Design of Beam in Shear

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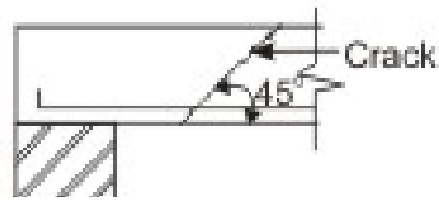
Introduction

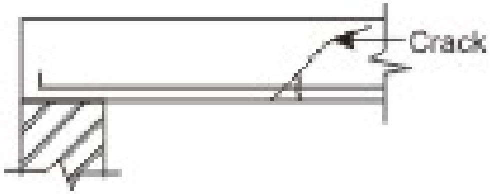
- It explains the three failure modes due to shear force in beams and defines different shear stresses needed to design the beams for shear.
- The critical sections for shear and the minimum shear reinforcement to be provided in beams are mentioned as per IS 456.
- The design of shear reinforcement has been illustrated in Lesson 14 through several numerical problems including the curtailment of tension reinforcement in flexural members.

Failure Modes due to shear

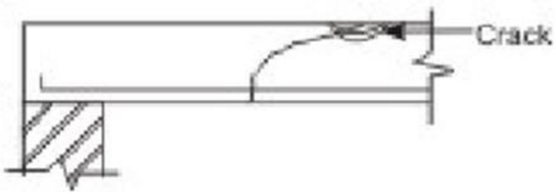
- Bending in reinforced concrete beams is usually accompanied by shear, the exact analysis of which is very complex.
- However, experimental studies confirmed the following three different modes of failure due to possible combinations of shear force and bending moment at a given section.
- Web Shear:



- Flexural Tension:

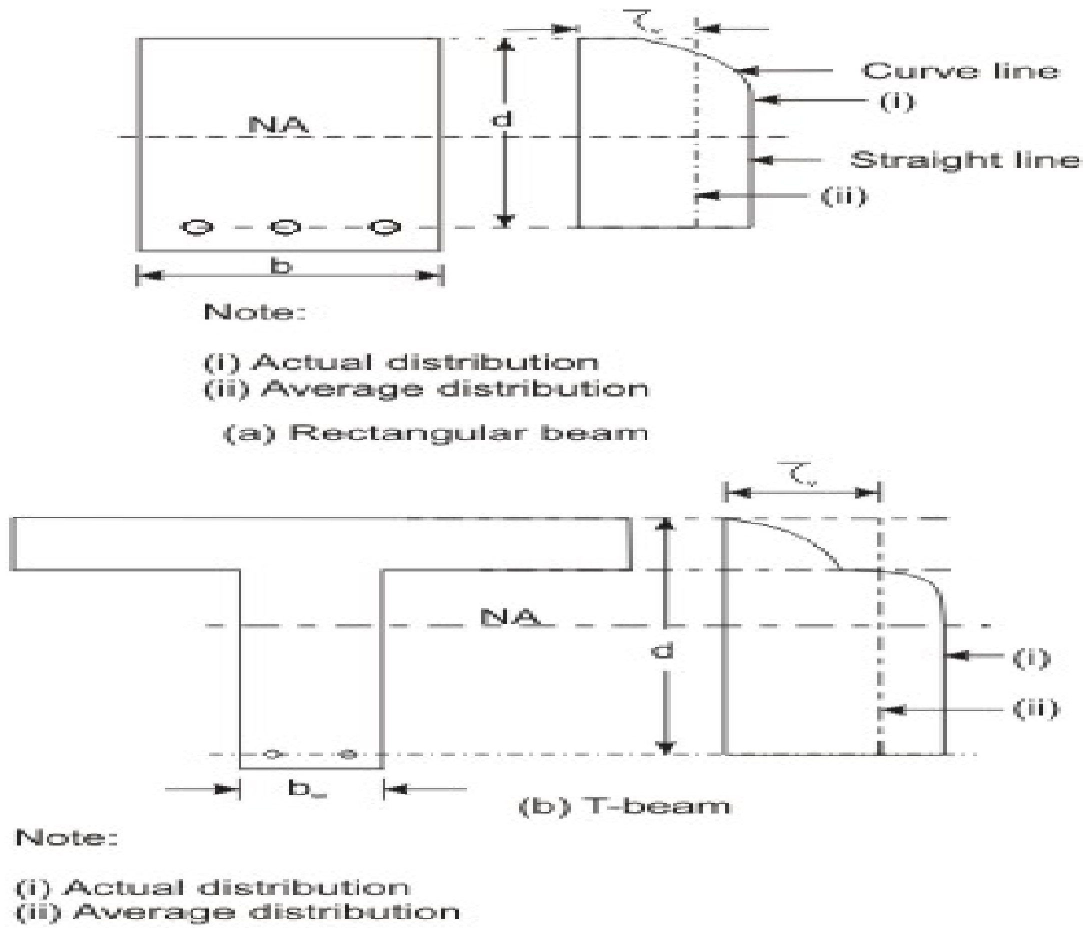


- Flexural Compression:



Shear Stress

- The distribution of shear stress in reinforced concrete rectangular, T and L-beams of uniform and varying depths depends on the distribution of the normal stress.
- The nominal shear stress τ_v is considered which is calculated as follows



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(i) In beams of uniform depth

$$\tau_v = \frac{V_u}{b\,d}$$

where V_u = shear force due to design loads,

b = breadth of rectangular beams and breadth of the web b_w for flanged beams, and

d = effective depth.

(ii) In beams of varying depth:

$$\tau_v = \frac{V_u \pm \dfrac{M_u}{d}\tan\beta}{b\,d}$$

where τ_v, V_u, b or b_w and d are the same as in (i),

M_u = bending moment at the section, and

β = angle between the top and the bottom edges.

The positive sign is applicable when the bending moment M_u decreases numerically in the same direction as the effective depth increases, and the negative sign is applicable when the bending moment M_u increases numerically in the same direction as the effective depth increases.

Design Shear Strength of Reinforced Concrete

As per IS 456:2000 the design shear strength of concrete depends on the grade of concrete and percentage of tension steel in beams.

Design shear strength of concrete, τ_c in N/mm^2

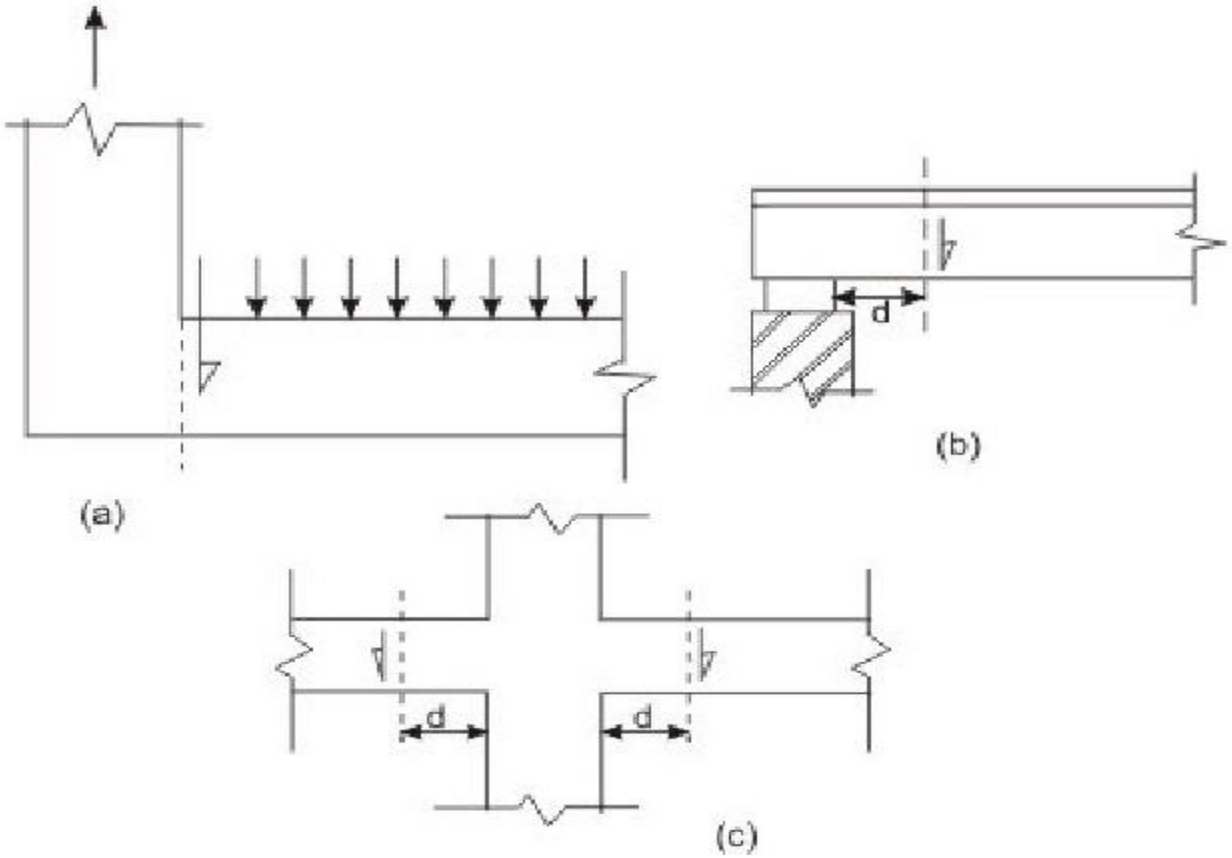
(100 A_s/b d)	Grade of concrete				
	M 20	M 25	M 30	M 35	M40 and above
≤ 0.15	0.28	0.29	0.29	0.29	0.30
0.25	0.36	0.36	0.37	0.37	0.38
0.50	0.48	0.49	0.50	0.50	0.51
0.75	0.56	0.57	0.59	0.59	0.60
1.00	0.62	0.64	0.66	0.67	0.68
1.25	0.67	0.70	0.71	0.73	0.74
1.50	0.72	0.74	0.76	0.78	0.79
1.75	0.75	0.78	0.80	0.82	0.84
2.00	0.79	0.82	0.84	0.86	0.88
2.25	0.81	0.85	0.88	0.90	0.92
2.50	0.82	0.88	0.91	0.93	0.95
2.75	0.82	0.90	0.94	0.96	0.98
≥ 3.00	0.82	0.92	0.96	0.99	1.01

Maximum shear stress τ_{cmax} with shear reinforcement

As per IS456:2000 maximum shear strength of concrete depends only grade of concrete only

Grade of concrete	M 20	M 25	M 30	M 35	M 40 and above
τ_{cmax}, N/mm^2	2.8	3.1	3.5	3.7	4.0

Critical Section for Shear



Support conditions for locating factored shear force

Minimum Shear Reinforcement (IS 456:2000 Clause 40.3, 26.5.1.5 and 26.5.1.6)

The minimum shear reinforcement in the form of stirrups shall be provided such that:

$$\frac{A_{sv}}{b\,s_v} \geq \frac{0.4}{0.87\,f_y}$$

where A_{sv} = total cross-sectional area of stirrup legs effective in shear,

s_v = stirrup spacing along the length of the member,

b = breadth of the beam or breadth of the web of the web of flanged beam b_w, and

f_y = characteristic strength of the stirrup reinforcement in N/mm^2 which shall not be taken greater than 415 N/mm^2.

The above provision is not applicable for members of minor structural importance such as lintels where the maximum shear stress calculated is less than half the permissible value.

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The minimum shear reinforcement is provided for the following:

(i) Any sudden failure of beams is prevented if concrete cover bursts and the bond to the tension steel is lost.

(ii) Brittle shear failure is arrested which would have occurred without shear reinforcement.

(iii) Tension failure is prevented which would have occurred due to shrinkage, thermal stresses and internal cracking in beams.

(iv) To hold the reinforcement in place when concrete is poured.

(v) Section becomes effective with the tie effect of the compression steel.

Further, cl. 26.5.1.5 of IS 456 stipulates that the maximum spacing of shear reinforcement measured along the axis of the member shall not be more than 0.75 d for vertical stirrups and d for inclined stirrups at 45^o, where d is the effective depth of the section. However, the spacing shall not exceed 300 mm in any case.

Design of Shear Reinforcement (cl. 40.4 of IS 456)

When τ_v is more than τ_c given in Table shear reinforcement shall be provided in any of the three following forms:

(a) Vertical stirrups,
(b) Bent-up bars along with stirrups, and
(c) Inclined stirrups.

In the case of bent-up bars, it is to be seen that the contribution towards shear resistance of bent-up bars should not be more than fifty per cent of that of the total shear reinforcement.

The amount of shear reinforcement to be provided is determined to carry a shear force V_{us} equal to

$$V_{us} = V_u - \tau_c\, b\, d$$

where b is the breadth of rectangular beams or b_w in the case of flanged beams.

The strengths of shear reinforcement V_{us} for the three types of shear reinforcement are as follows:

(a) Vertical stirrups:

$$V_{us} = \frac{0.87\ f_y\ A_{sv}\ d}{s_v}$$

(b) For inclined stirrups or a series of bars bent-up at different cross-sections:

$$V_{us} = \frac{0.87\ f_y\ A_{sv}\ d}{s_v}(\sin\alpha + \cos\alpha)$$

(c) For single bar or single group of parallel bars, all bent-up at the same cross-section:

$$V_{us} = 0.87\ f_y\ A_{sv}\ s_v\ \sin\alpha$$

where A_{sv} = total cross-sectional area of stirrup legs or bent-up bars within a distance s_v,

s_v = spacing of stirrups or bent-up bars along the length of the member,

τ_v = nominal shear stress,

τ_c = design shear strength of concrete,

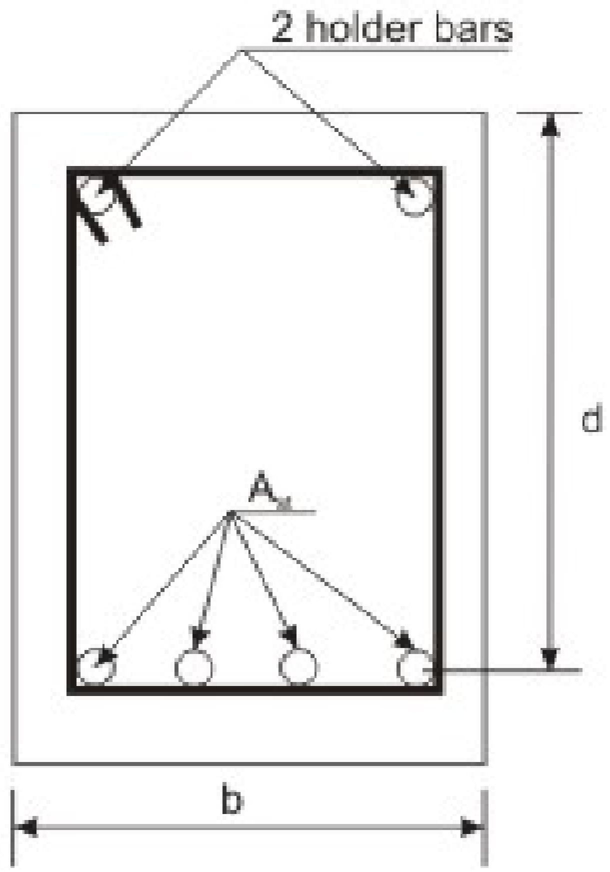
b = breadth of the member which for the flanged beams shall be taken as the breadth of the web b_w,

f_y = characteristic strength of the stirrup or bent-up reinforcement which shall not be taken greater than 415 N/mm^2,

α = angle between the inclined stirrup or bent-up bar and the axis of the member, not less than 45^o, and

d = effective depth.

Placement of stirrups



Placement of stirrups

Important Links

- https://nptel.ac.in/
- https://talktorashid.blogspot.com/
- http://keck.ac.in/department/civil/rm
- http://www.vssut.ac.in/lecture_notes/lecture1424715726.pdf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YOU