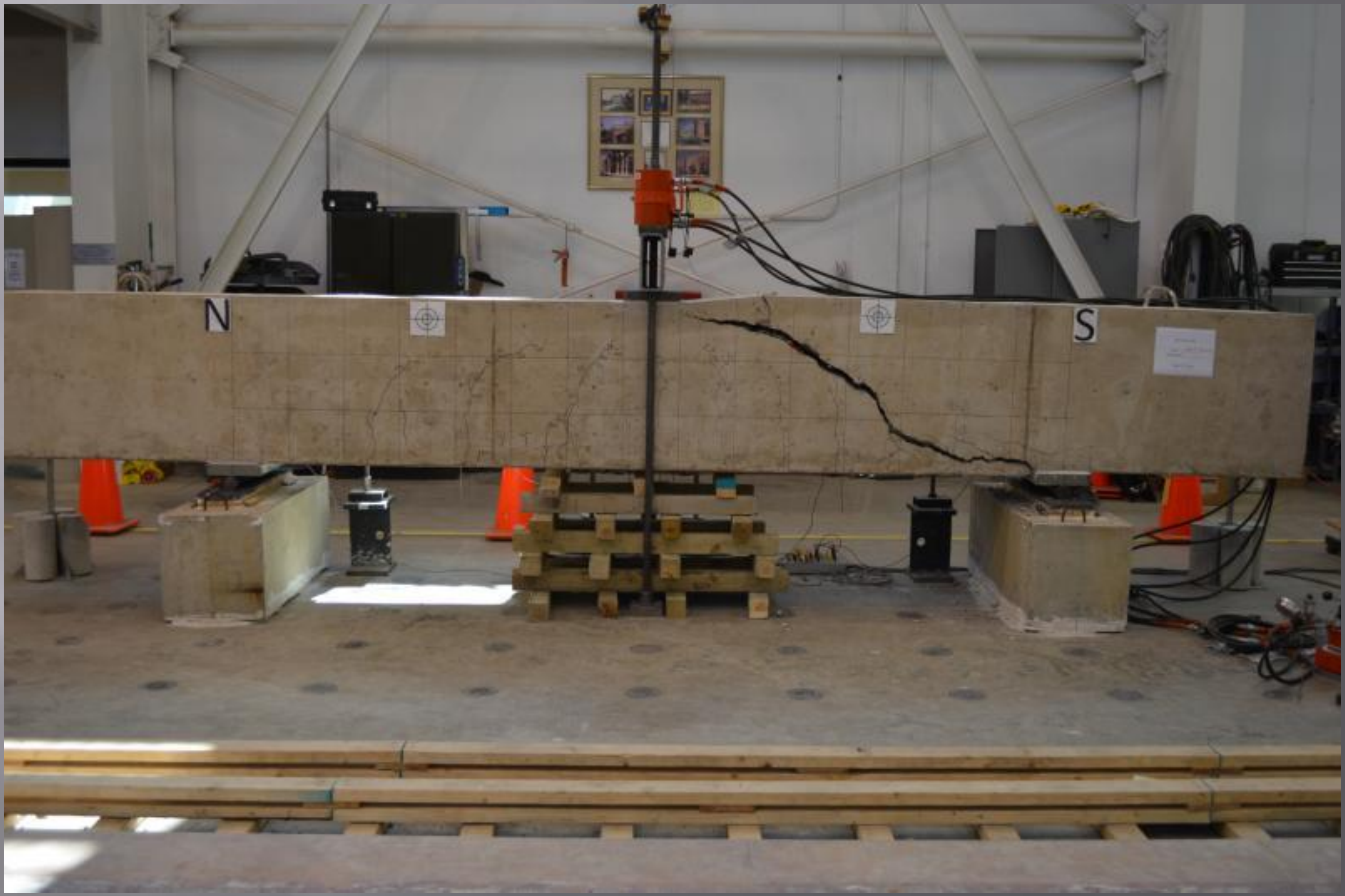
REINFORCED CONCRETE-I

(Shear and Diagonal Tension - Fundamentals)

Shear and diagonal tension

- Diagonal principal tensile stresses, called diagonal tension occur at different places and angles in concrete beams, and they must be carefully considered. If they reach certain values, additional reinforcing called web reinforcement, must be supplied.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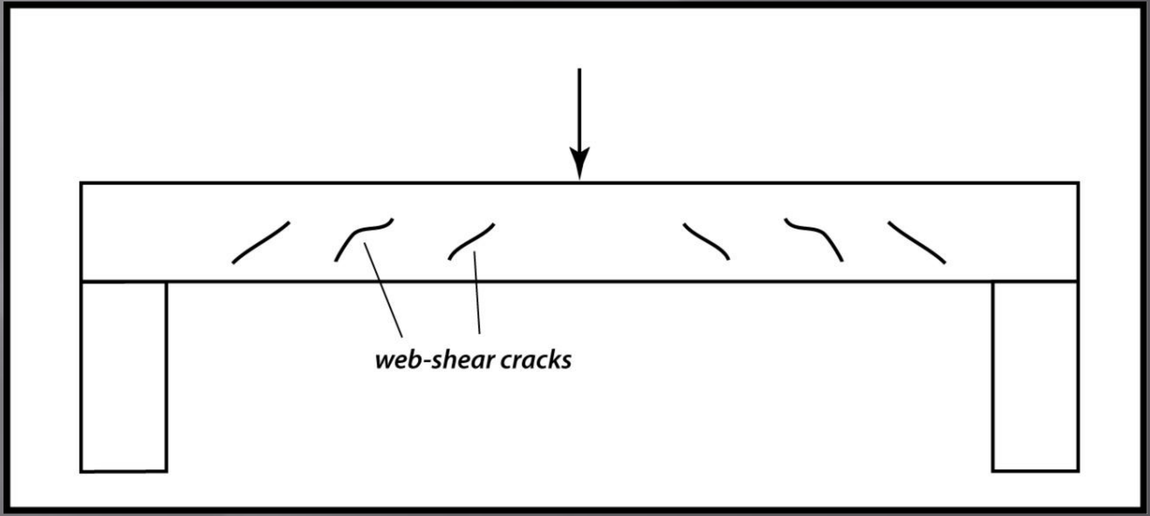
Modes of Failure

- *Several experimental studies have been conducted to understand the various modes of failure which could occur due to possible combination of shear and bending moment acting at a given section. These modes are as follows:*
- ***Diagonal tension failure***
- ***Flexural shear failure***
- ***Diagonal compression failure***

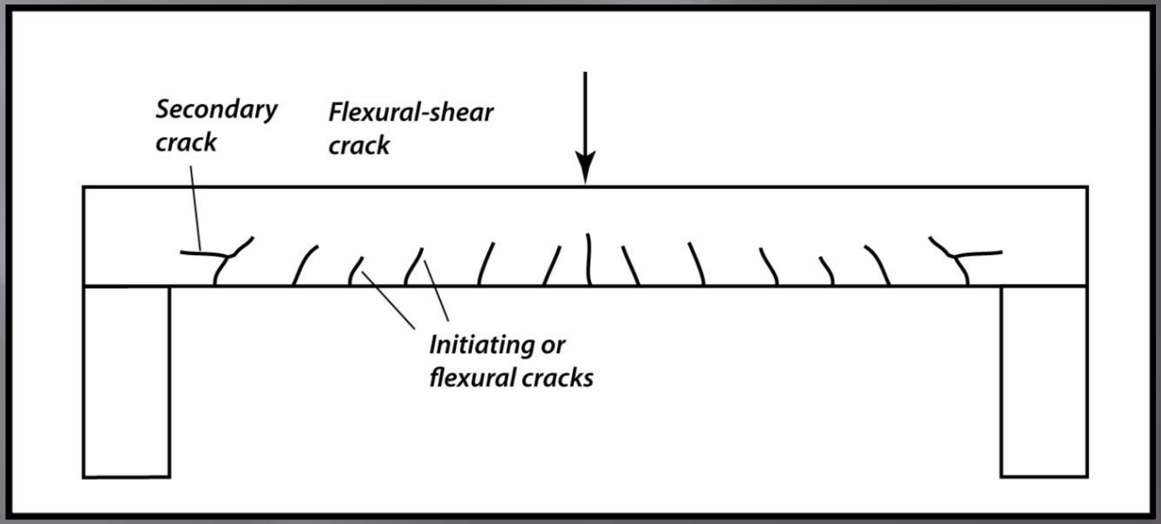
Diagonal tension Failure (Web-shear cracks)

- Such cracks occurs under large shear force and less bending moment. These cracks are normally at 45^0 with the horizontal and form near the mid-depth of sections and move on a diagonal path to the tension surface.
- Occur at ends of beams at simple supports and at inflection points at continuous beam



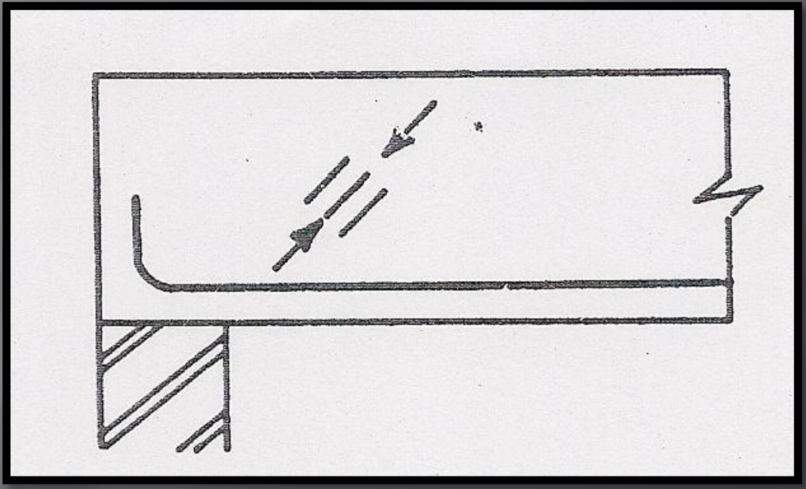
Flexural-shear Failure (Flexure-shear cracks)

- For flexure-shear cracks to occur, the moment must be larger than the cracking moment and the shear must be rather large. The cracks run at angles of about 45^0 with the beam axis and probably start at the top of the flexural cracks.



Diagonal compression failure

- Diagonal compression failure occurs under large shear force. It is characterized by the crushing of concrete. Normally it occurs in beams which are reinforced against heavy shear.



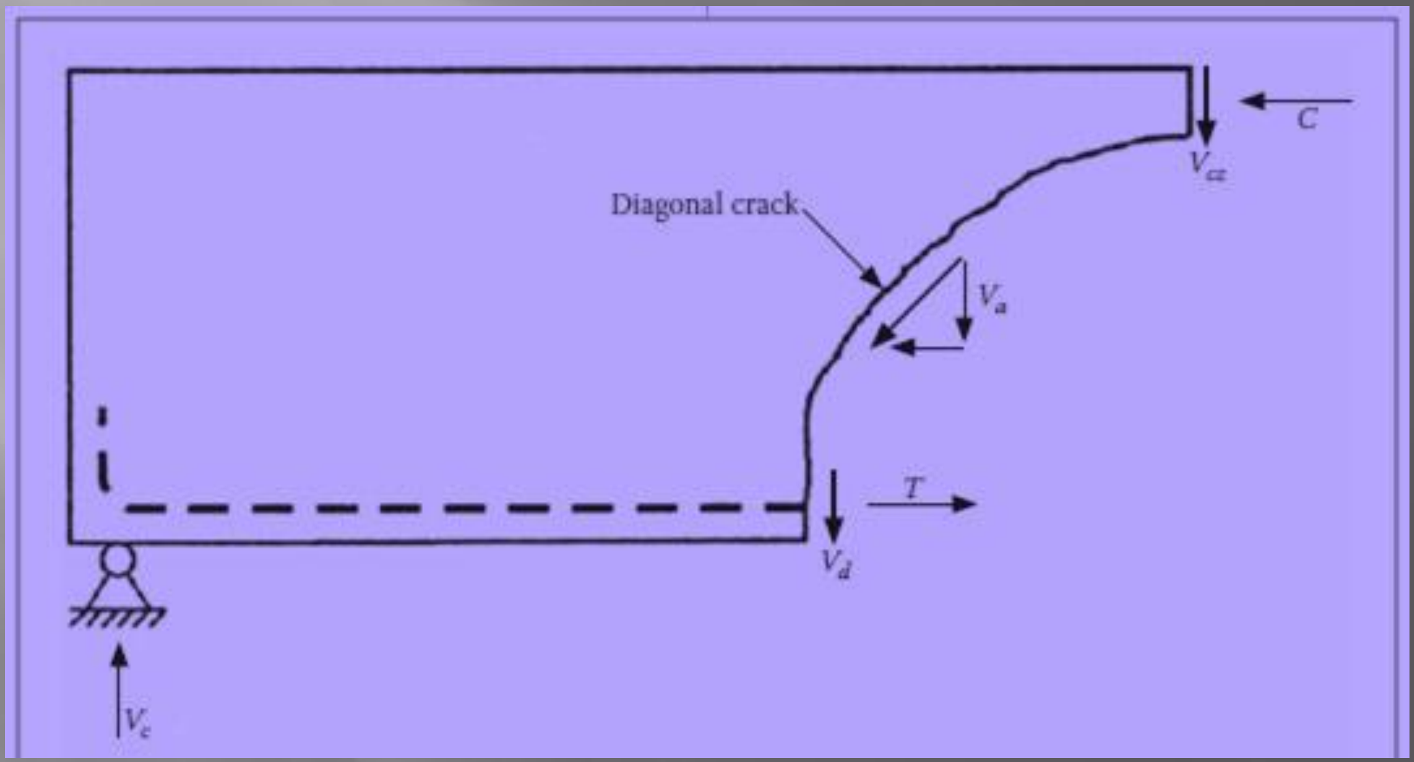
Note

- As a crack moves up to the neutral axis, the result will be reduced amount of concrete left to resist shear – meaning that shear stresses will increase on the concrete above the crack.
- It is worth mentioning that at the neutral axis the bending stresses are zero and the shear stresses are at their maximum values. The shear stresses will therefore determine what happens to the crack there.

Forces acting on beam when resisting shear forces

- Studies have shown that shear force is resisted by:
  - the uncracked concrete in compression region
  - The aggregate interlocking
  - Shear acting across the longitudinal steel bars. (The shear force across the steel bars is also known as dowel force.)
  - Shear reinforcement, if present, will also resist the shear force.

Forces acting on a beam when resisting shear forces (Contd.)



Shear Strength of Concrete

The nominal or theoretical shear strength of a member V_n is provided by theconcrete and by theshear reinforcement. That is

$$V_n = V_c + V_s$$

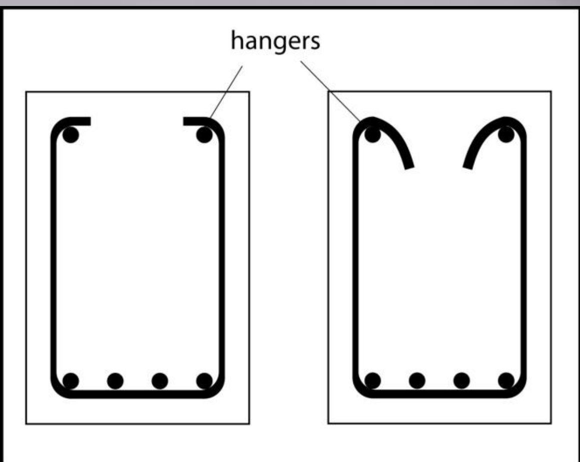
The design shear strength of a memebr ϕV_n, is equal to ϕV_c, plus ϕV_s, which must at least be equal to the factored shear force V_u, *i.e.*

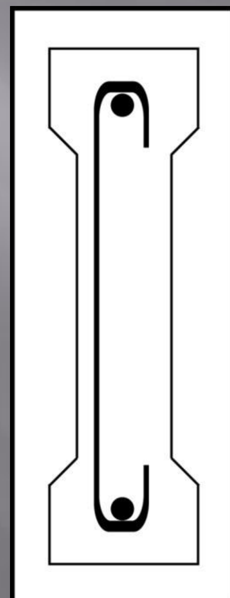
$$V_u = \phi V_n = \phi V_c + \phi V_s$$

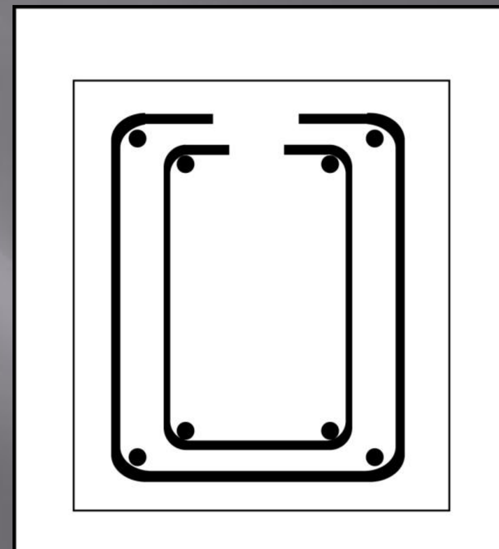
The shear strength provided by theconcrete, V_c, is considered to be equal to an average shear strength $\left(\text{normally } \frac{\sqrt{f_c'}}{6}; \text{ where } f_c' \text{ is in MPa} \right)$ times the effective cross-sectional area of the member, $b_w d$, where b_w is the width of a rectangular beam or of the web of a T beam or an I beam. Thus

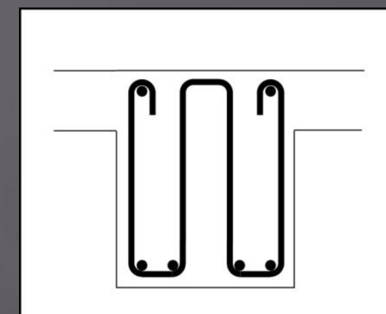
$$V_c = \left(\frac{\sqrt{f_c'}}{6} \right) b_w d$$

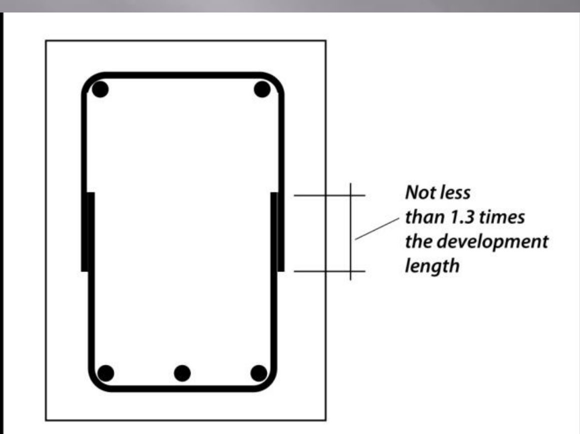
Shear Reinforcement
Stirrups - Types

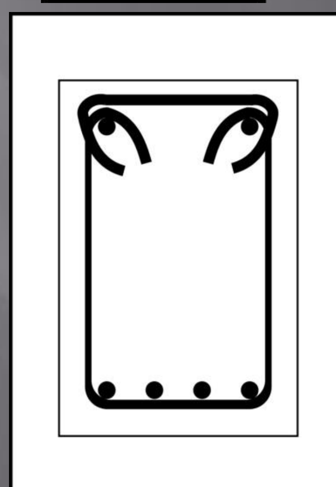


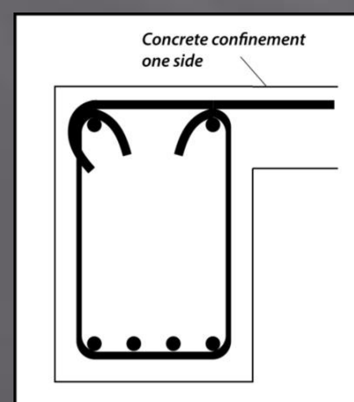


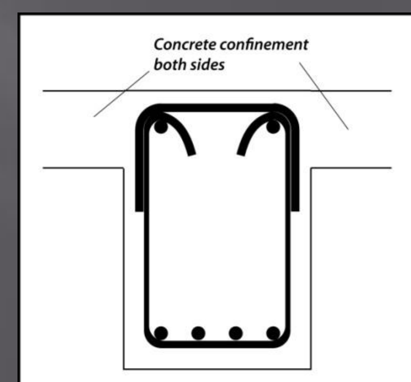






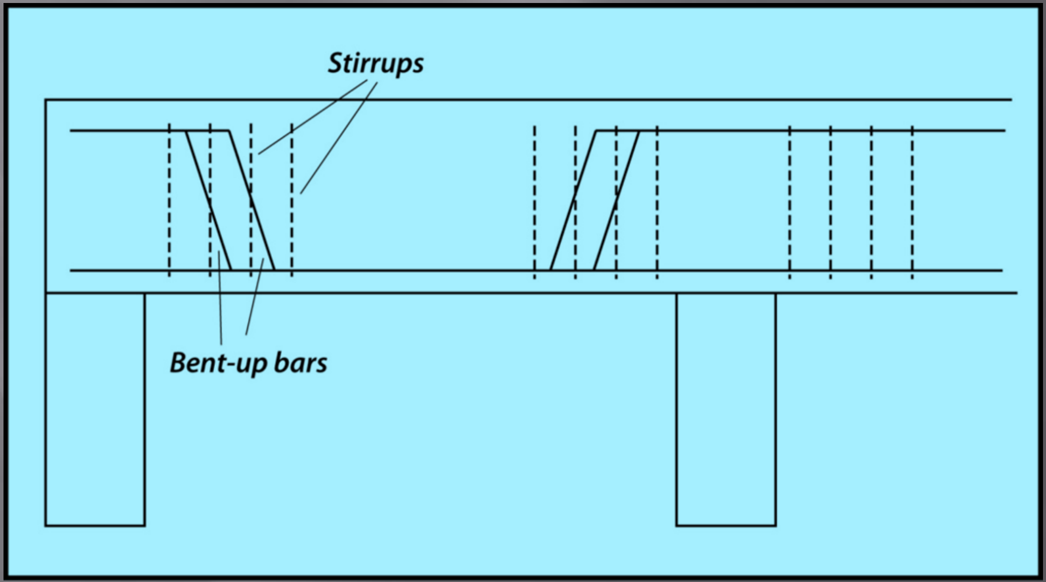






Positioning of Stirrups

- Inclined or diagonal stirrups lined up approximately with the principal stress directions are more efficient in carrying the shears and preventing or delaying the formation of diagonal cracks. Such stirrups, however, are not usually considered to be very practical because of the high labor costs for positioning them.
- Bent up bars (usually at 45^0 angles) are another satisfactory type of web reinforcement.



Shear Cracking

- The shear reinforcement makes its presence known only after the cracks begin to form. At that time, beams must have sufficient shear reinforcing to resist the shear force not resisted by the concrete.

Benefits of Stirrups

- Stirrups carry shear across the crack directly
- Promote aggregate interlock
- Confine the core of the concrete in the beam thereby increasing strength and ductility
- Confine the longitudinal bars and prevent cover from prying off the beam
- Hold the pieces of concrete on either side of the crack together and prevent the crack from propagating into the compression region