23CE503:STRUCTURAL ENGINEERING - I (RCC)

Topic: Unit- II : SHEAR,BOND & TORSION

PREPARED BY

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Topic: Unit- II : SHEAR

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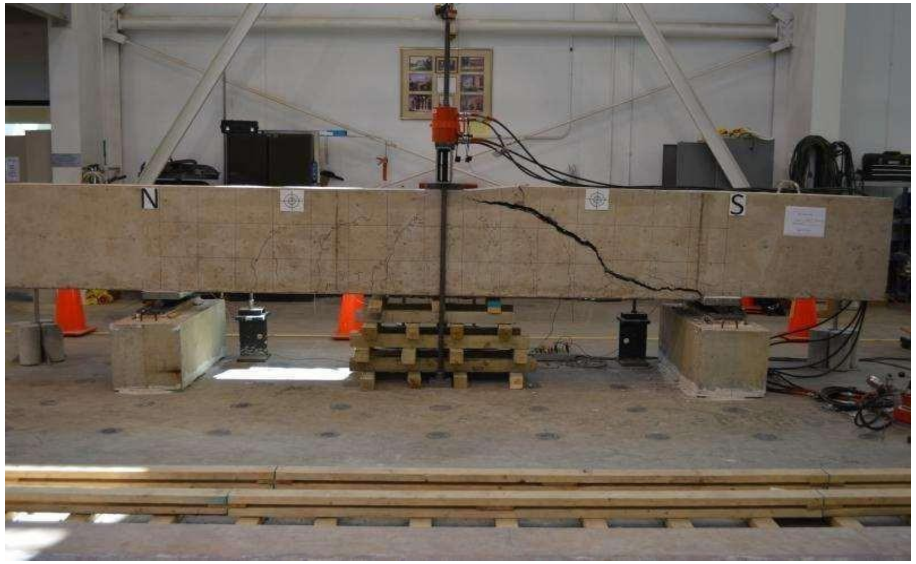
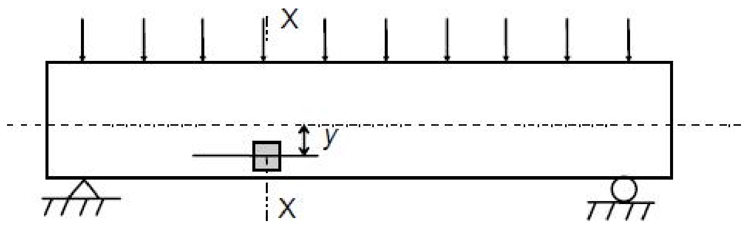
SHEAR

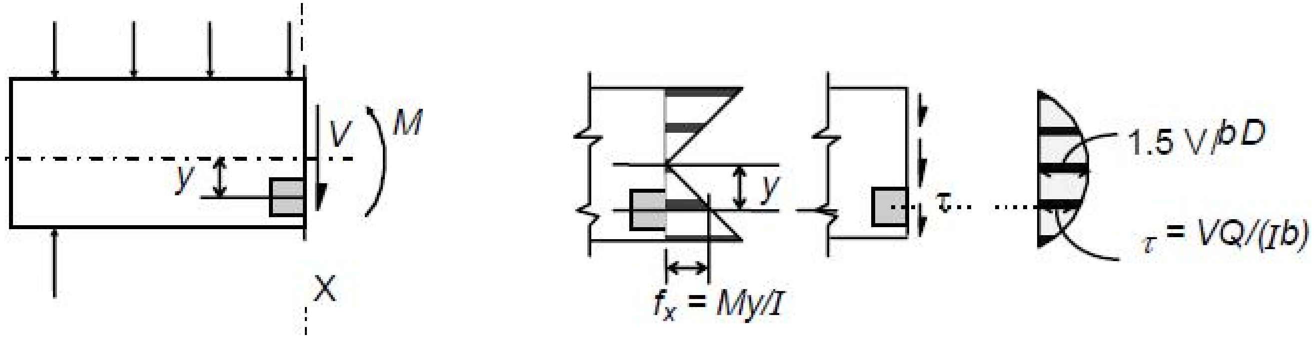


Module 1: Behaviour of RC Beams in Shear and Torsion:

Modes of Cracking , Shear Transfer Mechanisms , Shear Failure Modes, Critical Sections for Shear Design , Influence of Axial Force on Design Shear Strength, Shear Resistance of Web Reinforcement, Compression Field Theory, Strut-and- Tie Model. Equilibrium Torsion and Compatibility Torsion, Design Strength in Torsion, Design Torsional Strength with Torsional Reinforcement- Space Truss Analogy and Skew Bending Theory

1. Flexural and shear stresses in prismatic beams





❖ Flexural (normal) stress f_x and the Shear stress τ at any point in the section, located at a distance y from the neutral axis, are given by:

$$f_x = \frac{M\,y}{I} \qquad \tau = \frac{VQ}{Ib}$$

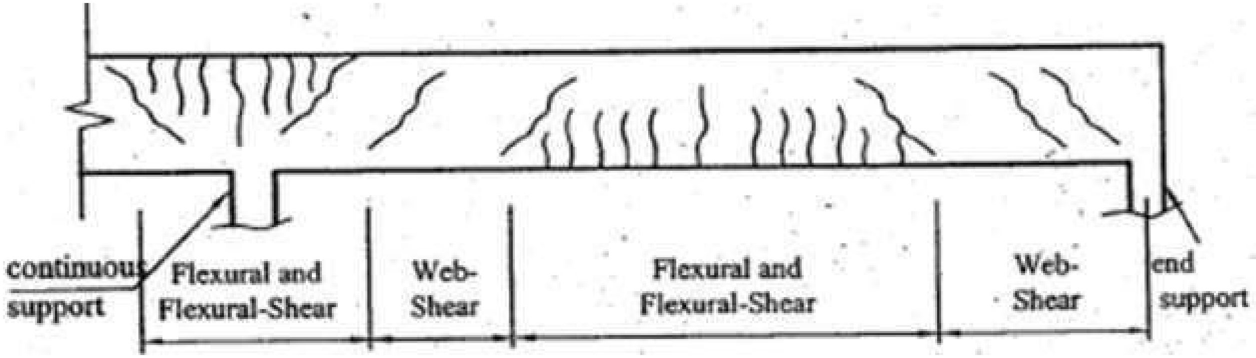
I = second moment of area of the section about the neutral axis

Q = first moment of area about the neutral axis of the portion of the section above the layer at distance y from the NA

b = width of the beam at the layer at which τ is calculated.

❖ variation of shear stress is parabolic, with a maximum value at the neutral axis and zero values at the top and bottom of the section.

2. Modes of Cracking in RC Beams



Two types of inclined cracking occur in concrete beams

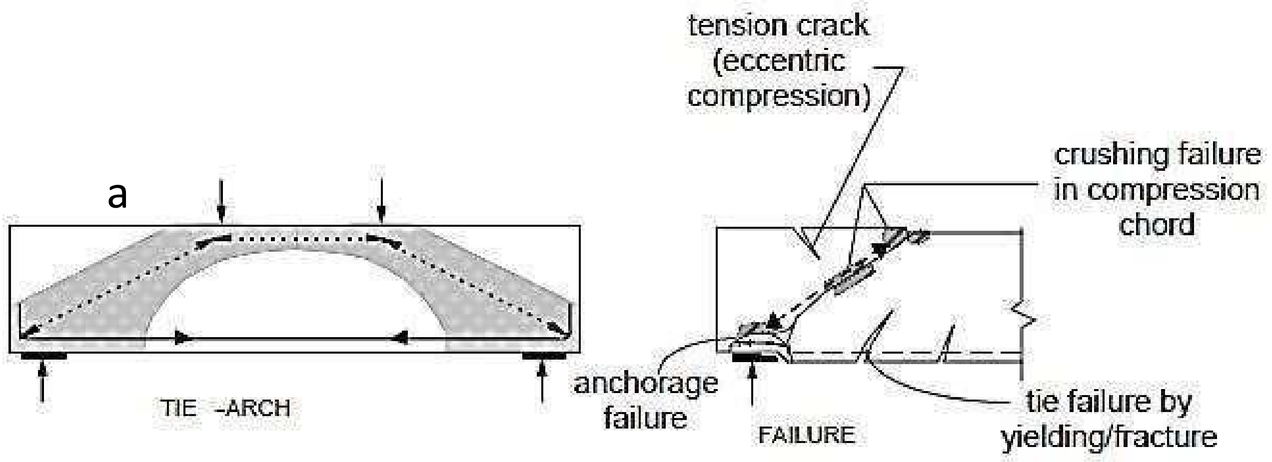
- ❖ Web Shear Cracking
- ❖ Flexure – Shear Cracking

- ❖ Web Shear cracking starts from near NA location when the PTS due to shear exceed the tensile strength of concrete. Usually occur in I beams (thin webs)

- ❖ Flexure – Shear cracking is an extension of vertical flexural cracking and develops when the PTS due to combined shear and flexural tensile stresses exceed the tensile strength of concrete.

3. Shear failure modes in beams without web rebars

Case 1: *a/d* < 1 DEEP BEAMS



Deep Beams : $a/d < 1$

- Without web reinforcement, inclined cracking transforms the beam into a *tied-arch* with tension element as longitudinal rebars and compression element as cracked concrete
- The tension element may fail by yielding, fracture or failure of anchorage.
- OR compression chord may fail by crushing of concrete

4. Shear Transfer Mechanisms

Shear resistance in reinforced concrete beams is provided by the shear transfer in the compression zone, aggregate interlock across crack face, stirrups crossing the shear crack, and dowel action of longitudinal reinforcing bars crossing the crack in concrete

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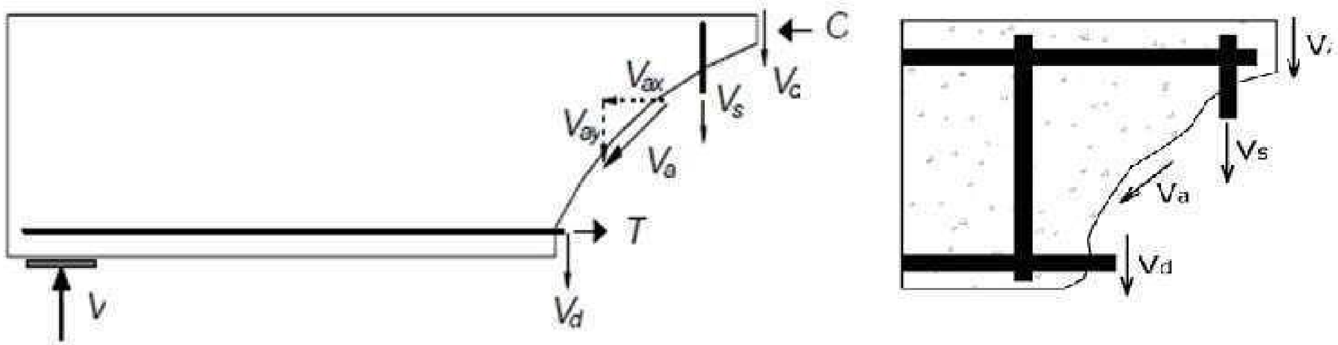


Internal forces acting at a flexural-shear crack

- Interface shear (aggregate interlock) force V_a ,

  transmitted along the inclined plane of the crack, resulting from the friction against relative slip between the interlocking surfaces of the crack. Its contribution can be significant, if the crack-width is limited.

5. Influence of Longitudinal Rebars content ; p_t – 100 Ast / bd

- The increase in p_t in the flexural tension zone contributes to enhanced dowel action V_d , and control the propagation of flexural cracks.

- This results in increase in the position of the neutral axis

$$\frac{x_u}{d} = \frac{0.87\, f_y\, A_{st}}{0.36\, f_{ck}\, b.d}$$

- The increased area of uncracked concrete in compression zone enhances contributions of V_a and V_c

- Thus the higher the percentage tension reinforcement, the greater the shear resistance in the

concrete – up to a limit : $X_u /d = X_{u,max}/d$

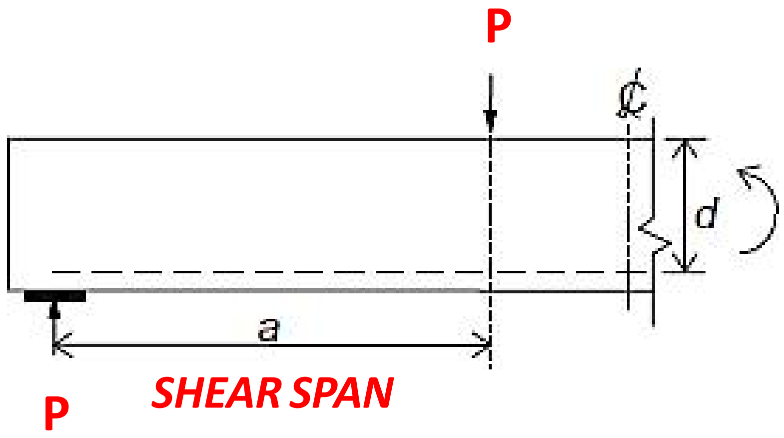
- This contribution is given in Table 19 of IS 456 which are computed from

6 Concept of Shear Span

With Mand Vas the applied bending moment and shear force at a section in the beam (b x d)

f_x a M/bd^2 and τ a V/bd

$$\frac{f_x}{r} \qquad \frac{M}{Vd}$$



With beams in four point bending

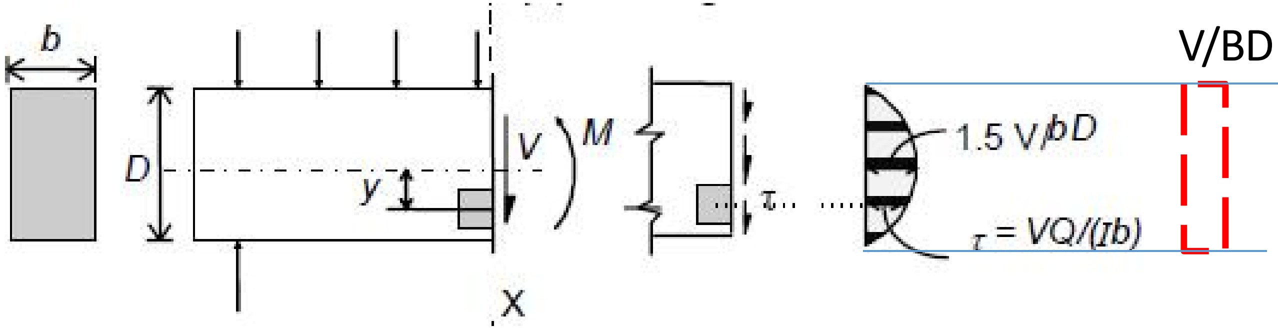
M = Pa and V = P

M/V = a -> Shear Span

$$\frac{f_x}{r} \qquad \frac{a}{d}$$

The dimensionless ratio a/d or M / V d enables the prediction of failure modes of beam in flexural shear

7. Concept of Nominal Shear Stress



V/BD = (1.5 V/BD)(2/3)

Average Shear Stress

A. Members with Uniform Depth

The concept of average shear stress in a beam section is used in mechanics of materials is used in RC sections also

$$\tau_v = \textit{shear force / area of cross section} = V_u / bd \qquad CL\ 40.1$$

τ_v is merely a parameter intended to aid design and to control shear stresses in RC members

It does not actually represent the true average shear stress as distribution is quite complex in RC.

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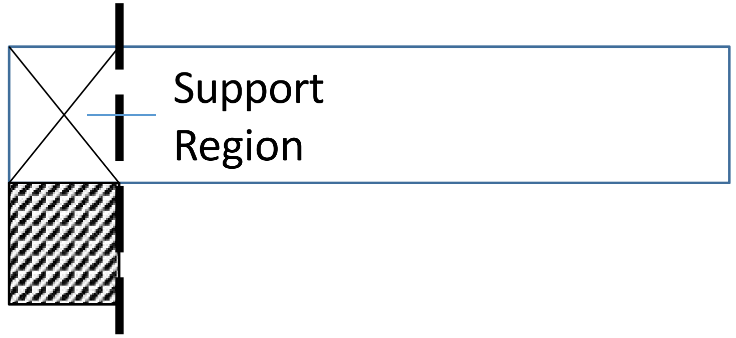
8. Critical sections for shear computation

Critical Section for Shear (22.6.2)



22.6.2 ***Critical Section for Shear***

The shears computed at the face of the support shall be used in the design of the member at that section except as in **22.6.2.1.**

22.6.2.1 When the reaction in the direction of the applied shear introduces compression into the end region of the member, sections located at a distance less than *d* from the face of the support may be designed for the same shear as that computed at distance *d* (*see* Fig. 2).

NOTE—The above clauses are applicable for beams generally carrying uniformly distributed load or where the principal load is located farther than 2*d* from the face of the support.

When a support reaction introduces transverse compression in the end region of the member, the shear strength of this region is enhanced, and inclined cracks do not develop near the face of the support (which is usually the location of maximum shear).

This is of particular significance in footing slabs where flexural (one-way) shear is a major design consideration

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1. Torsion in RC members

- RC members are also subjected to torsional moments in addition to bending and shear and sometimes with axial forces also.
- Torsional moments causes twisting of the member
- Torsional moments can be generated in two types of load transfer mechanisms and are identified as

1. Primary or equilibrium or statically determinate torsion
2. Secondary or Compatibility or statically indeterminate torsion torsion

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A. Equilibrium torsion

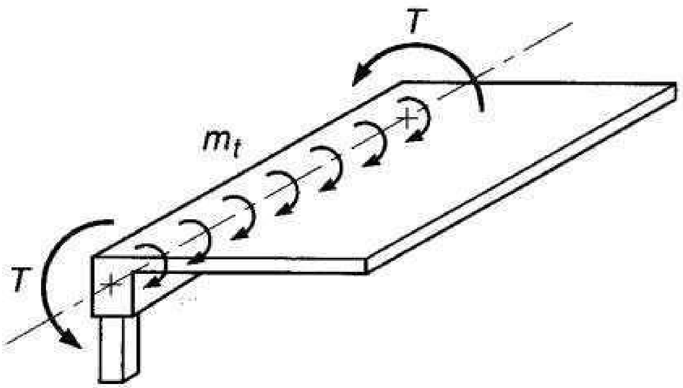
- exists when external load has no alternative load path but must be supported by torsion. In such cases torsion is required to maintain static equilibrium and can be uniquely determined.

Example : 1. Cantilevered slab from a beam

- Loads applied to the slab surface cause twisting moment m_t to act along the length of beam.

- These are equilibrated by the resisting torque T at the columns.

- In the absence of torsional moments structure will collapse



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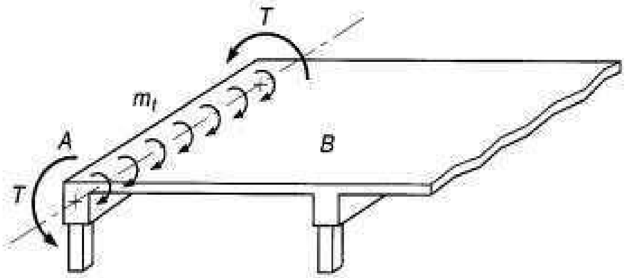
B. Compatibility Torsion

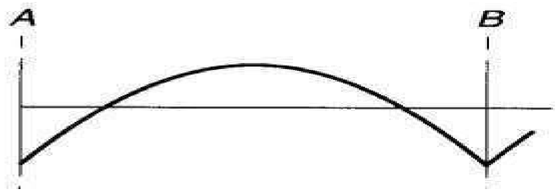
- arises from the requirements of compatibility of deformation between adjacent parts of a structure
- Torsional moments cannot be found based on static equilibrium alone.
- Ignoring this will lead to cracking but will not cause collapse.
- Internal redistribution of forces is forced and an alternative equilibrium path is found

Example : Spandrel or edge beam supporting a monolithic concrete slab



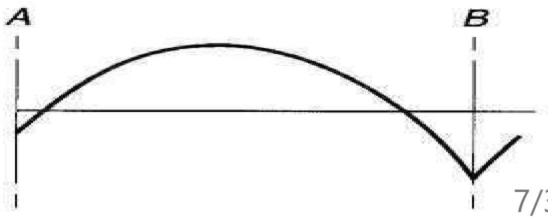
Case1:

Torsionally stiff and suitably reinforced the slab moments will be same as those for a rigid support.



Case2:

Little torsional stiffness and inadequate reinforcement cracking will occur and the slab moments will be same as those for a hinged support.



BOND

- RC design assumes perfect bond between concrete and steel
- There must be no slippage between steel bars and surrounding concrete
- Bond stress results from variation of axial force in bars, caused by moment variation
- Bond stress is affected by development of tensile cracks.
- At a point where a tensile crack crosses a reinforcing bar, all the tensile force is carried by the reinforcement.
- At a short distance from the crack, tension is resisted by both the reinforcement and uncracked concrete.
- Bond stress is zero at the crack, but may be large a short distance away.

- Note: ***If there is no bonding between the two materials and if the bars are not anchored at their ends, they will pull out of the concrete. As a result, the concrete beam will act as an unreinforced member and will be subject to sudden collapse as soon as the concrete cracks.***

Mechanism of bond transfer

- Bond between concrete and steel bars is due to chemical adhesion, friction and bearing of reinforcement ribs on the concrete
- Adhesion and friction are lost when the bar is loaded in tension as a result of diameter reduction due to Poisson's ratio effect
- Adhesion and friction are neglected
- Bond is transferred mainly by bearing of the deformed bars
- Plain bars have a poor bond transfer and are no longer used
- Steel bars subjected to axial compression develop a better bond because of Poisson's ratio effect

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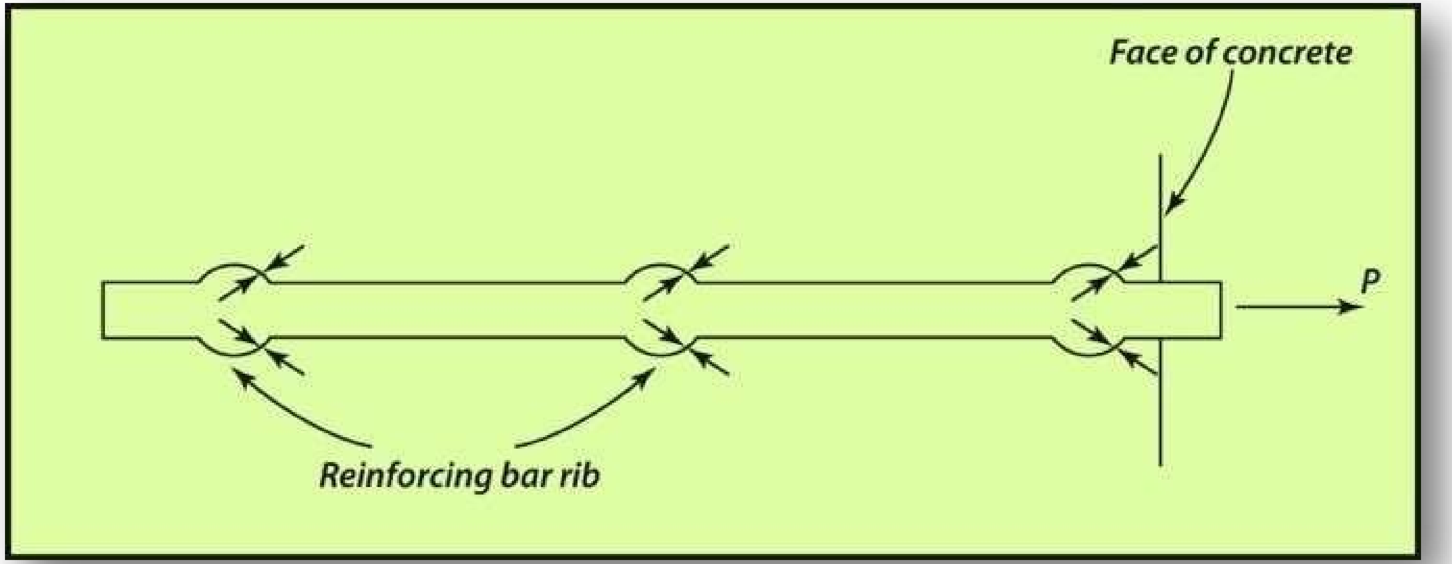
Mechanism of bond transfer Bar Bearing



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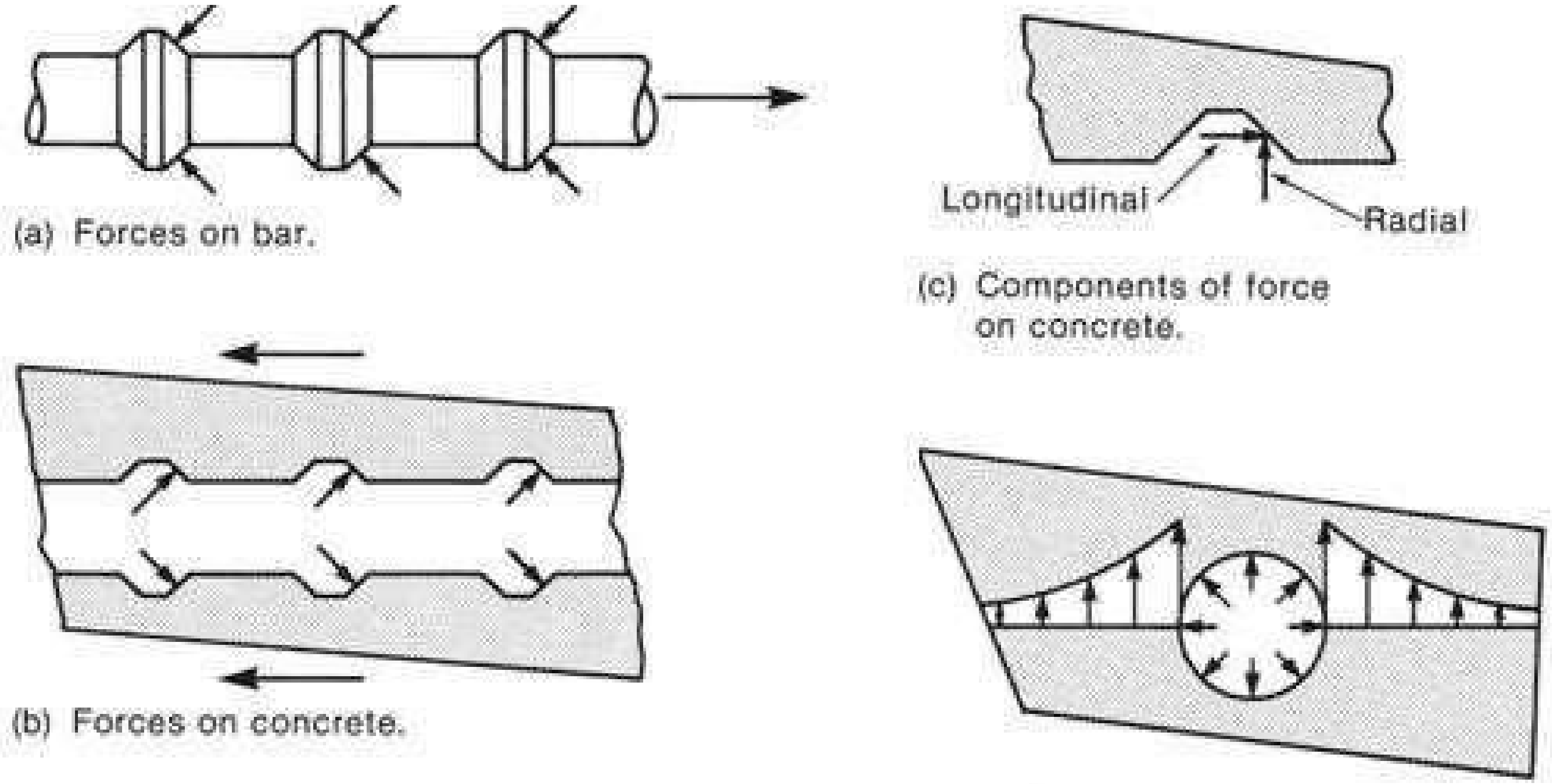
Mechanism of bond transfer



(a) Forces on bar.

(b) Forces on concrete.

(c) Components of force on concrete.

(d) Radial forces on concrete and splitting stresses shown on a section through the bar.

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Types of Bond Failures

- Forces in concrete have longitudinal and radial components
- Wedging action of ribs against concrete produces tension in a cylindrical section around the bars (similar to a concrete pipe filled with water)
- Wedging action causes cracks (splits) to occur around the reinforcement
- Bond failure occurs by splitting of concrete parallel to the bar
- Splitting failure surface depends on cover and bar spacing values

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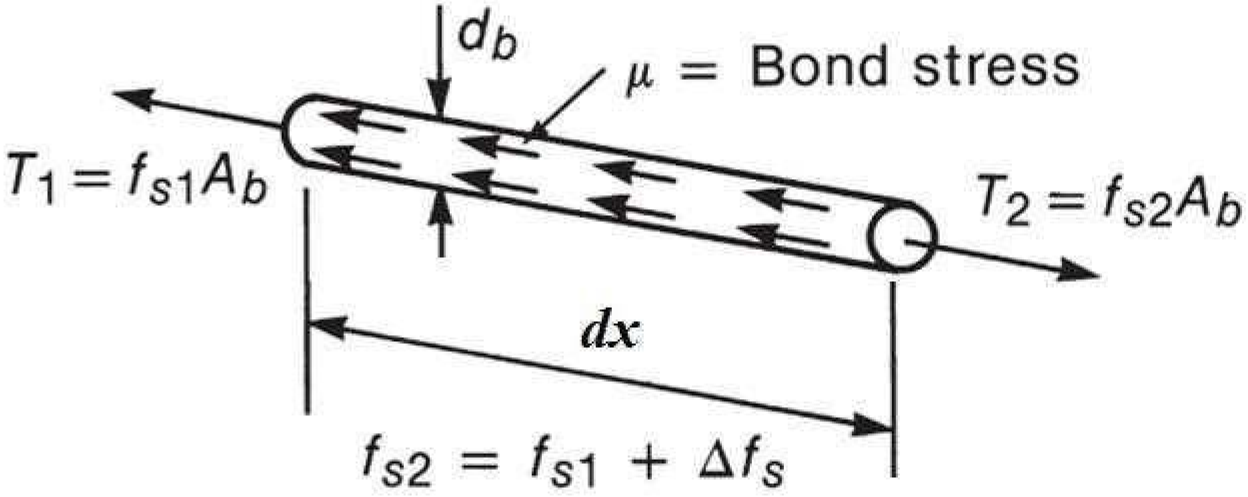
Bond stress



Bond stress results from

variation of axial force in bars, caused by moment variation

$$\Delta T = T_2 - T_1 = \frac{\Delta M}{jd} = \mu \times \pi d_b \times dx$$

jd = Lever arm

$$\Rightarrow V = \frac{\Delta M}{\times jd \; dx} = \mu \times \pi d_b$$

$$\Rightarrow \mu = \frac{V}{\pi d_b \times jd}$$

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Development length

- Development length is the minimum embedment length of a bar in concrete necessary to develop the yield stress in the bar, plus some additional distance to insure toughness
- If the distance from a point where the bar stress is equal to yield stress f_y to the end of the bar (zero stress) is less than the development length, then the bar will pull out of the concrete

$$\Delta T = T_2 - 0 = A_b f_y = \frac{\pi d_b^2}{4} f_y = \mu_u \times \pi d_b \times l_d$$

$$\Rightarrow l_d = \frac{f_y d_b}{4\mu_u}$$

Thank You..