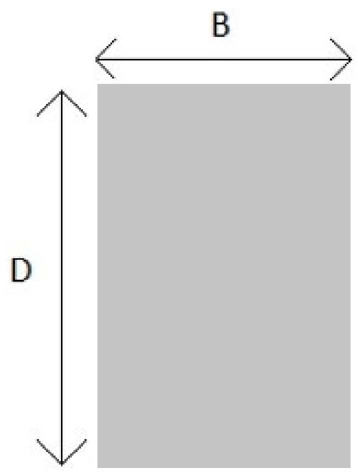
DESIGN OF RC STRUCTURES – ABOUT SUBJECT

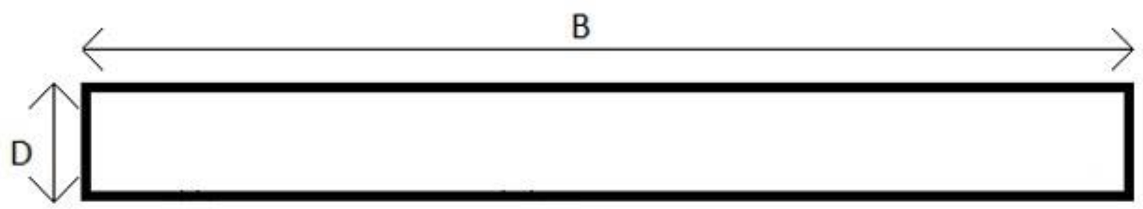


DESIGN OF RC STRUCTURES – ABOUT SUBJECT

- Design of Structure…………???
  - It is a method or tool by which we find out safe and economical specifications of a structure or a member of the structure sufficient to carry the load.
  - Specifications:



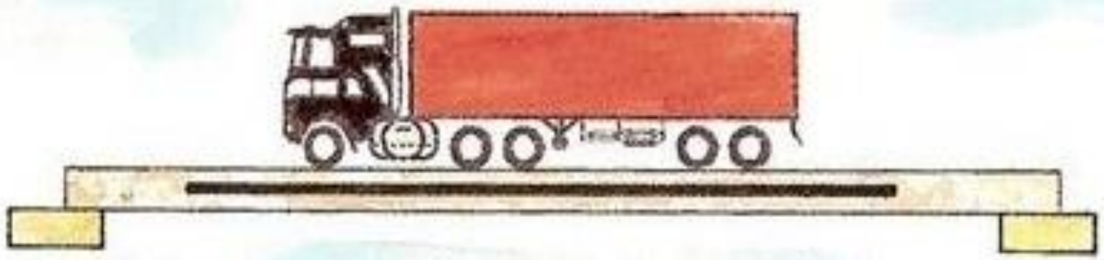
BEAM



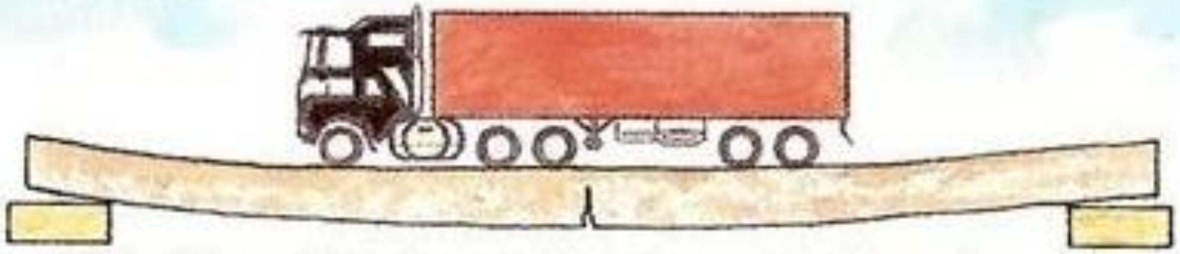
SLAB

DESIGN OF RC STRUCTURES – ABOUT SUBJECT

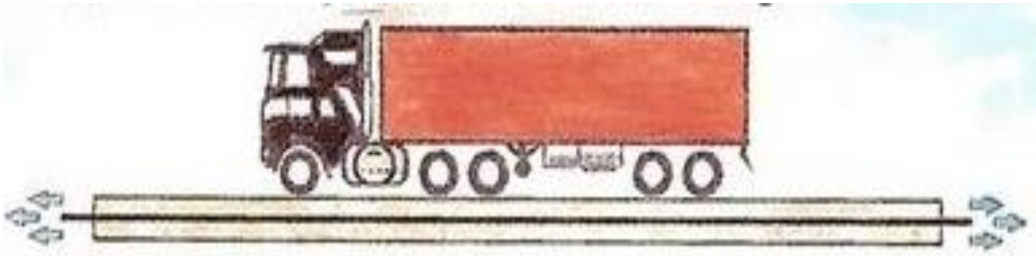
▲ A concrete beam will begin to bend when heavily loaded.



▲ Placing a steel rod inside the beam holds the concrete together and stops the beam from cracking.



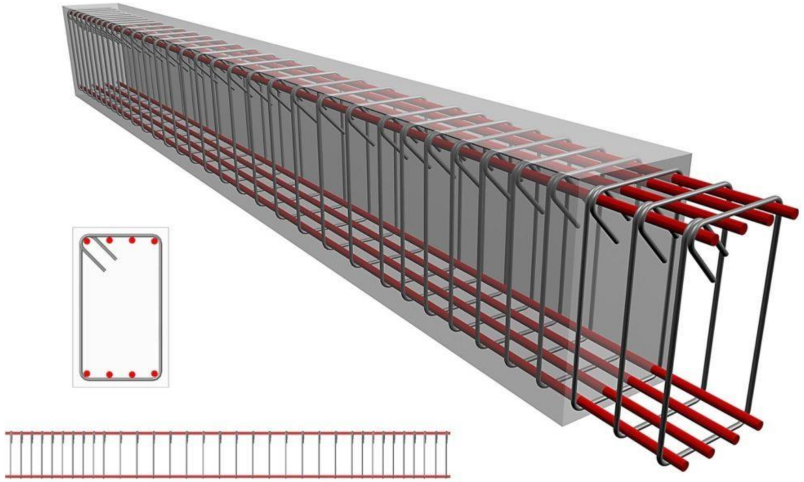
▲ The base of the beam starts to crack where the concrete is pulled apart.



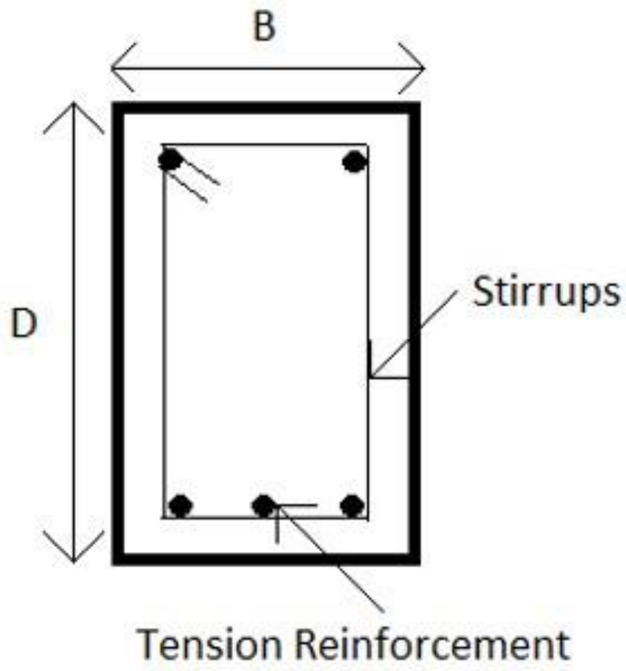
▲ Stretching the rod and then releasing it to squeeze the concrete makes the beam very strong.

DESIGN OF RC STRUCTURES – ABOUT SUBJECT

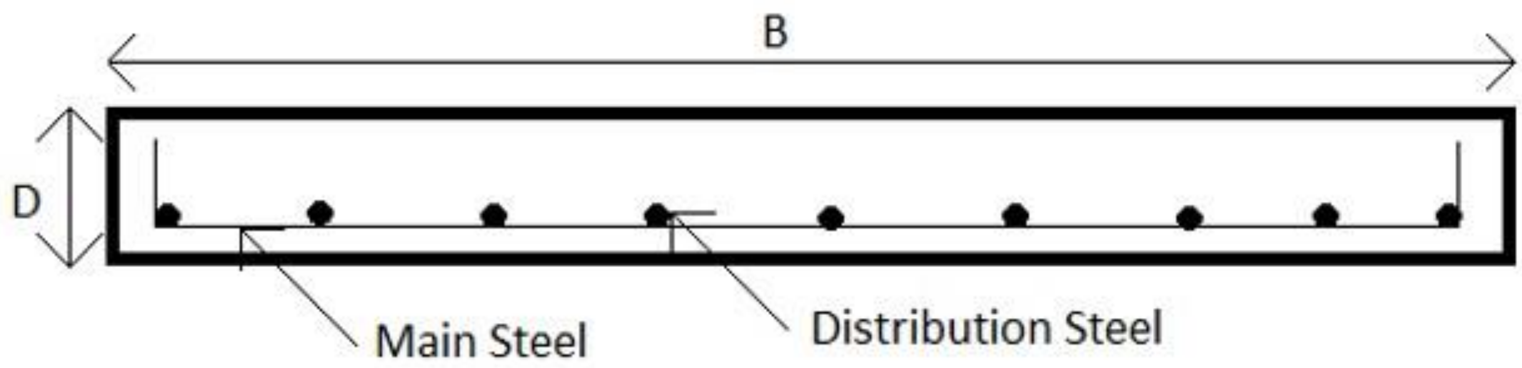
- Reinforced Concrete (RC)…??
  - A product having steel bars embedded in concrete.



DESIGN OF RC STRUCTURES – ABOUT SUBJECT



BEAM



SLAB

DESIGN OF RC STRUCTURES – ABOUT SUBJECT

- Unit – 1

Introduction to Reinforced Cement Concrete (RCC): Properties of Concrete and Reinforcing Steel, Introduction to Working stress and Limit state methods, Characteristic and Design Value and Partial Safety Factors, Loads and Load Factors, Load Combinations.
Design Philosophies for Reinforced Cement Concrete (RCC): Limit State of Flexure, Design of Singly Reinforced Beams, Design of Doubly Doubly Reinforced Beams, Concept of Flanged Beam or T-Beam.

DESIGN OF RC STRUCTURES – ABOUT SUBJECT

- **Pre – requisites for Unit No. 1**

1) Stress Strain Curve of Materials (Concrete & Steel) – Material Science and Concrete Technology
2) Basics of Concrete properties – Concrete Technology
3) Bending Moment Diagrams – Strength of Materials
4) Basic Mathematical manipulations
5) Calculation of Centroid – Engineering Mechanics

DESIGN OF RC STRUCTURES – ABOUT SUBJECT

- Unit – 2

Limit State of Shear: Nominal Shear Stress, Design Shear Strength of Concrete, Minimum Shear Reinforcement, Design of Shear Reinforcement, Design of Beams for Shear.
Limit State of Torsion: Reinforcement in members subjected to Torsion, Design of Beams for torsion. Bond, Development Length, Limit State of Serviceability: Deflections and Crack Width.

DESIGN OF RC STRUCTURES – ABOUT SUBJECT

- **Pre – requisites for Unit No. 2**

1) Principal Stress and Strain, Shear Force Diagram, Shear Stress and Torsion – Strength of Materials

2) Basic Mathematical manipulations

DESIGN OF RC STRUCTURES – ABOUT SUBJECT

- Unit – 3

Solid Slabs: Introduction to Yield Line Theory and simple problems, One-way Slab, Simply Supported One-way Slab, Design of One Way Slab, Two Way Slabs, Simply Supported Two-Way Slab, Design of Two-Way Slab Reinforcement detailing for One way and Two Way Slabs.
Design of Staircases: Classification of Stairs, Terms Used, Design Requirement d for Stair, Design of Transversely and Longitudinally Supported Staircase.
Load Calculation: Loads on Slabs, Loading on Beams from One-way and Two-way Slab, Wall Loads and Self-weight of Beams, Unit Loads

DESIGN OF RC STRUCTURES – ABOUT SUBJECT

- **Pre – requisites for Unit No. 3**

1) Basics of Stairs and Basic terms associated with it – Building construction
2) Theories and derivations of unit – 1 of this subject
3) Basic mathematical manipulations

DESIGN OF RC STRUCTURES – ABOUT SUBJECT

- Unit – 4

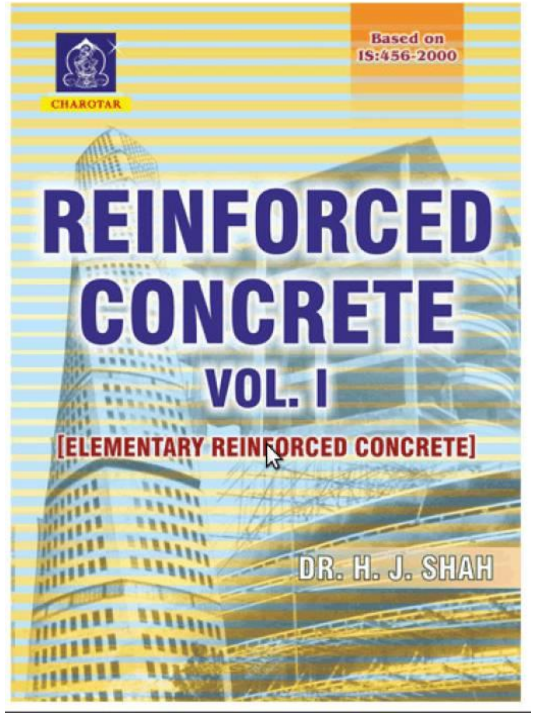
Limit State of Compression: Minimum eccentricity, Effective Length of Compression Members, Slender Limits for Columns, Design of Short axially loaded columns in compression, Members subjected to combined Axial load and Uniaxial bending, Members subjected to combined Axial Load and Biaxial bending, Design of Slender compression members.
Design of Foundations: Classification of Foundations, Types of Footings, General Soil Design Consideration, General Structural Design Consideration, Transfer of Load at base of Column, Design of Axially Loaded Pad Footings, Design of Eccentrically Loaded Footings.

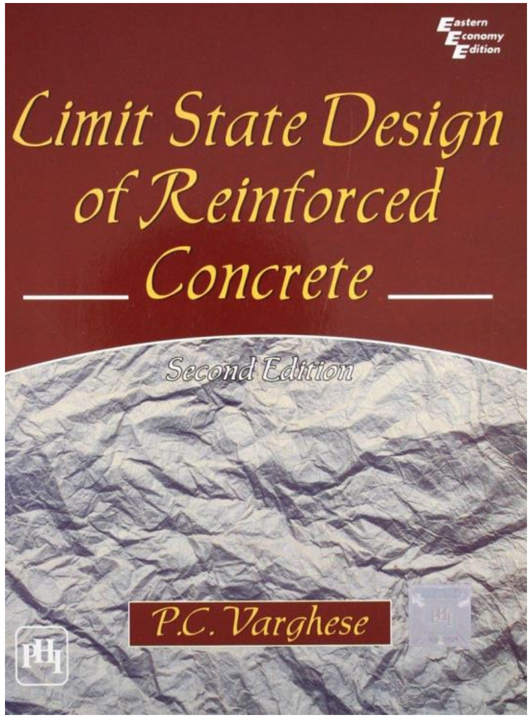
DESIGN OF RC STRUCTURES – ABOUT SUBJECT

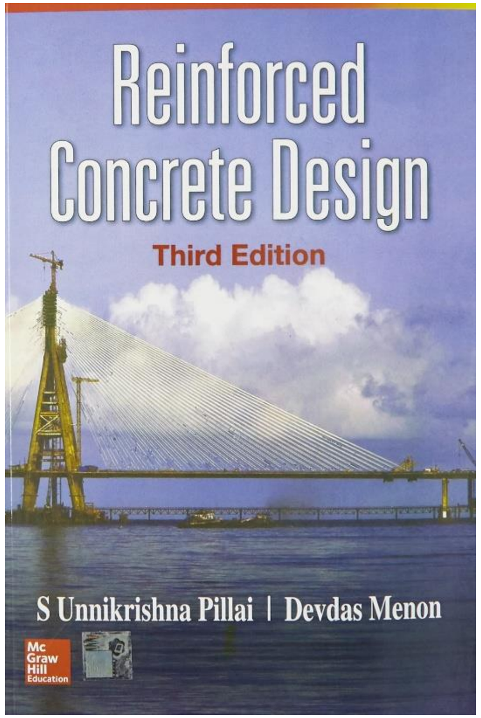
- **Pre – requisites for Unit No. 4**

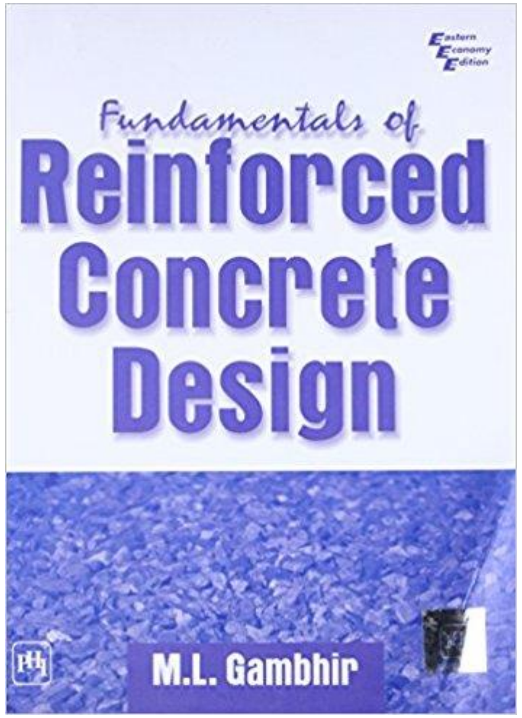
1) Basics of deformation of member subjected to axial forces – strength of materials
2) Concepts of bending stresses in column – Structural Analysis – 1
3) Basics of Unit – 1 of this subject
4) Basic mathematical manipulations

DESIGN OF RC STRUCTURES – ABOUT SUBJECT









DESIGN OF RC STRUCTURES – ABOUT SUBJECT

- LIST OF IS CODES:

1) IS 456 : 2000
2) IS 13920 : 2016
3) SP 16 : 1988
4) SP 34 : 1987
5) IS 875
    1) PART 1 – DEAD LOAD
    2) PART 2 – LIVE LOADS

UNIT - 1

UNIT 1 – Introduction to Reinforced Concrete

Properties of Concrete

1) Characteristic Strength Property

- Characteristic strength is defined as the strength below which not more than five per cent of the test results are expected to fall.
- Concrete has three groups as:

  (i) Ordinary Concrete (M 10 to M 20)

  (ii) Standard Concrete (M 25 to M 60)

  (iii) High Strength Concrete (M 65 to ……..)

UNIT 1 – Introduction to Reinforced Concrete

Properties of Concrete

2) Other Strengths of Concrete

- Concrete also possesses a) Flexural Strength and b) Tensile strengths.
- Both these strength can be determined as per IS 516 and IS 5816 respectively.
- Tensile strength is found to be 8 – 10 percentage of compressive strength of concrete.
- Flexural strength can be determined by an empirical relation given in **Clause no. 6.2.2 of IS 456 : 2000**.

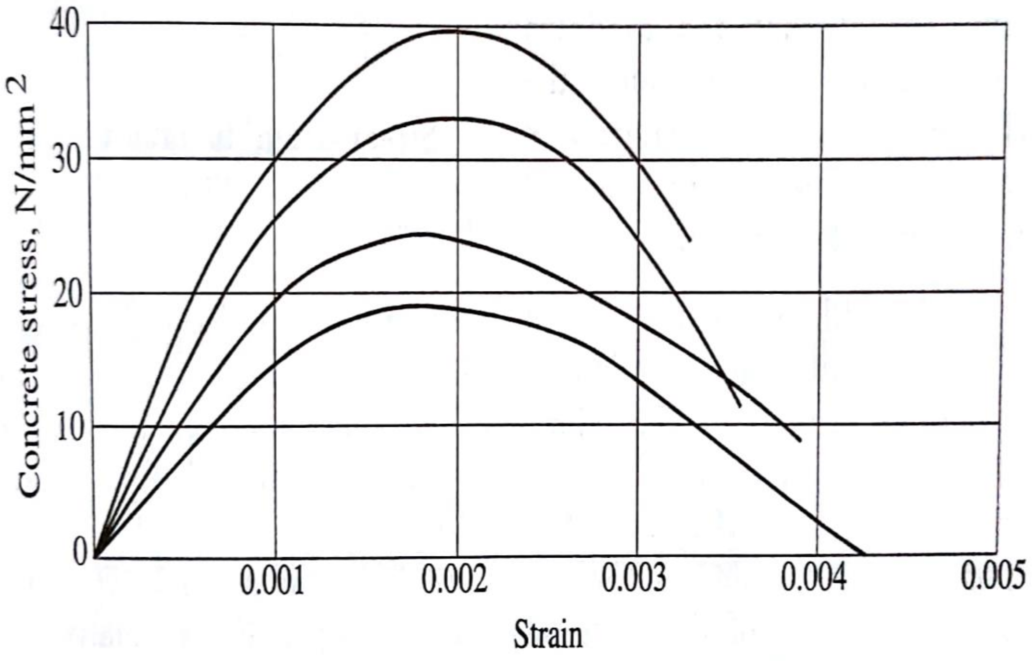
$$f_{cr} = 0.7\sqrt{f_{ck}}\ \text{N/mm}^2$$

UNIT 1 – Introduction to Reinforced Concrete

Properties of Concrete

3) Stress – Strain Curve of Concrete

- Maximum Compressive stress occurs approximately at strain value of 0.002.
- Lower the strength = Higher Ductility (Comparatively)
- Failure strain varies from 0.003 – 0.005. Hence IS code permits the strain value of **0.002 in Compression** and **0.0035 in Bending**.



UNIT 1 – Introduction to Reinforced Concrete

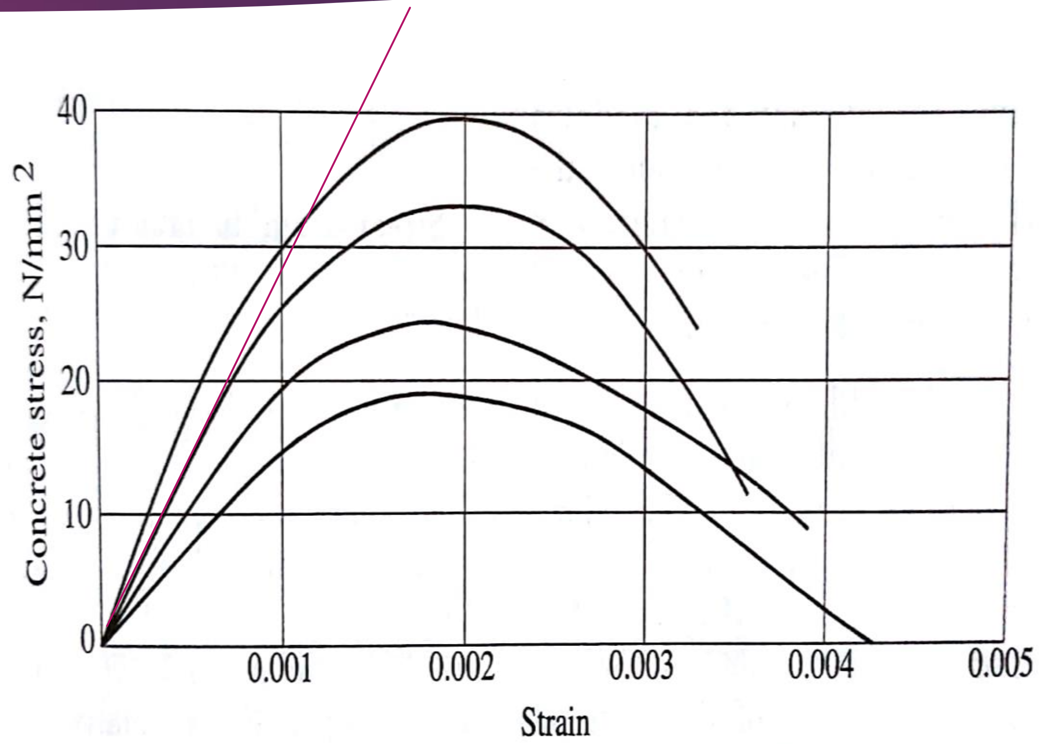
Properties of Concrete

3) Stress – Strain Curve of Concrete

- Modulus of elasticity E_c is taken as initial tangent modulus which is given by following relation with characteristic strength of concrete:

$$E_c = 5000\sqrt{fck}\ N/mm^2$$

- This modulus of elasticity is also known as short term static modulus of elasticity of concrete.

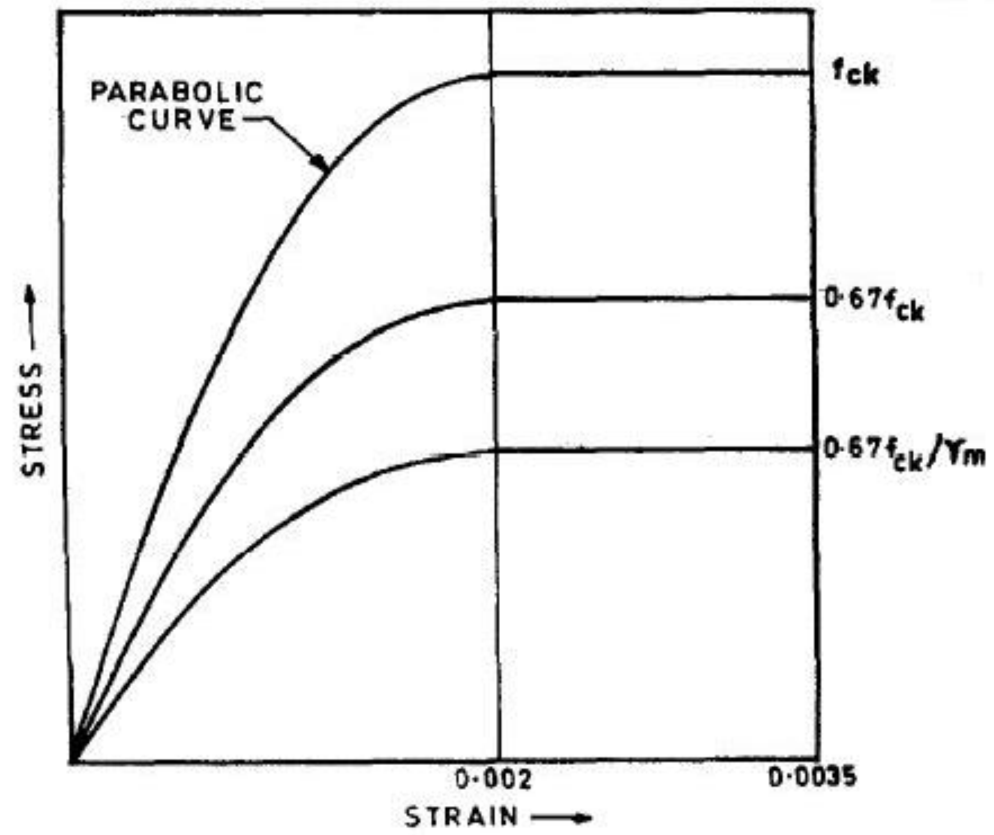


UNIT 1 – Introduction to Reinforced Concrete

Properties of Concrete

3) Stress – Strain Curve of Concrete

- Adjacent figure is the idealised stress strain curve of concrete for design. (IS 456 : 2000, P-69)
- F_{ck} = characteristic strength of concrete
- As strength of concrete depends on site conditions, factor of 0.67 shall be applied to the same and in addition to this partial safety factor shall also be applied.

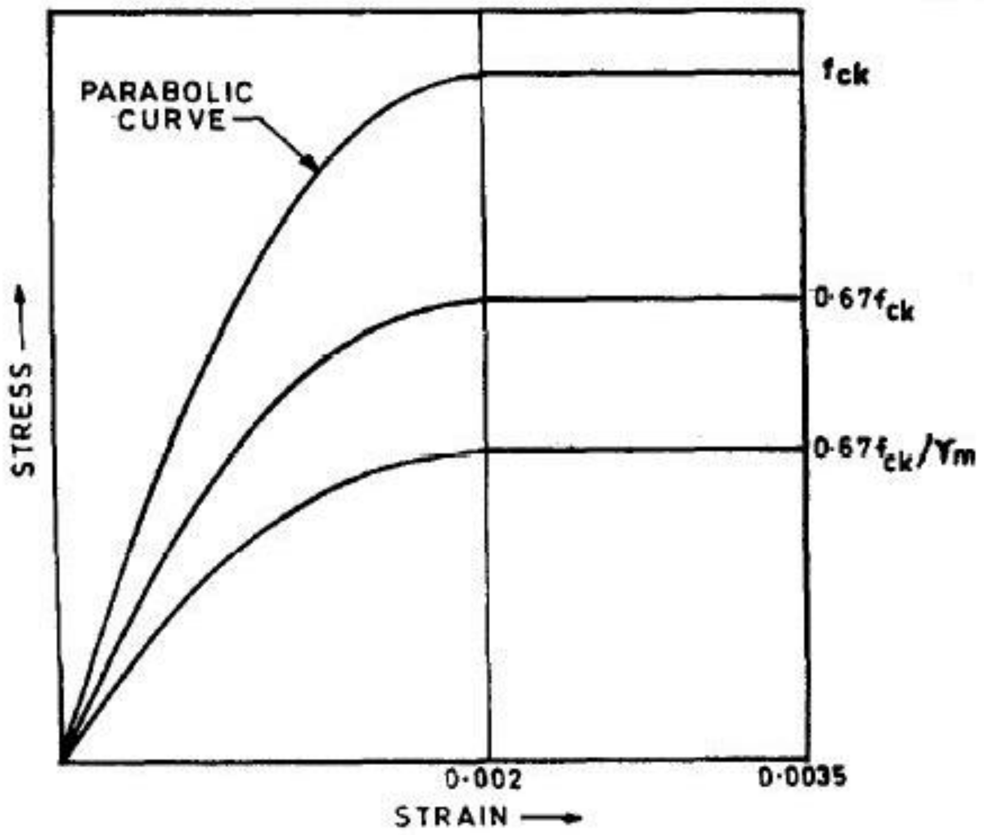


UNIT 1 – Introduction to Reinforced Concrete

Properties of Concrete

IS RECOMMENDATIONS: (PAGE : 69)

- Considering the human factor and errors made, the strength of concrete is considered to be 67% of the total strength; i.e. 0.67 f_{ck}.
- Partial Factor of Safety : 1.5
- Further the strength (0.67 f_{ck}) is reduced by applying partial factor of safety and hence the maximum stress taken for design is 0.446 f_{ck}.

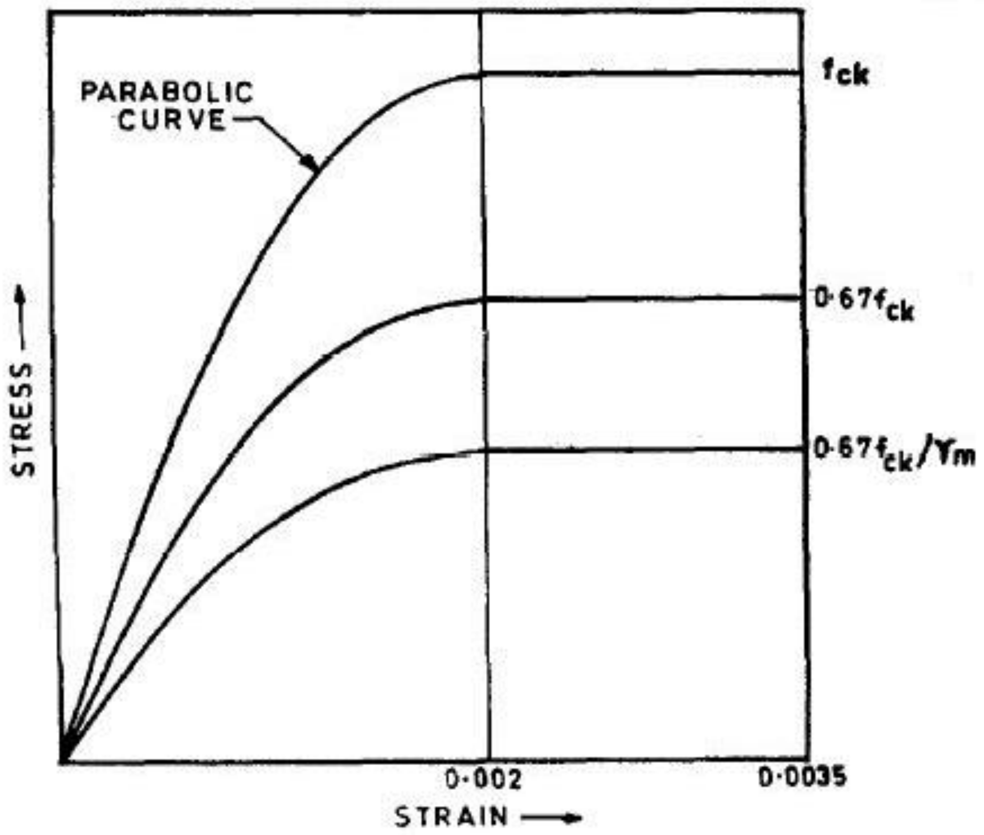


UNIT 1 – Introduction to Reinforced Concrete

Properties of Concrete

IS RECOMMENDATIONS: (PAGE : 69 & 70)

- Tensile strength of concrete is Ignored for design.
- Maximum compressive strain in outermost fibre in concrete is 0.0035 in bending and in axial compression it is 0.002.
- The maximum compressive strain at the highly compressed extreme fibre in concrete subjected to axial compression and bending and when there is no tension on the section shall be 0.0035 minus 0.75 times the strain at the least compressed extreme fibre.



UNIT 1 – Introduction to Reinforced Concrete

Properties of Steel

1) General:

- Steel is used as the reinforcing material in concrete to make it good in tension.
- Unlike concrete, steel reinforcement rods are produced in steel plants. Moreover, the reinforcing bars or rods are commercially available in some specific diameters.
- Like concrete, steel also has several types or grades, viz. mild steel (fy250), HYSD bars (above Fe415).
- Here, fy stands for yield stress (yield strength) and Fe is used for denoting iron.

UNIT 1 – Introduction to Reinforced Concrete

Properties of Steel

MS BARS

HYSD BARS

UNIT 1 – Introduction to Reinforced Concrete

Properties of Steel

1) Stress - Strain Curve:

- Steel is used as the reinforcing material in concrete to make it good in tension.
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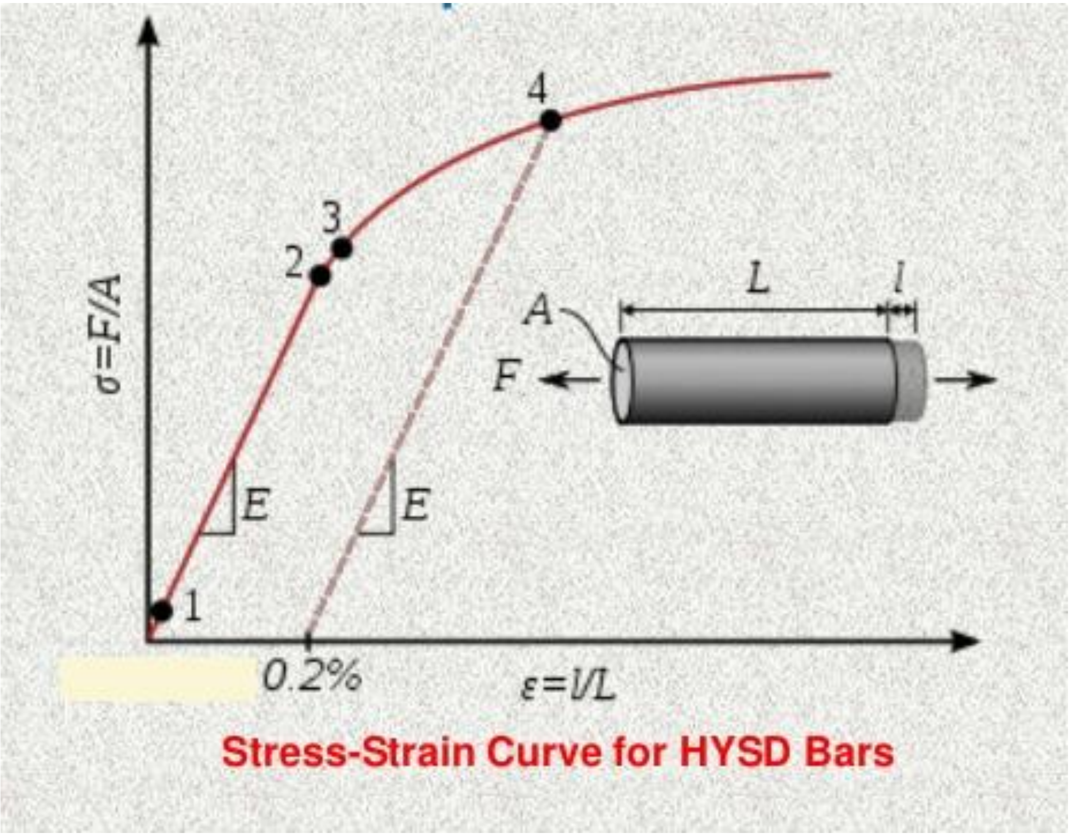
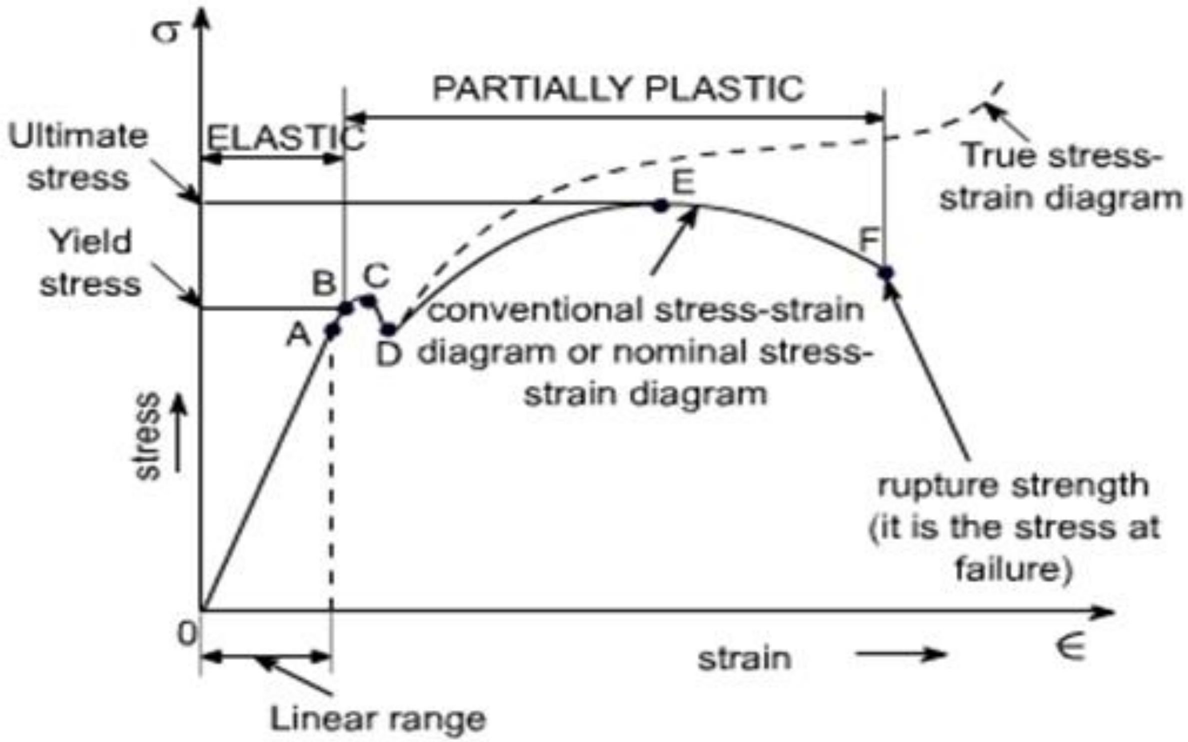
UNIT 1 – Introduction to Reinforced Concrete

Properties of Steel : Stress – Strain Curve

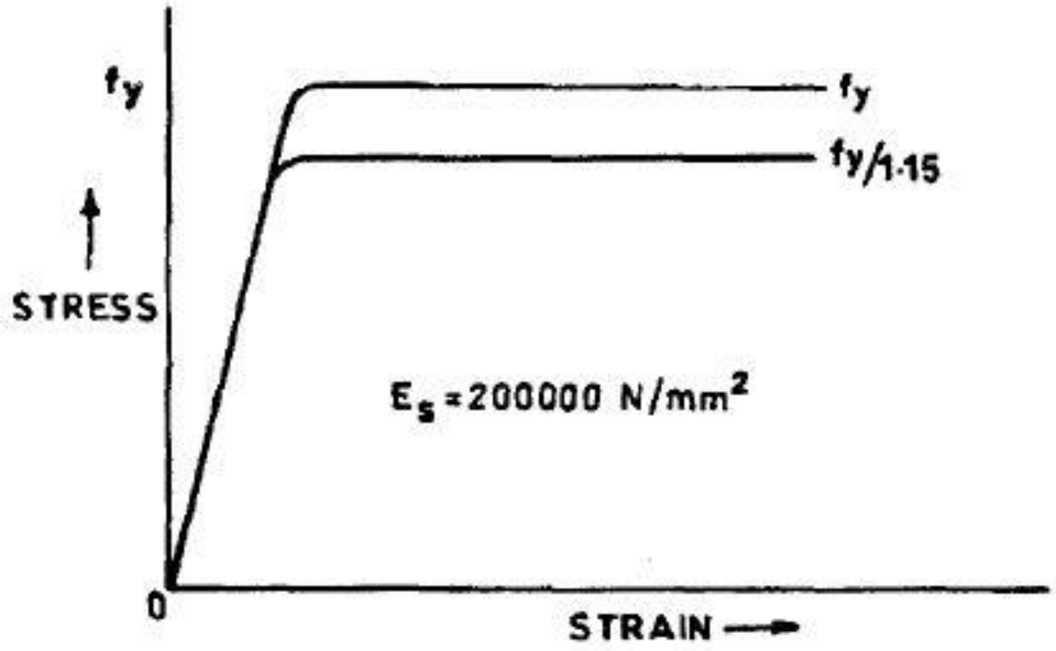




UNIT 1 – Introduction to Reinforced Concrete

Properties of Steel : Stress – Strain Curve

- Adjacent figure is the idealised stress strain curve of steel (mild steel) for design. (IS 456 : 2000, P-70)
- F_y = Yield Stress (Strength) of steel.
- As reinforcement bars are being manufactured in factories under controlled condition, the partial factor of safety (less than concrete) of **1.15** is to be applied.

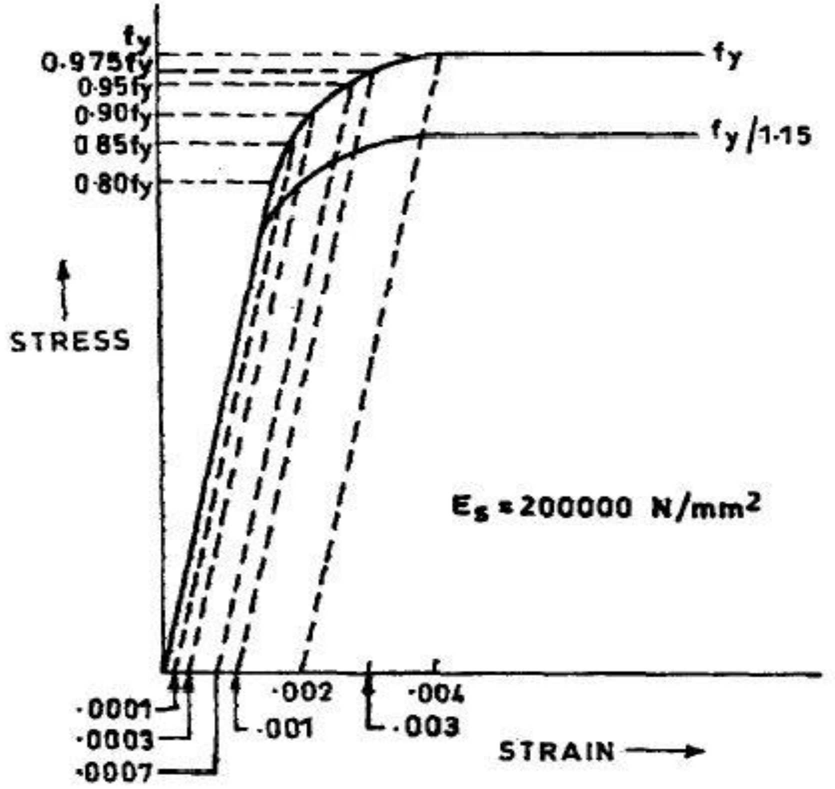


23B STEEL BAR WITH DEFINITE YIELD POINT

UNIT 1 – Introduction to Reinforced Concrete

Properties of Steel : Stress – Strain Curve

- Attached figure here is of HYSD (**H**igh **Y**ield **S**trength **D**eformed) bar, which contains grade like Fe – 415, Fe – 500, Fe – 550 etc.)
- HYSD bars are manufactured by Cold/Hot Working.
- For such bars, stress is proportional to strain till 0.8 fy and beyond this limit, the variations is inelastic as given ahead.

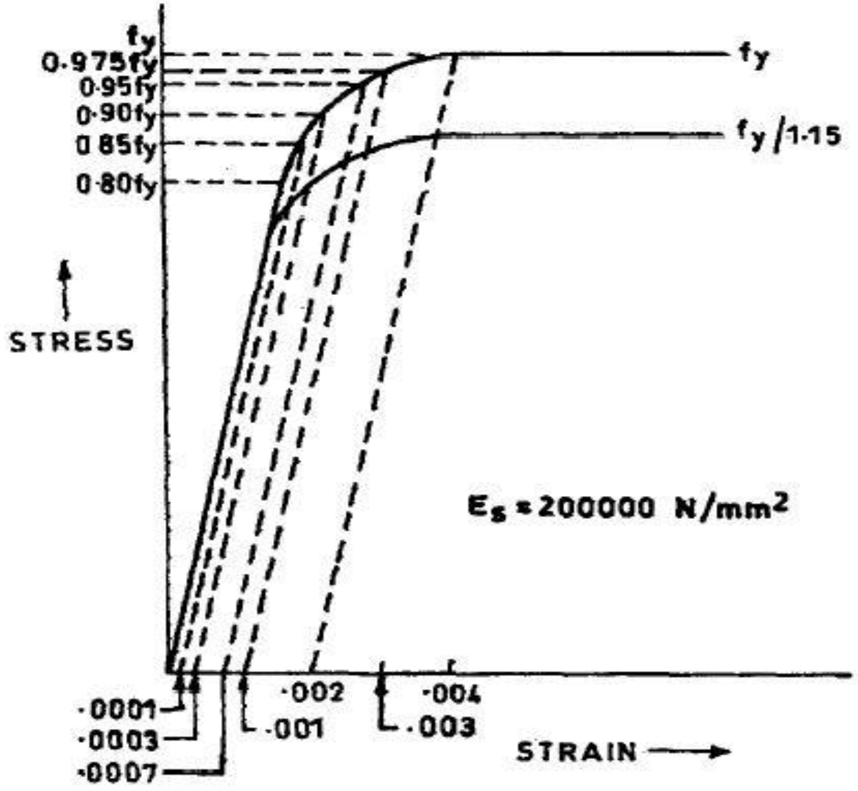


23A Cold Worked Deformed Bar

UNIT 1 – Introduction to Reinforced Concrete

Properties of Steel : Stress – Strain Curve

Stress	Inelastic strain
0.80 f_y	Nil
0.85 f_y	0.0001
0.90 f_y	0.0003
0.95 f_y	0.0007
0.975 f_y	0.0010
1.00 f_y	0.0020



23A Cold Worked Deformed Bar

UNIT 1 – Introduction to Reinforced Concrete

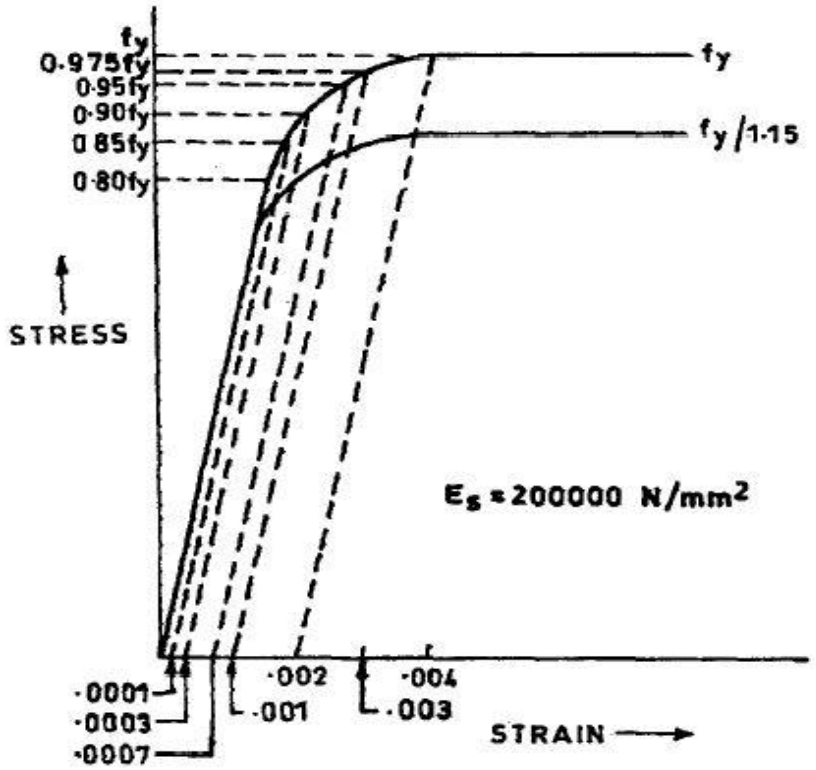
Properties of Steel : Stress – Strain Curve

IS RECOMMENDATIONS: (PAGE : 69)

- Partial factor of safety : 1.15.
- The maximum strain in the tension reinforcement in the section at failure shall not be less than:

$$\frac{0.87 * fy}{E_s} + 0.002$$

- Compressive stress is not discussed as reinforcements are provided only for tensile stresses.



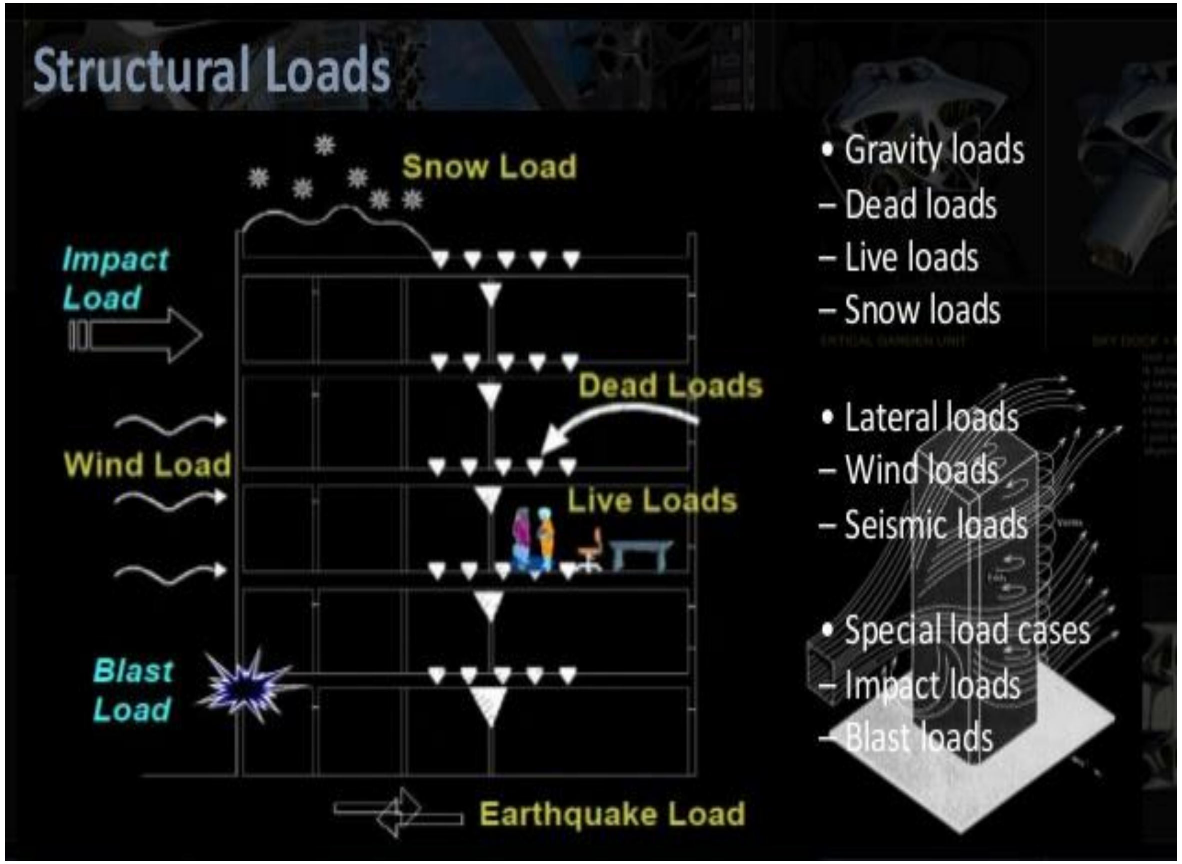
23A Cold Worked Deformed Bar

UNIT 1 – Introduction to Reinforced Concrete

Loads, Load Factors and Load Combinations

Loads acting on structure are:

- Dead load (DL)
- Live load (LL)
- Wind load (WL)
- Seismic load (EQ)



Loads Combinations: (IS 456 : 2000, page 68)

- 1.5 * (DL + LL)
- 1.2 * (DL + LL ± WL_X)
- 1.2 * (DL + LL ± WL_Y)
- 1.5 * (DL ± WL_X)
- 1.5 * (DL ± WL_Y)
- 0.9 * DL ± 1.5 * WL_X
- 0.9 * DL ± 1.5 * WL_Y

UNIT 1 – Methods of Design

Working Stress Method

Design Methods

- Working Stress Method
- Ultimate Load Method
- Limit State Method

Considers Strength of materials up to elastic limit → Sections are heavy → Uneconomical

UNIT 1 – Methods of Design

Ultimate Load Method

Design Methods
- Working Stress Method
- Ultimate Load Method
- Limit State Method

Considers Ultimate Strength → Sections are Slender → Economical with failure issues

UNIT 1 – Methods of Design

Limit State Method

Design Methods
- Working Stress Method
- Ultimate Load Method
- Limit State Method

- Considers ultimate strength with FOS
- Sections are appropriate
- Economical

UNIT 1 – Limit State Method

Limit State of Collapse

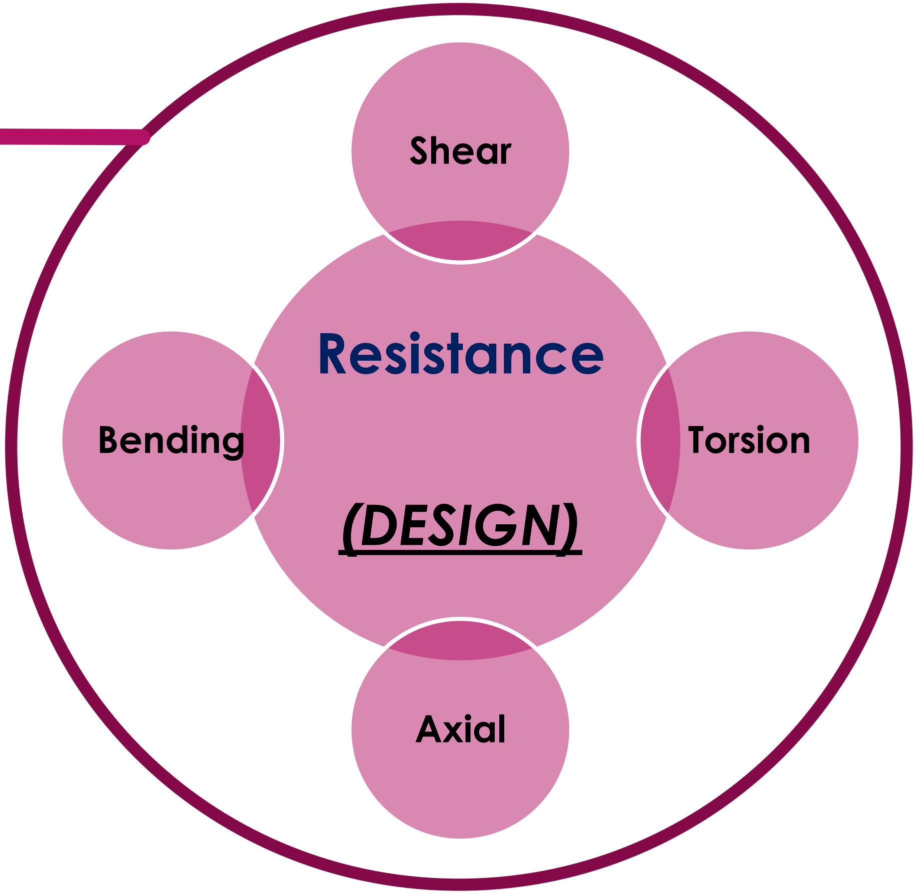
Limit State Method

- Limit State of Collapse
- Limit State of Serviceability

Unfavourable condition of loads

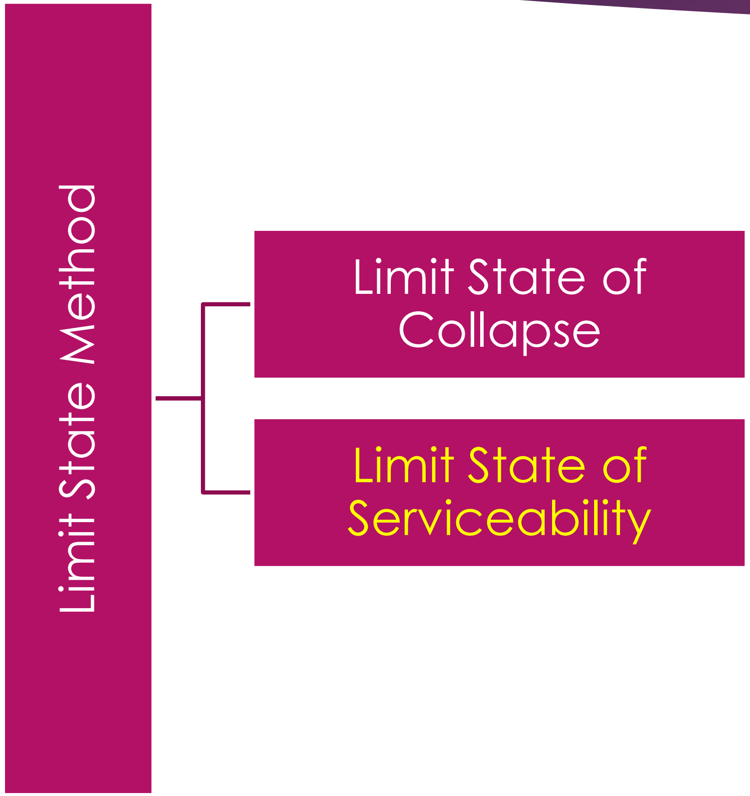
Note

Loads and resistance are to be taken into account considering *Safety Factors*



UNIT 1 – Limit State Method

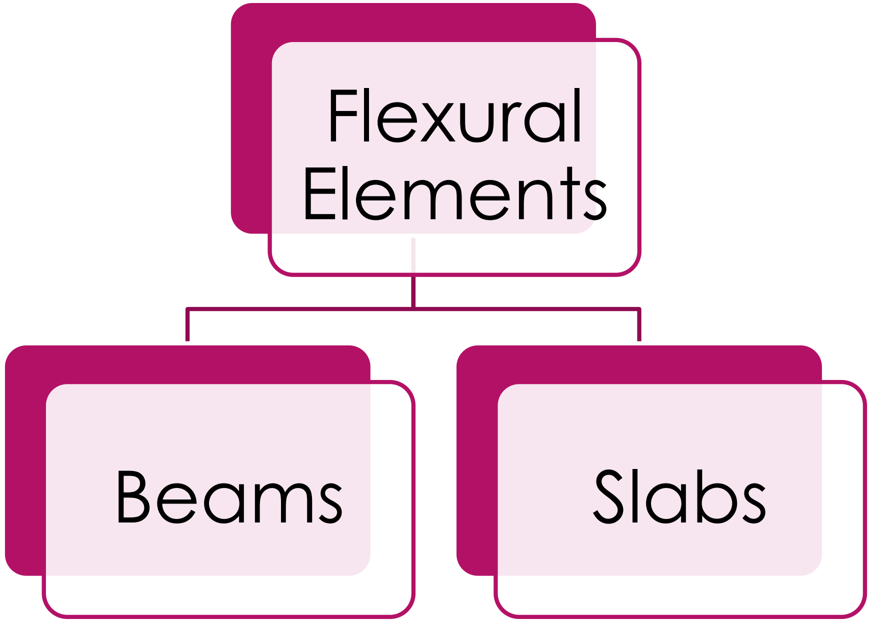
Limit State of Serviceability



Limit State of Flexure (Bending)

UNIT 1 – Limit State Method

Limit State of Flexure

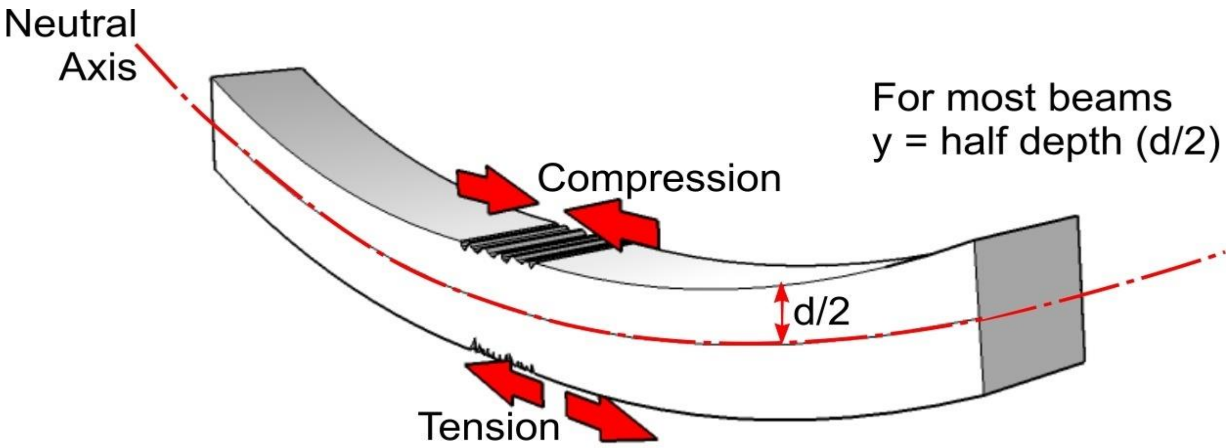


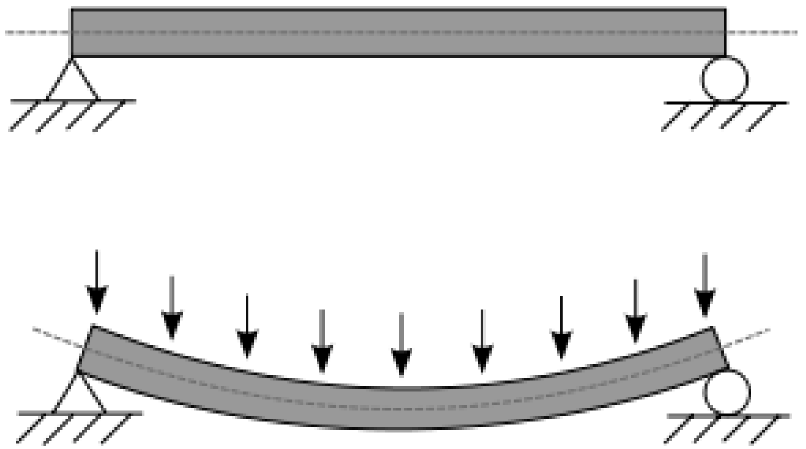
UNIT 1 – Limit State Method

Limit State of Flexure - Beams

Definition

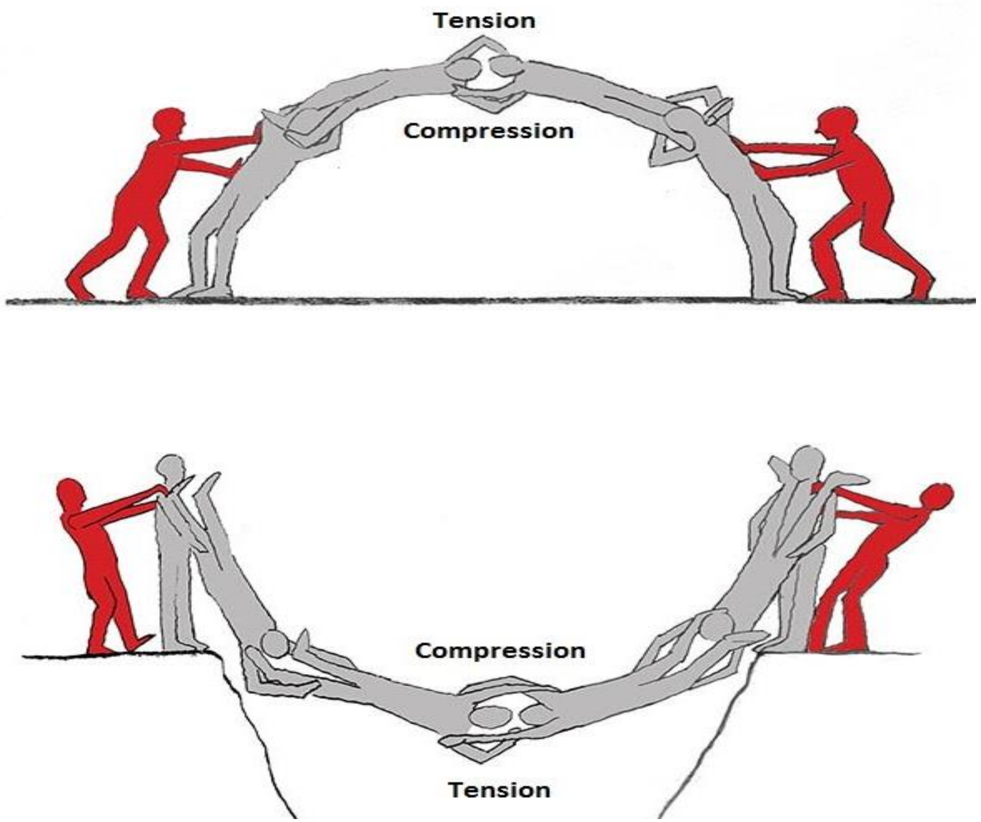
- Horizontal or inclined structural member spanning a distance between one or more supports, and carrying vertical loads across (transverse to) its longitudinal axis, for eg. a girder, joist, purlin etc.
- Its mode of deflection is primarily by bending.

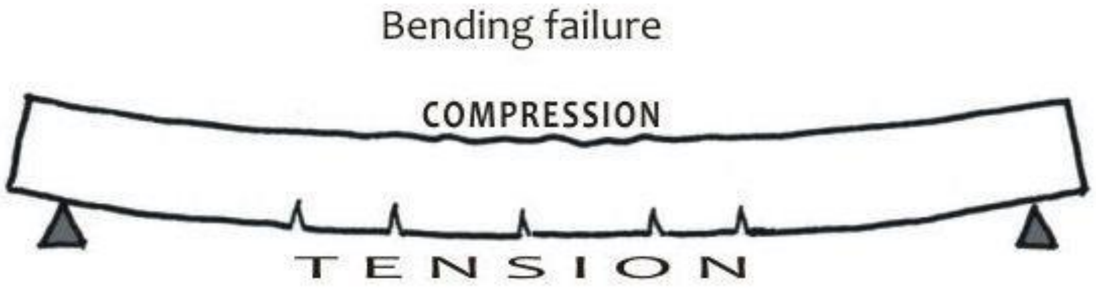




UNIT 1 – Limit State Method

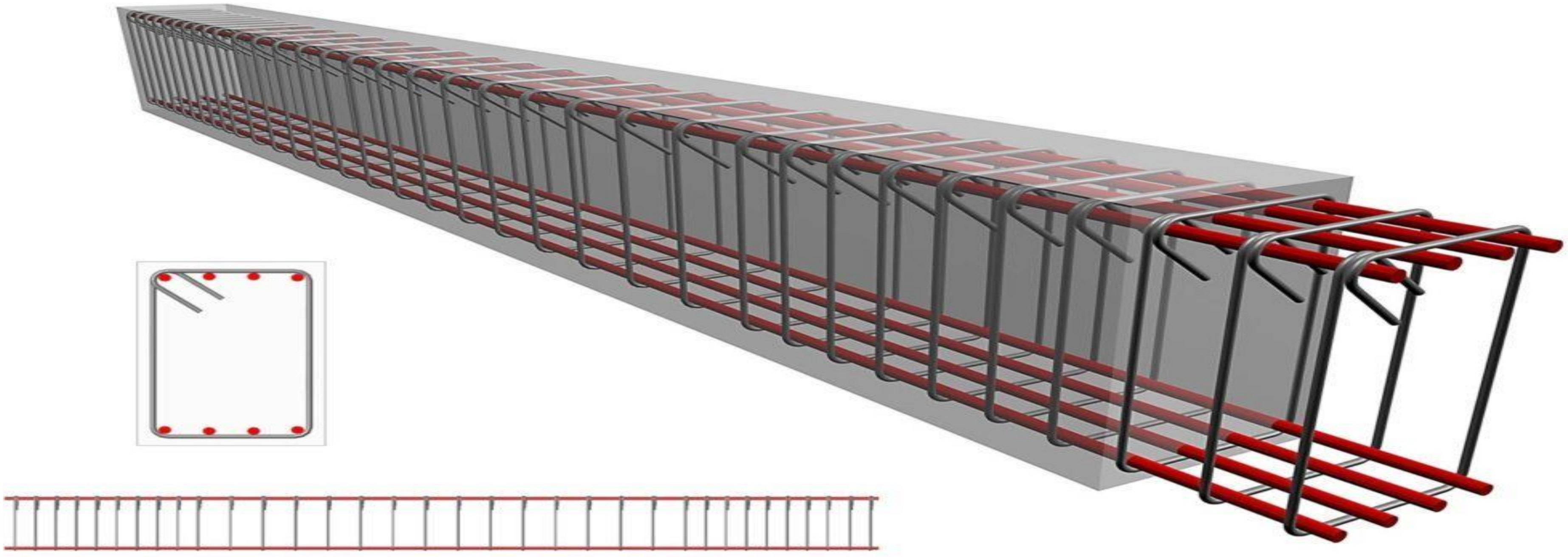
Limit State of Flexure - Beams





UNIT 1 – Limit State Method

Limit State of Flexure - Beams



UNIT 1 – Limit State Method

Limit State of Flexure - Beams

- Assumptions

1. Plane sections normal to the axis of the member remain plane during bending. This means that the strain at any point on the cross section is directly proportional to the distance from the neutral axis.

2. The maximum strain in concrete at the outermost compression fibre is 0.0035.

3. The tensile strength of concrete is ignored.

4. The strain in the tension reinforcement is to be not less than $\frac{0.87\, f_y}{E_s} + 0.002$

This assumption is intended to ensure ductile failure, that is, the tensile reinforcement has to undergo a certain degree of inelastic deformation before the concrete fails in compression.

UNIT 1 – Limit State Method

Limit State of Flexure - Beams

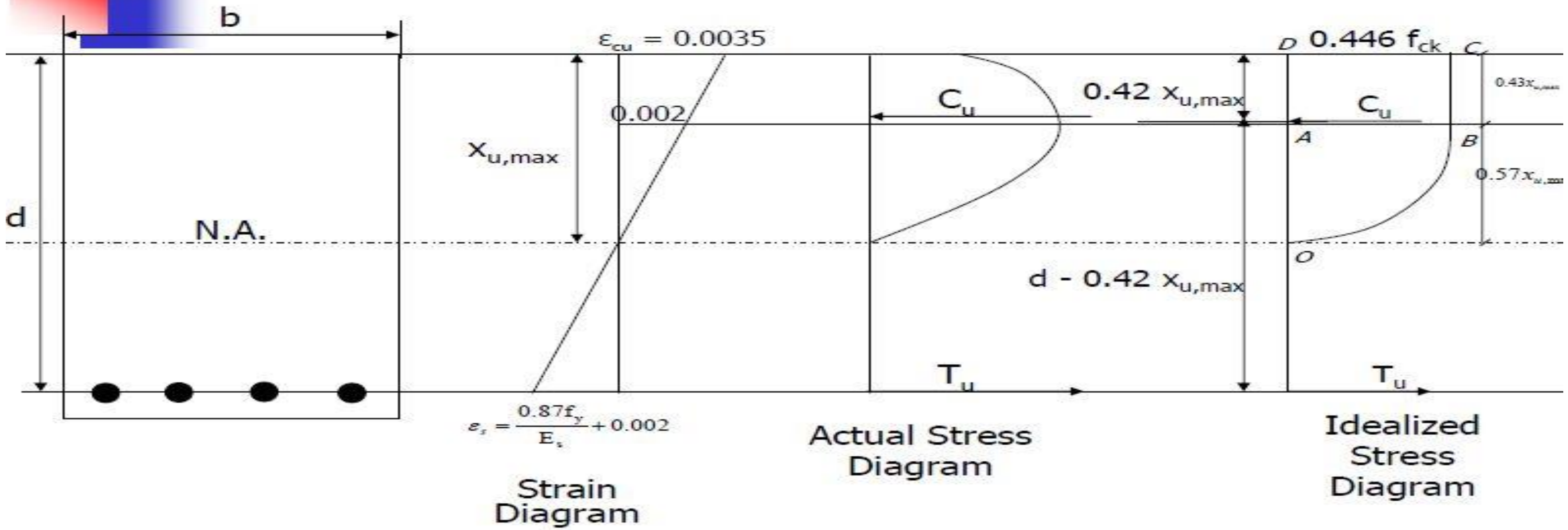


*Diagram taken from NPTEL lecture content