

DEEP - BEAMS

Introduction

- span/depth ratio of simply supported beam is < 2 , continuous beam < 2.5 , it is classified as deep beam.
- Such structures are found in transfer girders and in shear wall structures that resist lateral forces in buildings. It is also found in some of the industrial buildings.



Introduction.....

The traditional principles of stress analysis are neither suitable nor adequate to determine the strength of reinforced concrete deep beams.

In deep beams, the bending stress distribution across any transverse section deviates appreciably from straight line distribution assumed in the elementary beam theory.

Behaviour.....

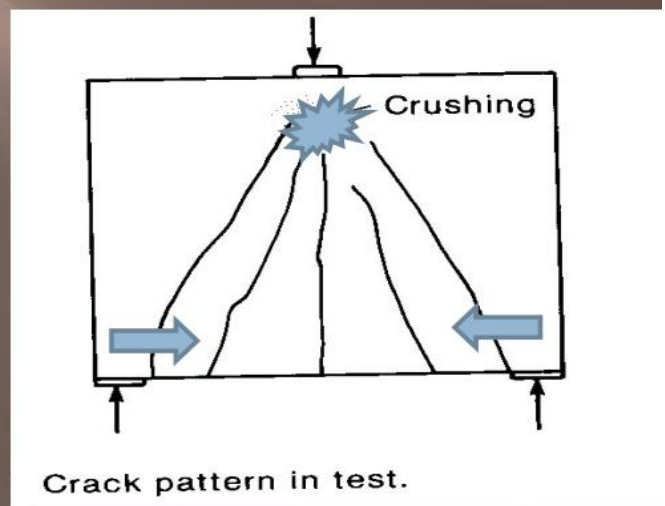
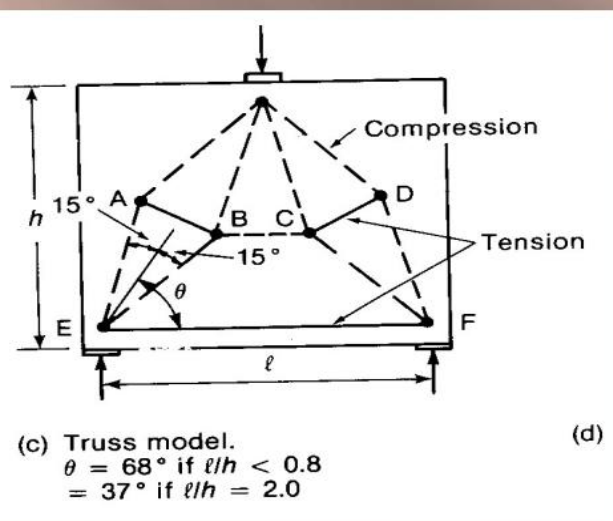
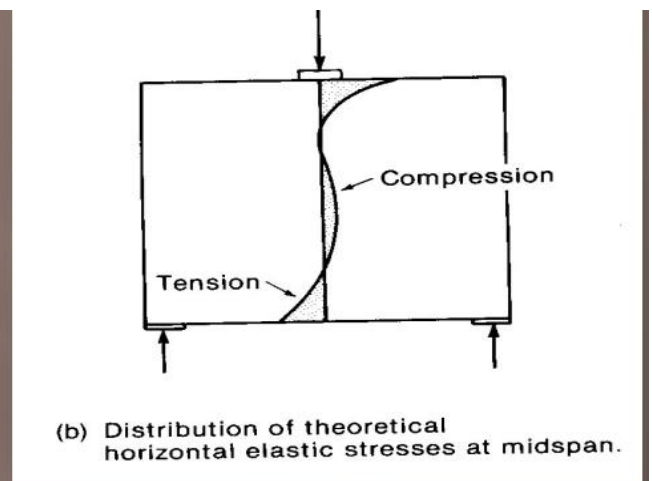
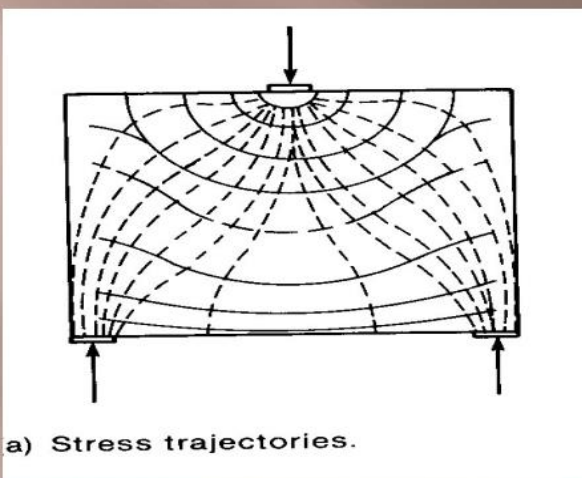
The behaviour of a deep beam depends also on how they are loaded & special considerations should be given to this aspect in design.

Here cracking will occur at one-third to one-half of the ultimate load.

In the single span beam supporting a concentrated load at mid span, the compressive stresses act roughly parallel to the lines joining the

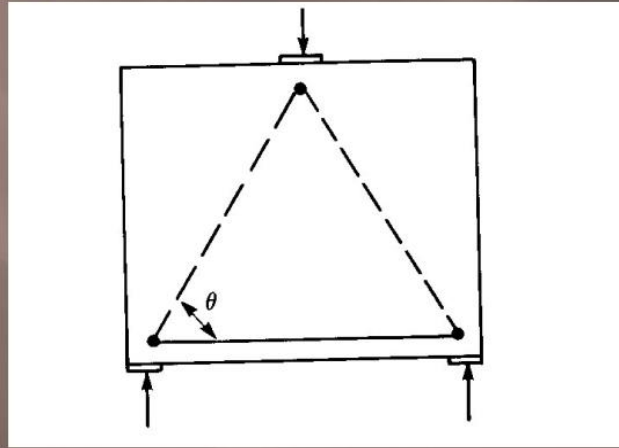
load and the supports and the tensile stresses act parallel to the bottom of the beam.

- The flexural stresses at the bottom is constant over much of the span.
- The figure shows the crack pattern and the truss analogy of the same.

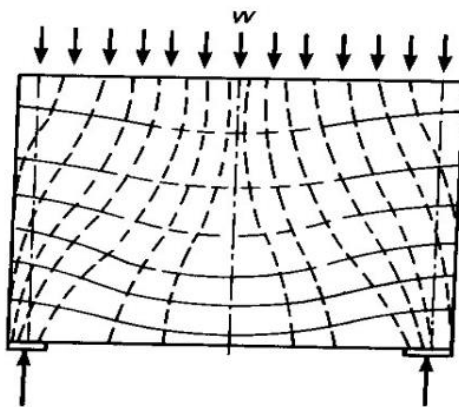


Each of the three tension AB, CD and EF ties have cracked and at failure shaded region would crush or the anchorage zones at E and F would fail.

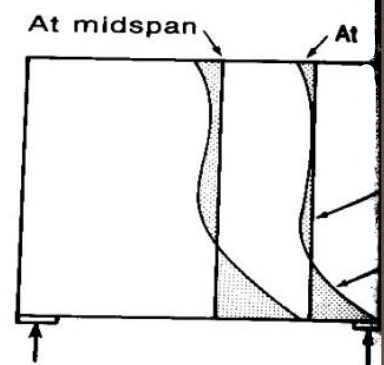
simplified truss model



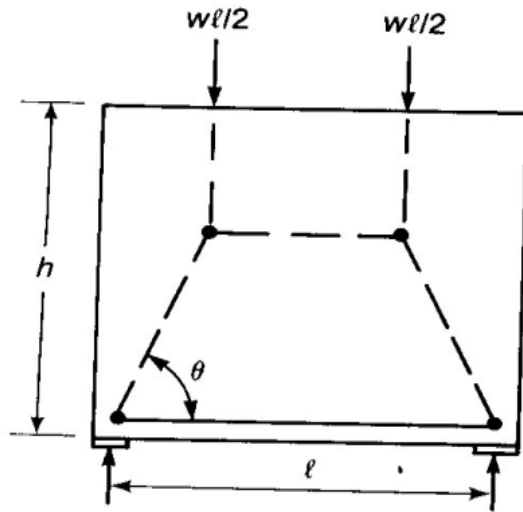
- A single span beam supporting a uniform load acting on the top has the stress trajectories, crack pattern and simplified truss as shown.



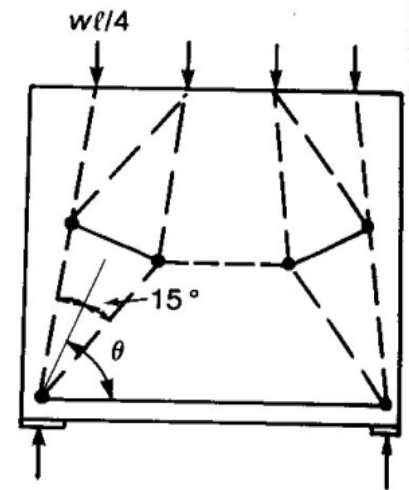
(a) Stress trajectories.



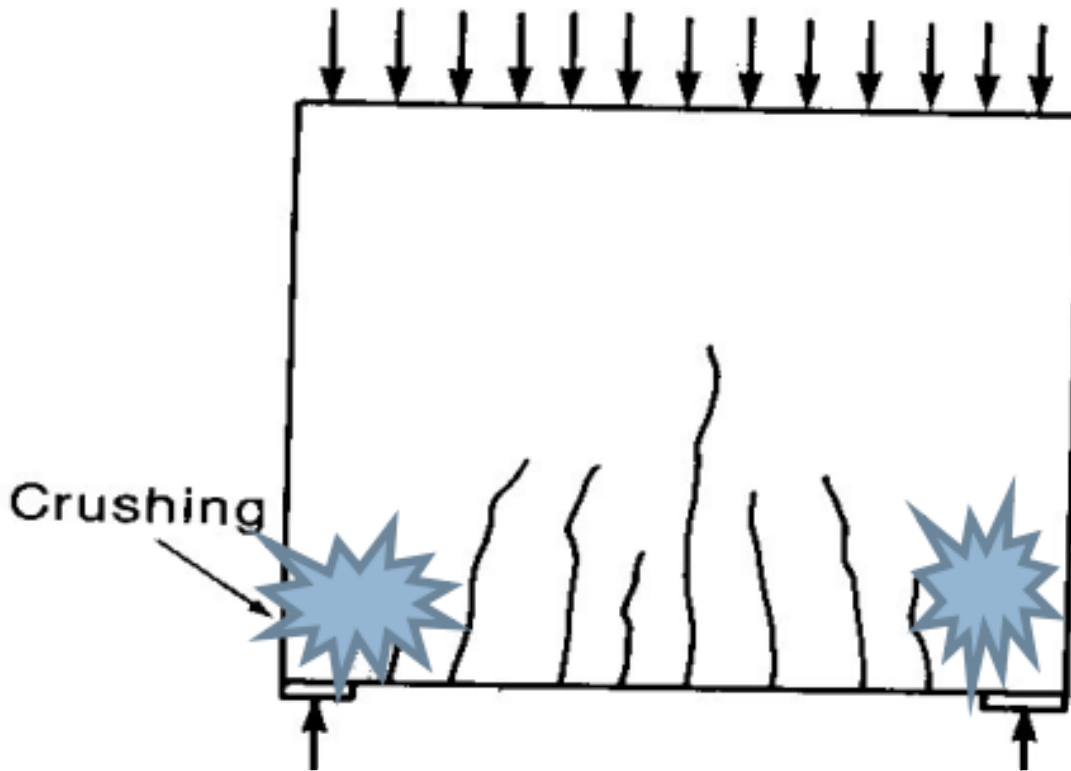
(b) Distribution of theoretical horizontal elastic stresses.



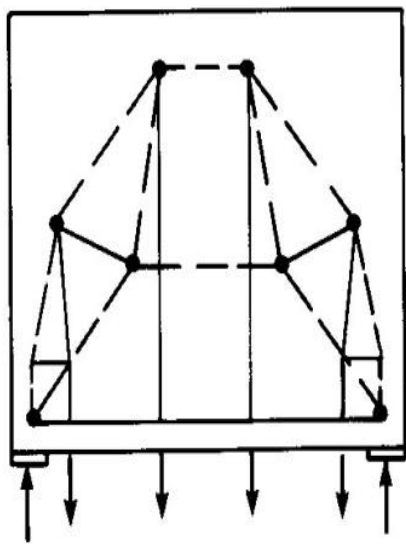
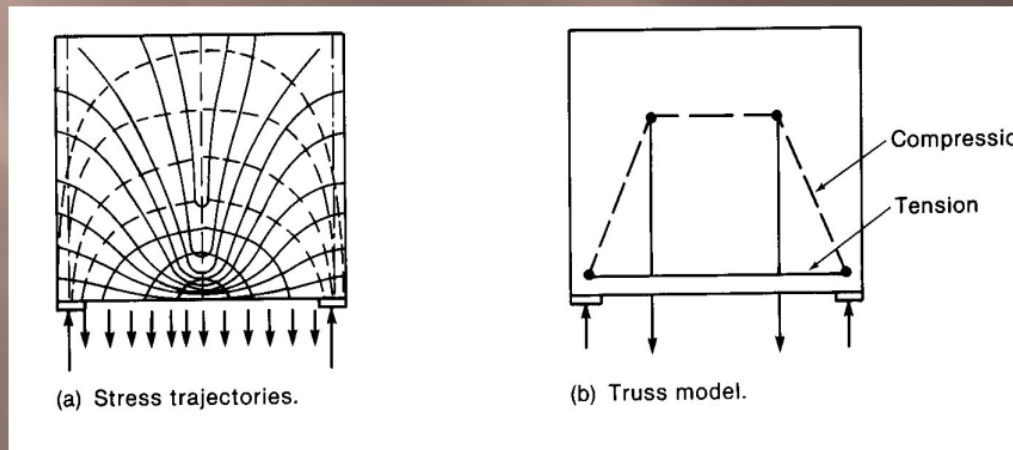
(c) Truss model.
 $\theta = 68^\circ$ if $\ell/h \leq 1$
 $= 54^\circ$ if $\ell/h = 2$



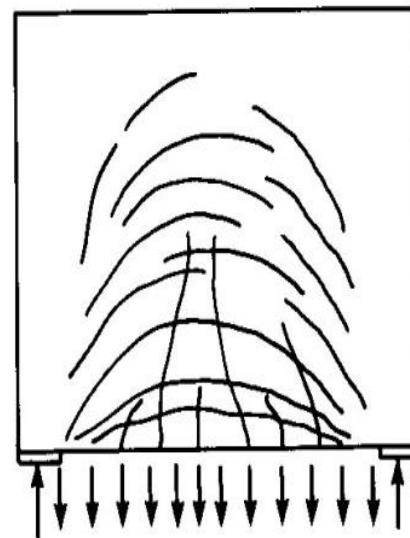
(d) Refined truss model.



- A single span beam supporting a uniform load acting on the lower face of the beam has the stress trajectories , crack pattern and simplified truss as shown.

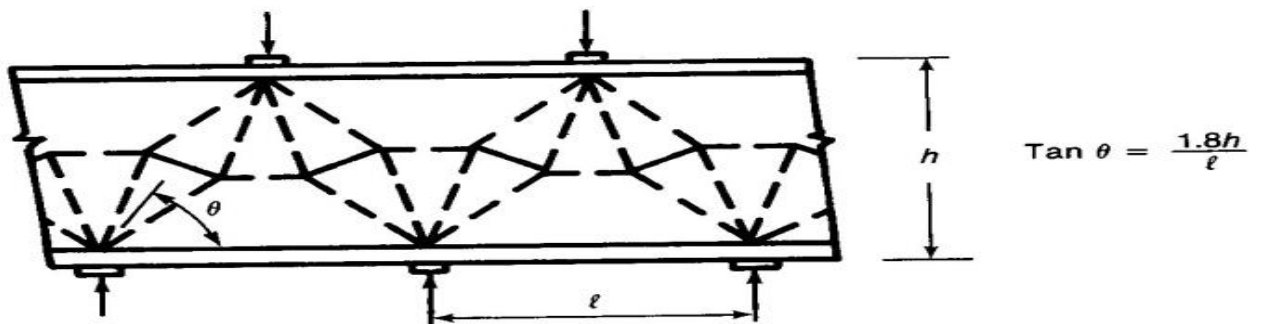


(c) Refined truss model.

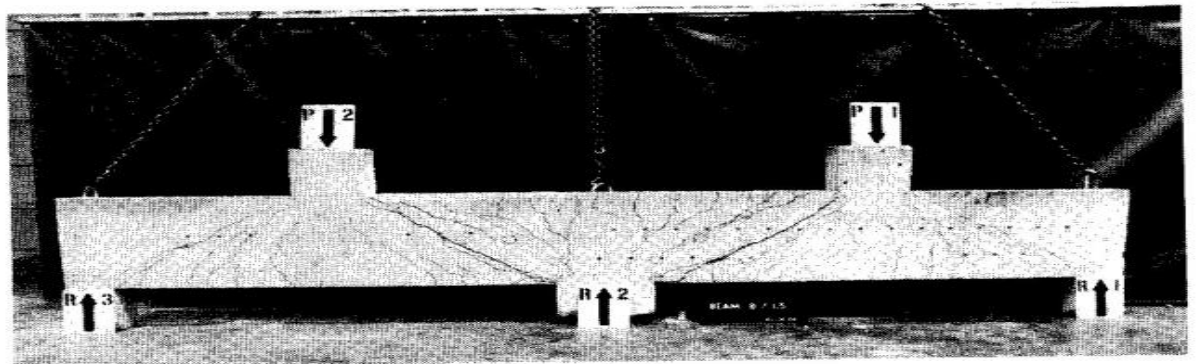


(d) Crack pattern.

- The compression trajectories form an arch with the loads hanging from it. The crack pattern shows that the load is transferred upward by reinforcement until it acts on the compression arch, which then transfers the load down to the supports.
- The force in the longitudinal tension ties will be constant along the length of the deep beam. This is the reason that the steel must be anchored at the joints over the reaction, failure of which is a major cause of distress



(b) Truss model.



(d) Crack pattern in a two-span beam.

Parameters influencing

- Parameters influencing deep beam behavior are:
 - Width of support = C
 - Overall depth of beam = D
 - Effective span = L
 - Width / Thickness of beam = t
 - Type of loading, uniform = w

Minimum Thickness

The Min. thickness of deep beams should be based on two considerations:

1. It should be thick enough to prevent buckling with respect to its span & height i.e.

$$\frac{D}{t} < 25 \ \& \ \frac{L}{t} < 50$$

where t = thickness of beam.

2. The thickness should be such that the concrete itself should be able to carry a good amount of the shear force that acts in the beam without the assistance of any steel.

Design for flexure

- $Z = 0.6L$ or $0.6D$
- i.e. $Z = 0.6L$ when $L/D < 1$
- & $Z = 0.6D$ when $L/D > 1$

Design for flexure

- From those values,

$$M_u = A_s \cdot f_s \cdot Z \quad \text{where } f_s = 0.87 f_y$$

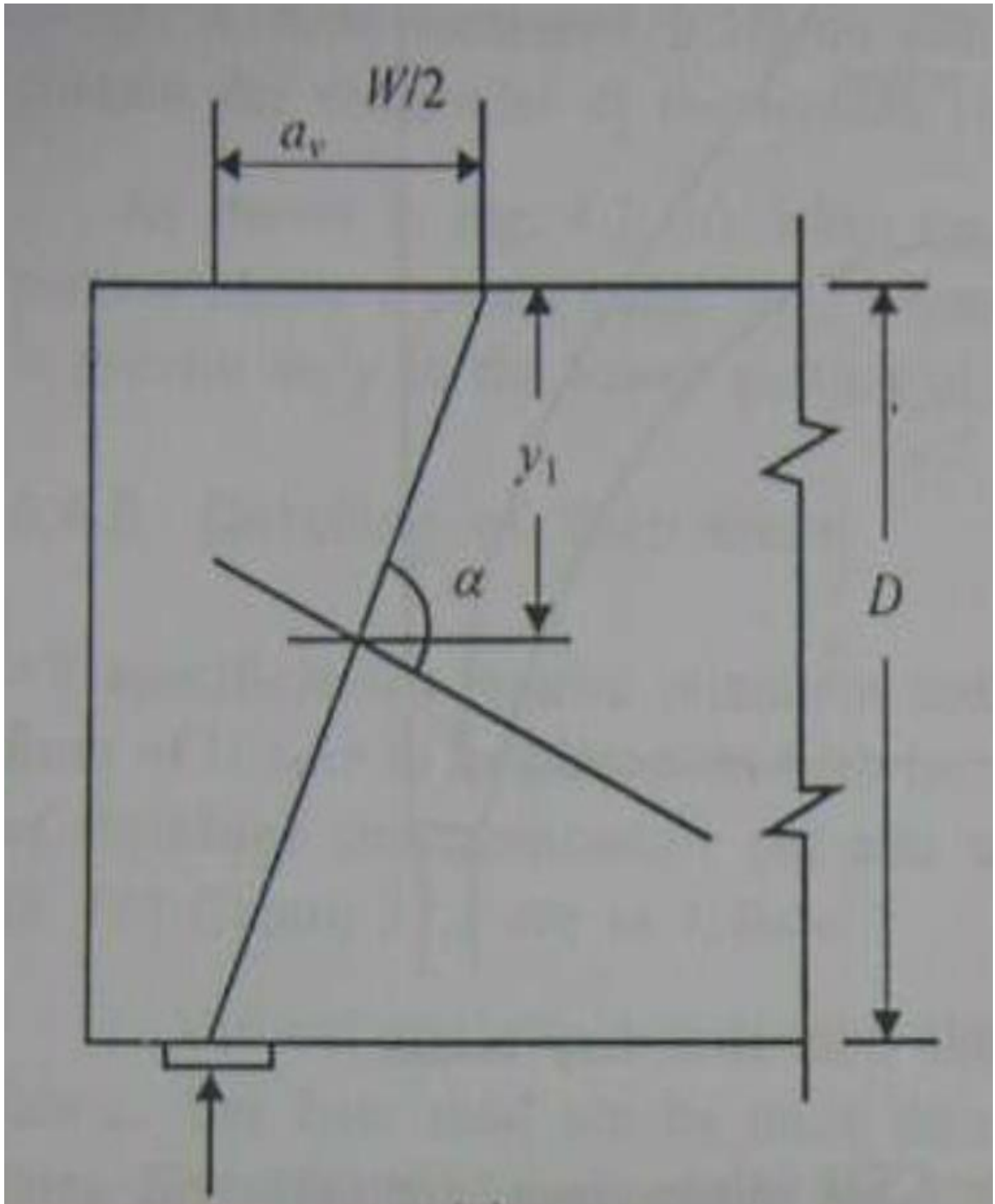
$$A_s = \frac{M_u}{f_s \cdot Z} = \frac{M_u}{(0.87 f_y)(0.6D)} = \frac{1.9 M_u}{f_y D}$$

or

$$A_s = \frac{M_u}{(0.87 f_y)(0.6L)} = \frac{1.9 M_u}{f_y \cdot L}$$

- The greater value of A_s is taken as tension steel.

Design for shear



Design for shear

□ Design procedure :

a) Determine Nominal Shear

$$T_v = \frac{V_u}{t.Du} \text{ where } T_v < T_{\max}$$

b) $V_u = V_c + V_s$

c) $V_c = C_1 \left[1 - 0.35 \frac{av}{D} \right] ft.t.D$ where

$C_1 = C_o$ – eff. equal to 0.72 for normal wt. concrete

$$\frac{av}{D} = \frac{\text{Shear span}}{\text{Depth}}$$

$ft = 0.5\sqrt{fck}$, the tensile strength.

Hence, the equation becomes

$$V_c = 0.72(D - 0.35av) ft.t$$

□ When designing for shear, it is assumed that concrete itself should carry at least 65% of the ultimate shear.

□ This is ensured by choosing a suitable thk. of beam by the following formula :

$$t = \frac{0.65V_u}{0.72(D - 0.35av) ft}$$

- Shear capacities of tension steel & nominal web steel should also be taken into account in resisting the shear. Their shear capacity is calculated as :

$$V_s = C_2 \sum_1^n A_s \cdot \frac{y_1}{D} \sin^2 \alpha$$

where,

$C_2 = 225 \text{ N/mm}^2$ for Fe415

A_s = Area of tension steel provided.

α = Angle between the bar considered & the critical diagonal crack.

y_1 = Depth from the top of the beam to the point where bar intersects the critical diagonal crack line.

n = Number of bars including tension steel cut by the assumed crack line

D = Total depth of beam

Web steel / side reinforcement

- Vertical steel A_v and Horizontal steel A_h
- Horizontal steel bars acts as shear reinforcement and also overcome the effects of shrinkage & temperature.
- The amounts specified in IS:456-2000 are :
 - a) Vertical steel shall be 0.12% for Fe415, the bar diameter shall not be more than 14mm and spacing not more than 3x thk. of beam or 450mm.
 - b) Horizontal steel shall be 0.20% for Fe415, the bar diameter shall not be more than 16mm & spacing not more than 3x thk. of beam or 450mm.
 - c) Necessary side reinforcement should also be provided.

Detailing

Detailing of tension steel:

- In deep beams, the tension steel is placed in a zone of depth equal to $(0.25D-0.05L)$ adjacent to the face of beam.
- No curtailment of the bars. It should be bent upwards at the ends to obtain adequate anchorage & embedment .

Steps for designing deep beams

1. Determine whether the given beam is deep or not.
2. Check its thickness.
3. Design for flexure.
4. Design for minimum web steel & its distribution in the beam.
5. Design for shear.
6. Check for bearing pressure at support & point loading for local failures.
7. Detailing (BRITISH PRACTICE)