

DESIGN OF SINGLY REINFORCED BEAM

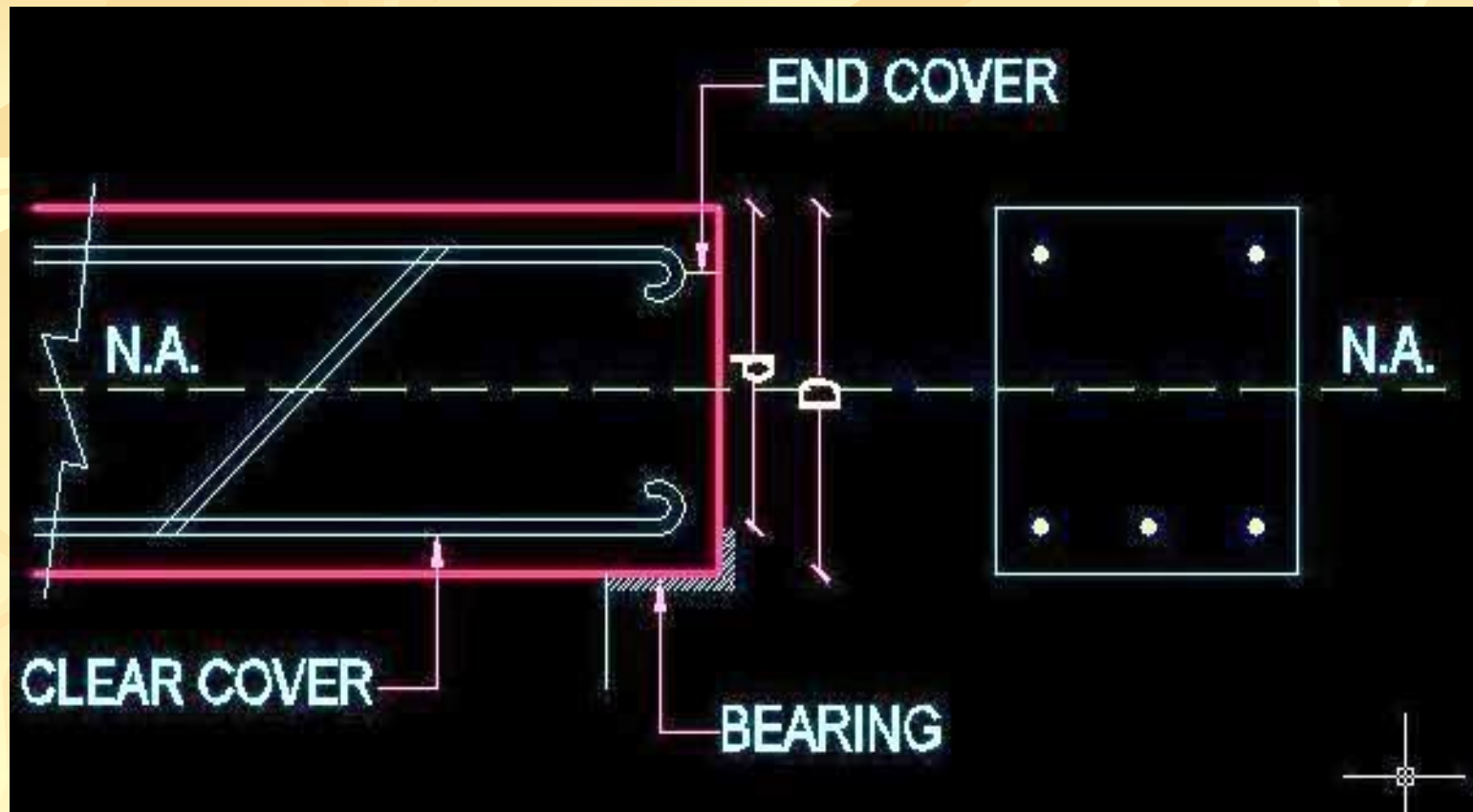
BEAM:-

*A Beam is any structural member which resists load mainly by bending. Therefore it is also called flexural member. Beam may be singly reinforced or doubly reinforced. When steel is provided only in tensile zone (i.e. below neutral axis) is called **singly reinforced beam**, but when steel is provided in tension zone as well as compression zone is called **doubly reinforced beam**.*

The aim of design is:

- *To decide the size (dimensions) of the member and the amount of reinforcement required.*
- *To check whether the adopted section will perform safely and satisfactorily during the life time of the structure.*

FEW DEFINITIONS



OVER ALL DEPTH :-

THE NORMAL DISTANCE FROM THE TOP EDGE OF THE BEAM TO THE BOTTOM EDGE OF THE BEAM IS CALLED OVER ALL DEPTH. IT IS DENOTED BY 'D'.

EFFECTIVE DEPTH:-

THE NORMAL DISTANCE FROM THE TOP EDGE OF BEAM TO THE CENTRE OF TENSILE REINFORCEMENT IS CALLED EFFECTIVE DEPTH. IT IS DENOTED BY 'd'.

CLEAR COVER:-

THE DISTANCE BETWEEN THE BOTTOM OF THE BARS AND BOTTOM MOST THE EDGE OF THE BEAM IS CALLED CLEAR COVER.

CLEAR COVER = 25mm OR DIA OF MAIN BAR, (WHICH EVER IS GREATER).

EFFECTIVE COVER:-

THE DISTANCE BETWEEN CENTRE OF TENSILE REINFORCEMENT AND THE BOTTOM EDGE OF THE BEAM IS CALLED EFFECTIVE COVER.

EFFECTIVE COVER = CLEAR COVER + $\frac{1}{2}$ DIA OF BAR.

END COVER:-

END COVER = 2XDIA OF BAR OR 25mm (WHICH EVER IS GREATER)

NEUTRAL AXIS:- THE LAYER / LAMINA WHERE NO STRESS EXIST IS KNOWN AS NEUTRAL AXIS. IT DIVIDES THE BEAM SECTION INTO TWO ZONES, COMPRESION ZONE ABOVE THE NETURAL AXIS & TENSION ZONE BELOW THE NEUTRAL AXIS.

DEPTH OF NEUTRAL AXIS:- THE NORMAL DISTANCE BETWEEN THE TOP EDGE OF THE BEAM & NEUTRAL AXIS IS CALLED DEPTH OF NEUTRAL AXIS. IT IS DENOTED BY 'n'.

LEVER ARM:- THE DISTANCE BETWEEN THE RESULTANT COMPRESSIVE FORCE (C) AND TENSILE FORCE (T) IS KNOWN AS LEVER ARM. IT IS DENOTED BY 'z'. THE TOTAL COMPRESSIVE FORCE (C) IN CONCRETE ACT AT THE C.G. OF COMPRESSIVE STRESS DIAGRAM i.e. $n/3$ FROM THE COMPRESSION EDGE. THE TOTAL TENSILE FORCE (T) ACTS AT C.G. OF THE REINFORCEMENT.

$$\text{LEVER ARM} = d - n/3$$

TENSILE REINFORCEMENT:-

THE REINFORCEMENT PROVIDED TENSILE ZONE IS CALLED TENSILE REINFORCEMENT. IT IS DENOTED BY A_{st}

COMPRESSION REINFORCEMENT :-

THE REINFORCEMENT PROVIDED COMPRESSION ZONE IS CALLED COMPRESSION REINFORCEMENT. IT IS DENOTED BY A_{sc}

TYPES OF BEAM SECTION:- THE BEAM SECTION CAN BE OF THE FOLLOWING TYPES:

1. BALANCED SECTION

2. UNBALANCED SECTION

(a) UNDER-REINFORCED SECTION

(b) OVER-REINFORCED SECTION

1. BALANCED SECTION:- A SECTION IS KNOWN AS BALANCED SECTION IN WHICH THE COMPRESSIVE STRESS IN CONCRETE (IN COMPRESSIVE ZONES) AND TENSILE STRESS IN STEEL WILL BOTH REACH THE MAXIMUM PERMISSIBLE VALUES SIMULTANEOUSLY.

THE NEUTRAL AXIS OF BALANCED (OR CRITICAL) SECTION IS KNOWN AS CRITICAL NEUTRAL AXIS (n_c). THE AREA OF STEEL PROVIDED AS ECONOMICAL AREA OF STEEL. REINFORCED CONCRETE SECTIONS ARE DESIGNED AS BALANCED SECTIONS.

2. UNBALANCED SECTION:-THIS IS A SECTION IN WHICH THE QUANTITY OF STEEL PROVIDED IS DIFFERENT FROM WHAT IS REQUIRED FOR THE BALANCED SECTION.

UNBALANCED SECTIONS MAY BE OF THE FOLLOWING TWO TYPES:

- (a) UNDER-REINFORCED SECTION
- (b) OVER-REINFORCED SECTION

(a) UNDER-REINFORCED SECTION:- IF THE AREA OF STEEL PROVIDED IS LESS THAN THAT REQUIRED FOR BALANCED SECTION, IT IS KNOWN AS UNDER-REINFORCED SECTION. DUE TO LESS REINFORCEMENT THE POSITION OF ACTUAL NEUTRAL AXIS (n) WILL SHIFT ABOVE THE CRITICAL NEUTRAL AXIS (n_c) i.e. $n < n_c$. IN UNDER-REINFORCED SECTION STEEL IS FULLY STRESSED AND CONCRETE IS UNDER STRESSED (i.e. SOME CONCRETE REMAINS UN-UTILISED). STEEL BEING DUCTILE, TAKES SOME TIME TO BREAK. THIS GIVES SUFFICIENT WARNING BEFORE THE FINAL COLLAPSE OF THE STRUCTURE. FOR THIS REASON AND FROM ECONOMY POINT OF VIEW THE UNDER-REINFORCED SECTIONS ARE DESIGNED.

(b) OVER-REINFORCED SECTION:- IF THE AREA OF STEEL PROVIDED IS MORE THAN THAT REQUIRED FOR A BALANCED SECTION, IT IS KNOWN AS OVER-REINFORCED SECTION. AS THE AREA OF STEEL PROVIDED IS MORE, THE POSITION OF N.A. WILL SHIFT TOWARDS STEEL, THEREFORE ACTUAL AXIS (n) IS BELOW THE CRITICAL NEUTRAL AXIS (n_c) i.e. $n > n_c$. IN THIS SECTION CONCRETE IS FULLY STRESSED AND STEEL IS UNDER STRESSED. UNDER SUCH CONDITIONS, THE BEAM WILL FAIL INITIALLY DUE TO OVER STRESS IN THE CONCRETE. CONCRETE BEING BRITTLE, THIS HAPPENS SUDDENLY AND EXPLOSIVELY WITHOUT ANY WARNING.

Basic rules for design of beam:-

1. **Effective span:-** In the case of simply supported beam the effective length,

$l = i.$ Distance between the centre of support

ii. Clear span + eff. Depth

eff. Span = least of i. & ii.

2. **Effective depth:-** The normal distance from the top edge of beam to the centre of tensile reinforcement is called effective depth. It is denoted by 'd'.

$d = D - \text{effect. Cover}$

where $D = \text{over all depth}$

3. Bearing :- Bearings of beams on brick walls may be taken as follow:

- Up to 3.5 m span, bearing = 200mm
- Up to 5.5 m span, bearing = 300mm
- Up to 7.0 m span, bearing = 400mm

4. Deflection control:- The vertical deflection limits assumed to be satisfied if **(a)** For span up to 10m

$$\text{Span / eff. Depth} = 20$$

(For simply supported beam)

$$\text{Span / eff. Depth} = 7$$

(For cantilever beam)

(b) For span above 10m, the value in (a) should be multiplied by 10/span (m), except for cantilever for which the deflection calculations should be made.

(c) Depending upon the area and type of steel the value of (a&b) modified as per modification factor.

5. Reinforcement :-

(a) Minimum reinforcement:- The minimum area of tensile reinforcement shall not be less than that given by the following:

$$A_{st} = 0.85 bd / f_y$$

(b) Maximum reinforcement:- The maximum area of tensile reinforcement shall not be more than $0.4bD$

(c) Spacing of reinforcement bars:-

i. The horizontal distance between to parallel main bars shall not be less than the greatest of the following:

- Diameter of the bar if the bars are of same diameter.*
- Diameter of the larger bar if the diameter are unequal.*
- 5mm more than the nominal maximum size of coarse aggregate.*

ii. When the bars are in vertical lines and the minimum vertical distance between the bars shall be greater of the following:

- 15mm.*
- $2/3^{\text{rd}}$ of nominal maximum size of aggregate.*
- Maximum diameter of the bar.*

6. Nominal cover to reinforcement :- *The Nominal cover is provided in R.C.C. design:*

- To protect the reinforcement against corrosion.*
- To provide cover against fire.*
- To develop the sufficient bond strength along the surface area of the steel bar.*

As per IS 456-2000, the value of nominal cover to meet durability requirements as follow:-

<i>Exposure conditions</i>	<i>Nominal cover(mm) Not less than</i>
<i>Mild</i>	20
<i>Moderate</i>	30
<i>Severe</i>	45
<i>Very severe</i>	50
<i>Extreme</i>	75

Procedure for Design of Singly Reinforced Beam by Working Stress Method

Given :

- (i) Span of the beam (l)
 - (ii) Loads on the beam
 - (iii) Materials-Grade of Concrete and type of steel.
- 1.** Calculate design constants for the given materials (k, j and R)

$$k = m \sigma_{cbc} / m \sigma_{cbc} + \sigma_{st}$$

where k is coefficient of depth of Neutral Axis

$$j = 1 - k/3$$

where j is coefficient of lever arm.

$$R = 1/2 \sigma_{cbc} k j$$

where R is the resisting moment factor.

2. *Assume dimension of beam:*

$$d = \text{Span}/10 \text{ to } \text{Span}/8$$

Effective cover = 40mm to 50mm

$$b = D/2 \text{ to } 2/3D$$

3. *Calculate the effective span (l) of the beam.*

4. *Calculate the self weight (dead load) of the beam.*

$$\text{Self weight} = D \times b \times 25000 \text{ N/m}$$

5. Calculate the total Load & maximum bending moment for the beam.

Total load (w) = live load + dead load

Maximum bending moment, $M = wl^2 / 8$ at the centre of beam for simply supported beam.

$M = wl^2 / 2$ at the support of beam for cantilever beam.

6. Find the minimum effective depth

$$\begin{aligned} M &= M_r \\ &= Rbd^2 \end{aligned}$$

$$d_{reqd.} = \sqrt{M / R.b}$$

7. Compare $d_{reqd.}$ With assumed depth value.

(i) If it is less than the assumed d , then assumption is correct.

(ii) If $d_{reqd.}$ is more than assumed d , then revise the depth value and repeat steps 4, 5 & 6.

8. Calculate the area of steel required (A_{st}).

$$A_{st} = M / \sigma_{st} jd$$

Selecting the suitable diameter of bar calculate the number of bars required

$$\text{Area of one bar} = \pi/4 \times \phi^2 = A\phi$$

$$\text{No. of bars required} = A_{st} / A\phi$$

9. Calculate minimum area of steel (A_s) required by the relation:

$$A_s = 0.85 bd / f_y$$

Calculate maximum area of steel by the area relation:

$$\text{Maximum area of steel} = 0.04bD$$

Check that the actual A_{st} provided is more than minimum and less than maximum requirements.

- 10.** *Check for shear and design shear reinforcement.*
- 11.** *Check for development length.*
- 12.** *Check for depth of beam from deflection.*
- 13.** *Write summary of design and draw a neat sketch.*