SNS COLLEGE OF TECHNOLOGY

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COIMBATORE

DEPARTMENT OF CIVIL ENGINEERING

19CET302 – DESIGN OF RC STRUCTURAL ELEMENTS

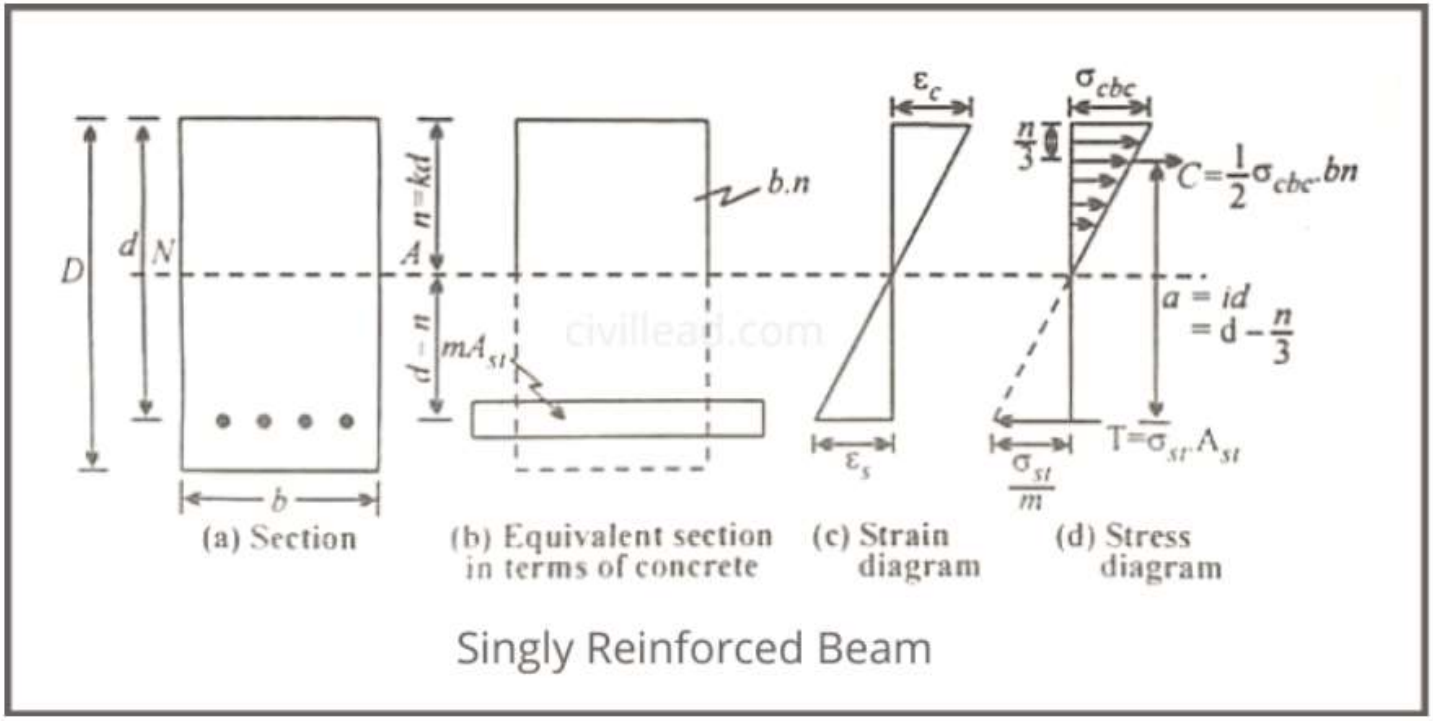
III YEAR / V SEMESTER

Unit 2 : Limit State Design of Beams

Topic 1: Design of Singly and Doubly Reinforced Beams

Singly Reinforced Beams

- A **singly reinforced** beam is one in which the concrete element is only reinforced near the tensile face and the reinforcement, called tension steel, is designed to resist the tension.

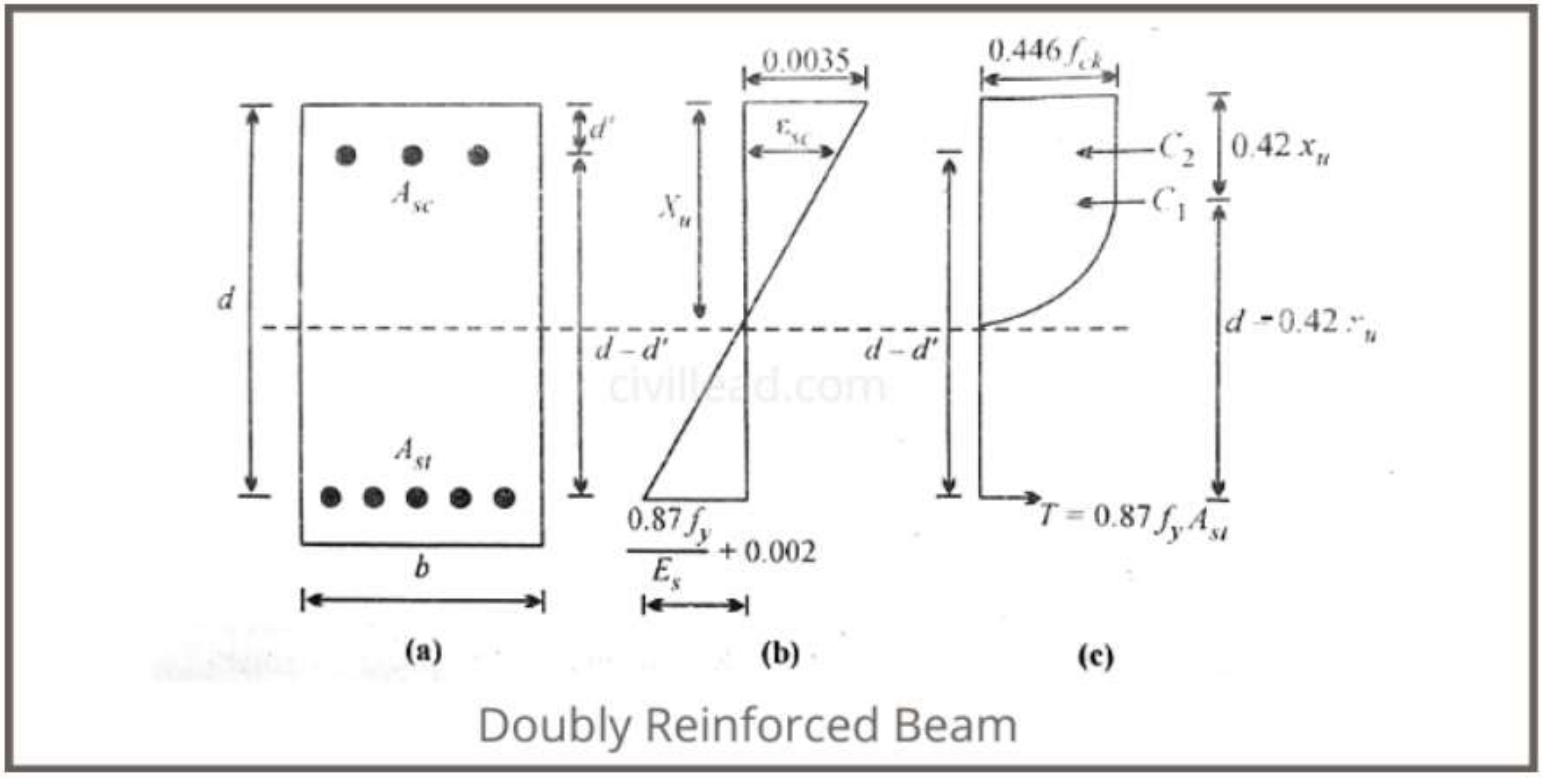


Singly Reinforced Beam

Doubly Reinforced Beams

- A **doubly reinforced** beam is one in which besides the tensile reinforcement the concrete element is also reinforced near the compressive face to help the concrete resist compression. The latter reinforcement is called compression steel.
- When the compression zone of a concrete is inadequate to resist the compressive moment (positive moment), extra reinforcement has to be provided if the architect limits the dimensions of the section.

Doubly Reinforced Beams



Doubly Reinforced Beam

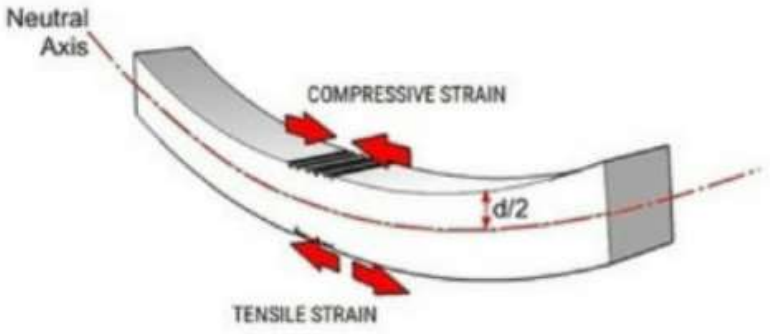
Doubly Reinforced Beams

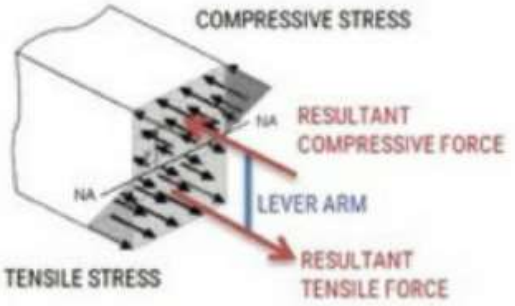
Doubly Reinforced Beams

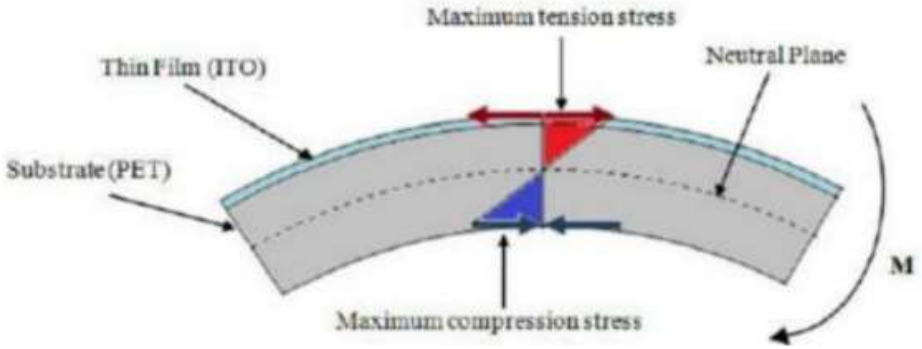
Moment of Resistance

- The algebraic sum of moments of the internal forces (compressive and tensile forces developed in the cross-section due to bending) about the neutral axis of the section is called the moment of resistance of the section.
- For equilibrium condition, the moment of resistance of a section will be equal to the applied bending moment at that section.
- The moment of resistance of a section corresponding to the maximum permissible stresses in the material is called the limiting moment of resistance of the section.
- This indicates the maximum bending moment that could be resisted by the section without the stresses exceeding the permissible values.

Moment of Resistance







Balanced Section

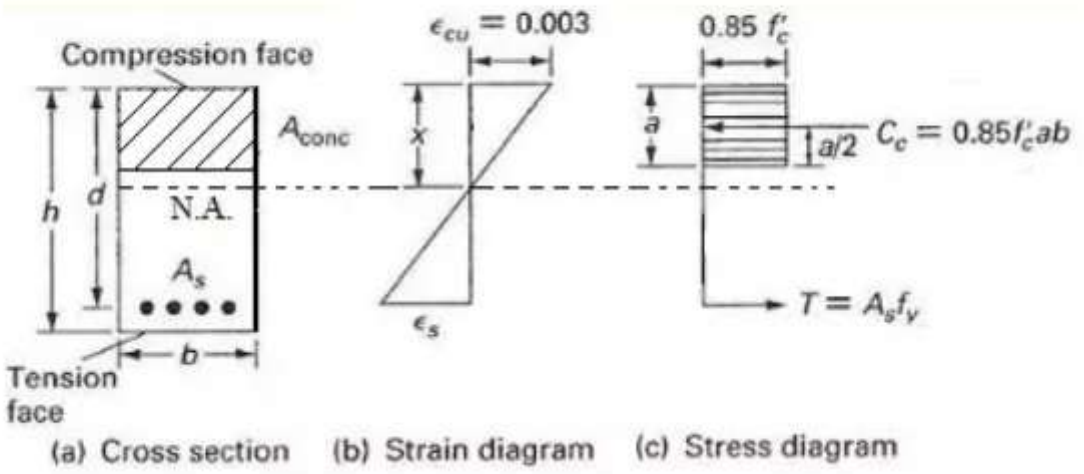
- A **balanced-reinforced** beam is one in which both the compressive and tensile zones reach yielding at the same imposed load on the beam, and the concrete will crush and the tensile steel will yield at the same time.
- This design criterion is however as risky as over-reinforced concrete, because failure is sudden as the concrete crushes at the same time of the tensile steel yields, which gives a very little warning of distress in tension failure.
- Steel-reinforced concrete moment-carrying elements should normally be designed to be under-reinforced so that users of the structure will receive warning of impending collapse.

Balanced Section

- The stresses in concrete and steel reach to permissible values at the same time.
- concrete and steel theoretically fail at the same time.
- Practically it is difficult to have a balanced section.
- Theoretically all the sections designed are balanced sections.
- The failure is by primary compression(In practise the ultimate failure is by crashing of concrete in compression zone only, even though beam is balanced section is called primary compression).
- **Xu=Xumax**

Balanced Section

STRESS AND STRAIN DISTRIBUTION FOR BALANCED SECTION:



Balanced Section

- **Xumax** is the maximum depth of neutral axis at failure condition at which concrete reaches to a maximum strain of 0.0035, At this condition steel will be in plastic zone with continuous yielding or deformation.
- ***Xumax Equation*: Xumax / 0.0035 = d-xumax / (0.87fy/Es + 0.002)**

GRADE OF STEEL	Xumax	Mu limit
Fe 250	0.53d	$0.148*f_{ck}bd^2$
Fe 415	0.48d	$0.138*f_{ck}bd^2$
Fe 500	0.46d	$0.133*f_{ck}bd^2$

Balanced Section

- *Mu limit* is Moment of resistance of balanced section.
- **Xu** is the Neutral axis at general loading condition where concrete and steel might not have reached their maximum strains ,how ever at collapse Xu will be equal to Xumax
- i.e Compressive force = Tensile force. (0.36*fck*b*Xu=0.87*fy*Ast)
- ***Xu Equation*: Xu= (0.87*fy*Ast)/(0.36*fck*b)**

Under Reinforced Section

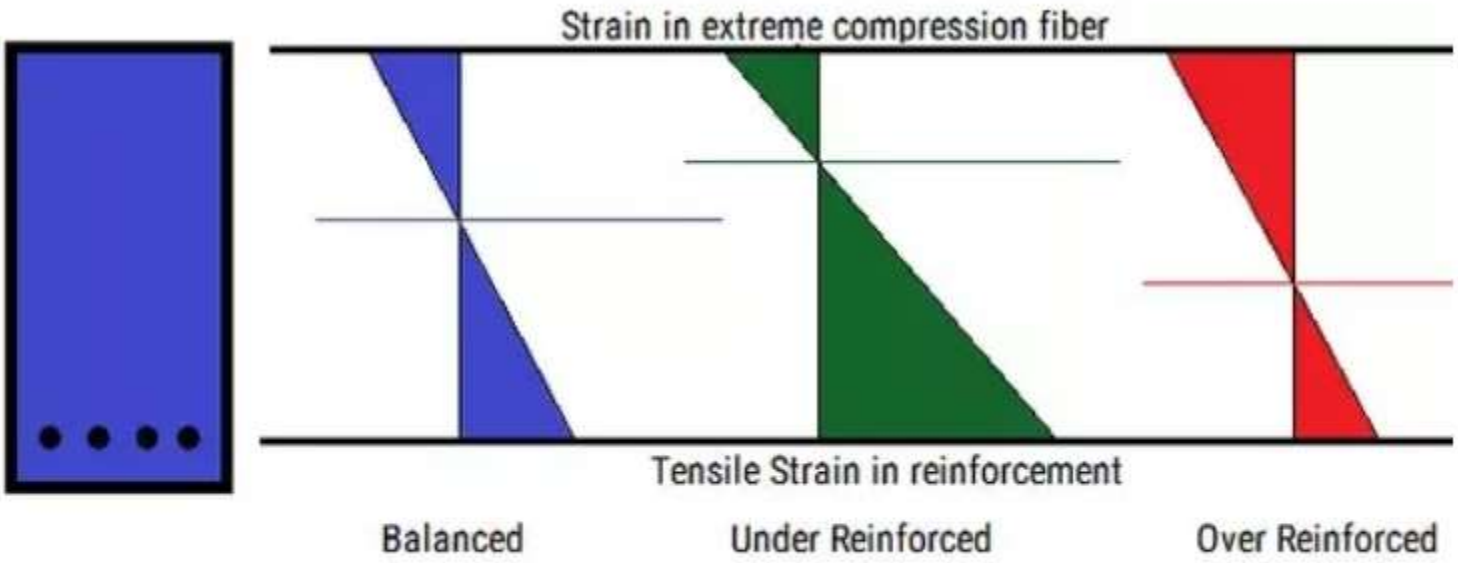
- An **under-reinforced** beam is one in which the tension capacity of the tensile reinforcement is smaller than the combined compression capacity of the concrete and the compression steel (under-reinforced at tensile face).
- When the reinforced concrete element is subject to increasing bending moment, the tension steel yields while the concrete does not reach its ultimate failure condition.
- As the tension steel yields and stretches, an “under-reinforced” concrete also yields in a ductile manner, exhibiting a large deformation and warning before its ultimate failure.
- In this case the yield stress of the steel governs the design.

Under Reinforced Section

- Reinforcement available in the beam is less than that of a balanced section, i.e **Xu < Xumax .**
- Failure is in steel ,causes a ductile failure and gives clear warning before failure.
- Most of the practical sections are under reinforced sections.
- Failure is by primary tension.

Over Reinforced Section

- An **over-reinforced** beam is one in which the tension capacity of the tension steel is greater than the combined compression capacity of the concrete and the compression steel (over-reinforced at tensile face).
- So the "over-reinforced concrete" beam fails by crushing of the compressive-zone concrete and before the tension zone steel yields, which does not provide any warning before failure as the failure is instantaneous.
- Steel in the section is more than that of required for a balanced section, i.e **Xu > Xumax.**
- Failure is in concrete , causes a brittle/sudden failure without any prior warning
- As per Limit state method of design of over reinforced sections should be avoided


Strain in extreme compression fiber
Tensile Strain in reinforcement
Balanced
Under Reinforced
Over Reinforced

Span to Depth Ratio

Table 8.1 Span/Depth ratios for Trial Section

Sl. No.	Span Range	Loading	Span/Depth ratio (*L/d*)
1	3 to 4m	Light	15 to 20
2	5 to 10	Medium to Heavy	12 to 15
3	> 10m	Heavy	12

Thank You!!