Flexure, Design of RC Beam

Lecture Goals

- Basic Concepts
- Rectangular Beams

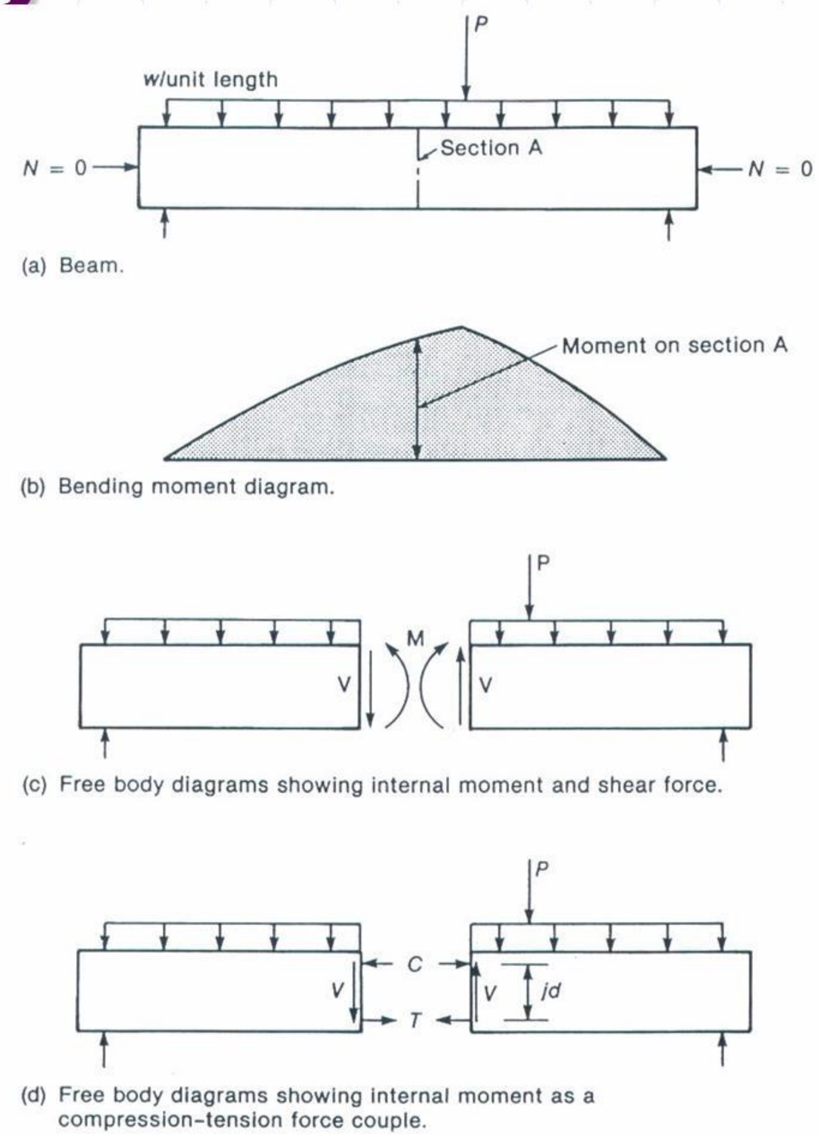
Flexural Stress

The beam is a structural member used to support the internal moments and shears. It would be called a beam-column if a compressive force existed.

$$C = T$$

$$M = C^*(jd)$$

$$= T^*(jd)$$



(a) Beam.

(b) Bending moment diagram.

(c) Free body diagrams showing internal moment and shear force.

(d) Free body diagrams showing internal moment as a compression-tension force couple.

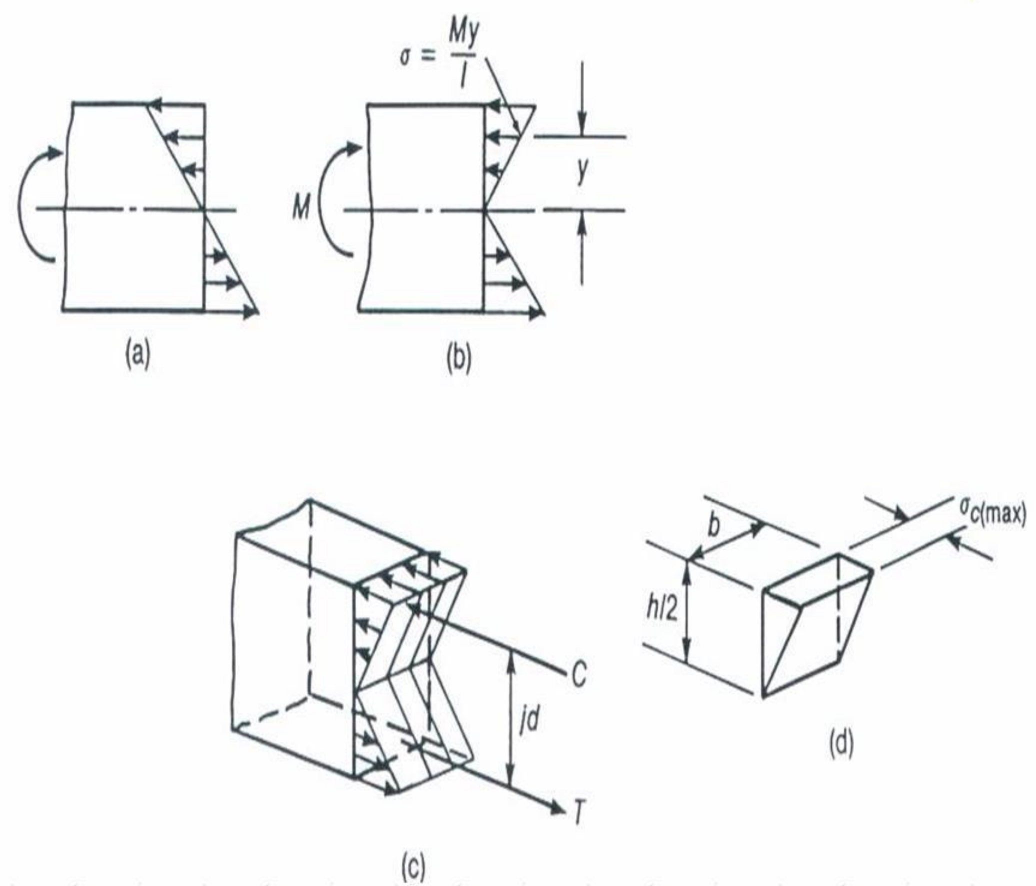
Flexural Stress

The stress in the block is defined as:

$$\sigma = (M*y) / I$$

$$S_{xx} = I / (y_{max})$$

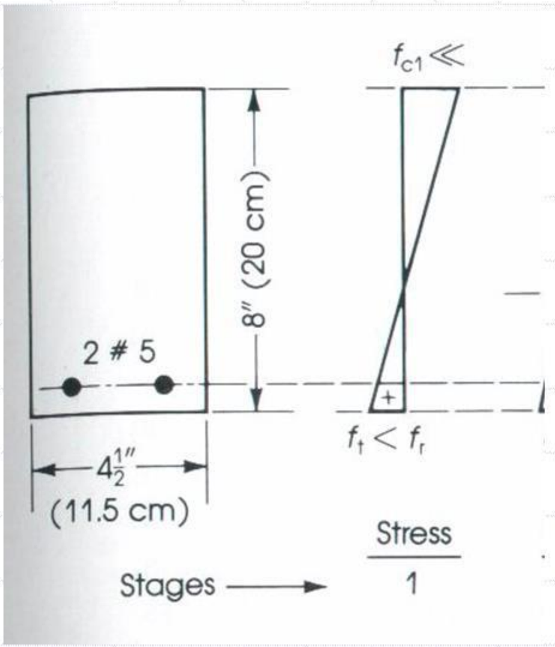
The equation for S_{xx} modulus for calculating maximum compressive stress.

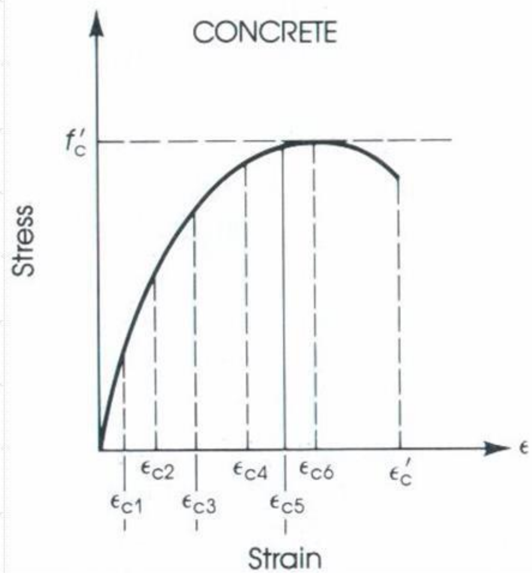


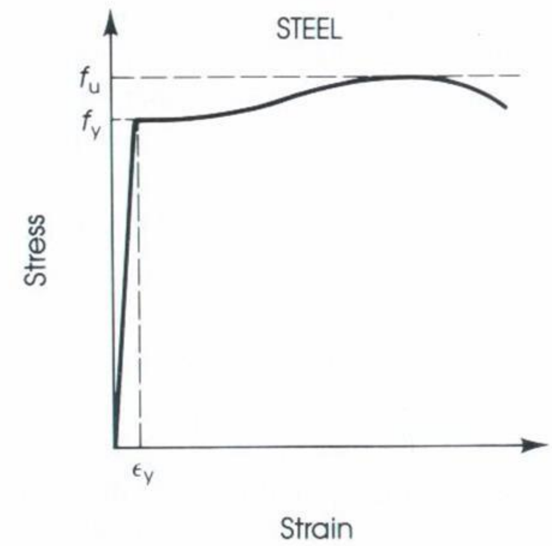
Flexural Stress

There are 5 stages the concrete through which the beam goes.

Stage 1: No external loads self weight.



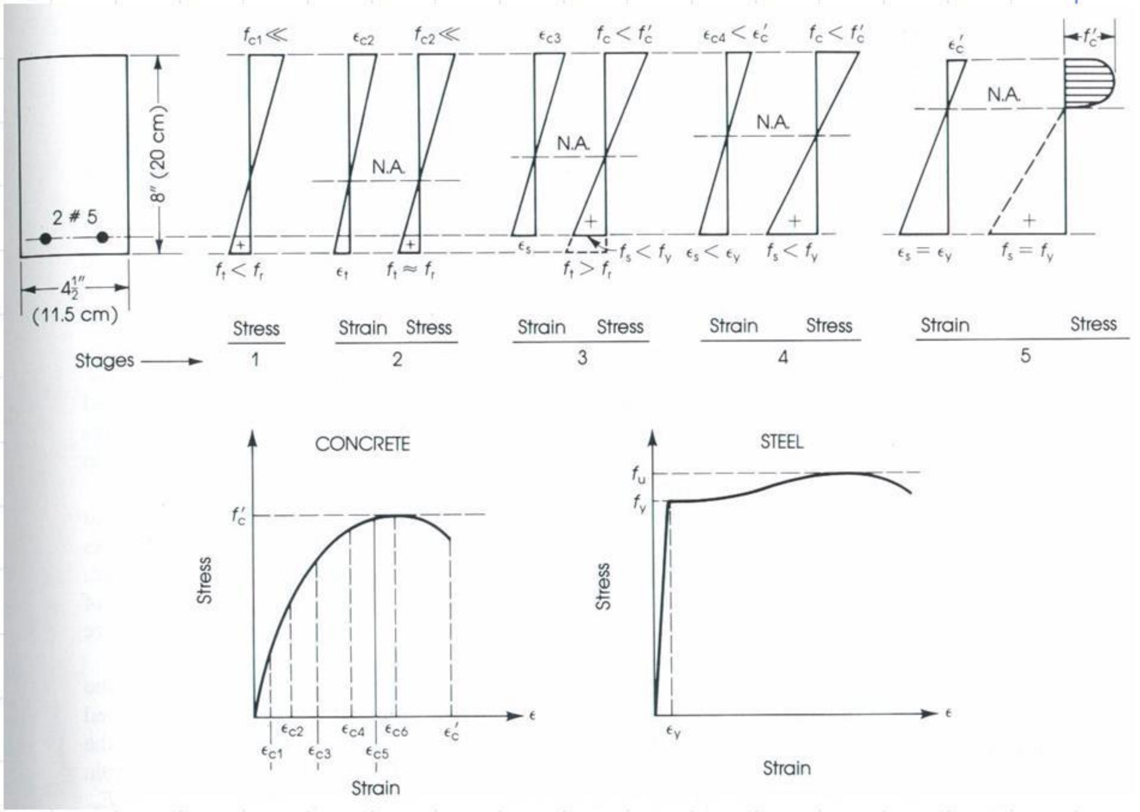




Flexural Stress

There are 5 stages the concrete through which the beam goes.

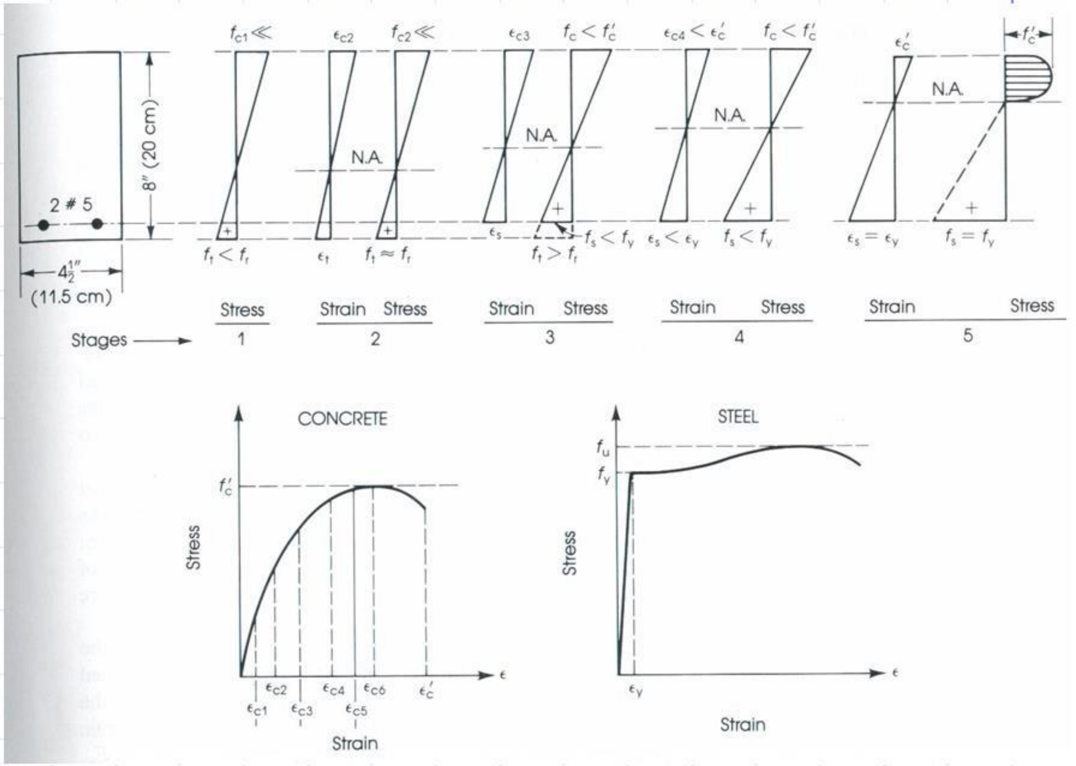
Stage 2: the external load P cause the bottom fibers to equal to modulus of rupture of the concrete. Entire concrete section was effective, steel bar at tension side has same strain as surrounding concrete.



Flexural Stress

- There are 5 stages the concrete through which the beam goes.

Stage 3: The tensile strength of the concrete exceeds the rupture f_r and cracks develop. The neutral axis shifts upward and cracks extend to neutral axis. Concrete loses tensile strength and steel starts working effectively and resists the entire tensile load.

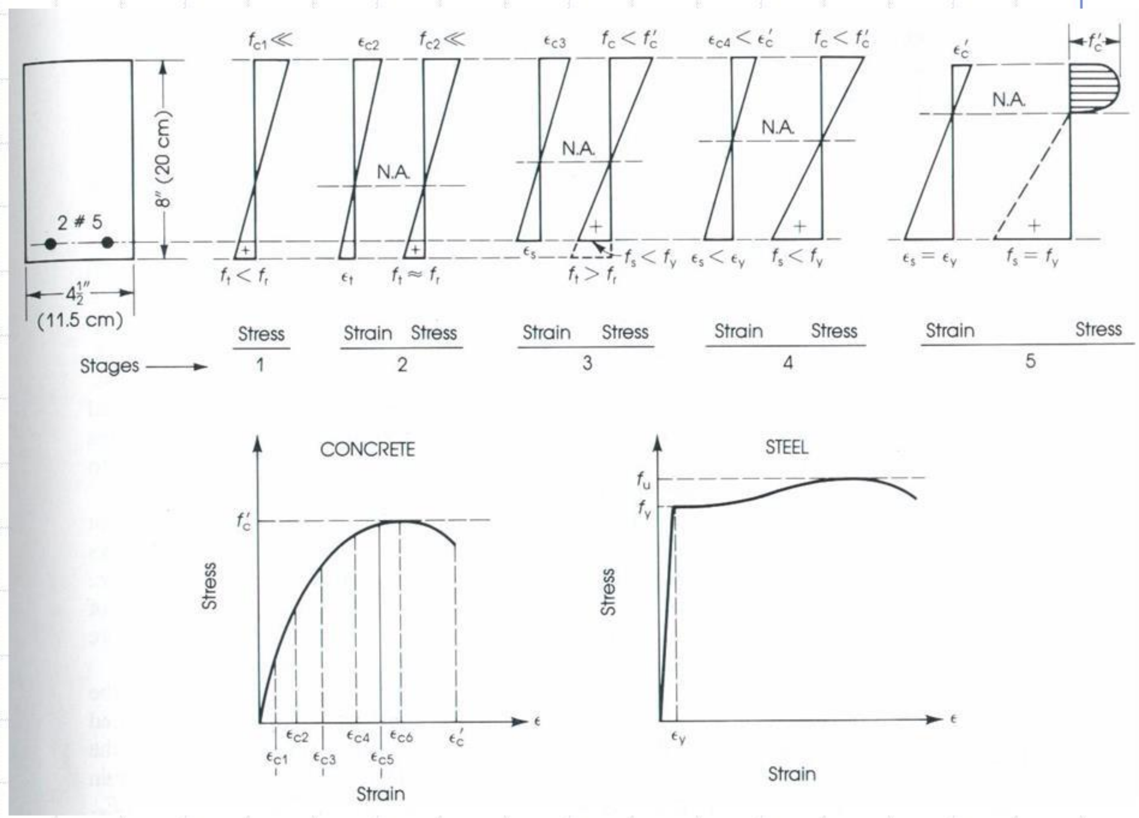


Flexural Stress

- There are 5 stages the concrete through which the beam goes.

Stage 4: The reinforcement yields.

Stage 5: Failure of the beam.



Flexural Stress

The three stages of the beam.

Stage 1: No external loads acting on the beam.

Stage 3: Service loading on the beam.

Stage 5: Beam failure.

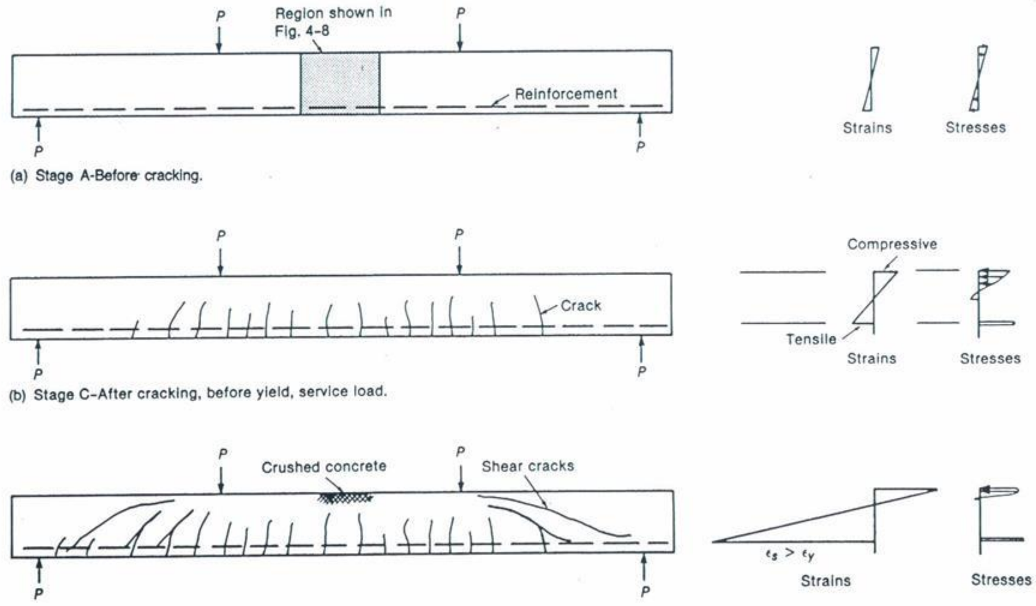


Fig. 4-5
Cracks, strains, and stresses in test beam.

Flexural Stress

The moment-curvature diagram show the five stages of the beam. The plot is of the curvature angle, ϕ , verse the moment.

$\phi = (\varepsilon / y) = [\, \sigma / E \,] / y$

$= [(My / I) / E] / y$

$\phi = M / (\, E I \,)$

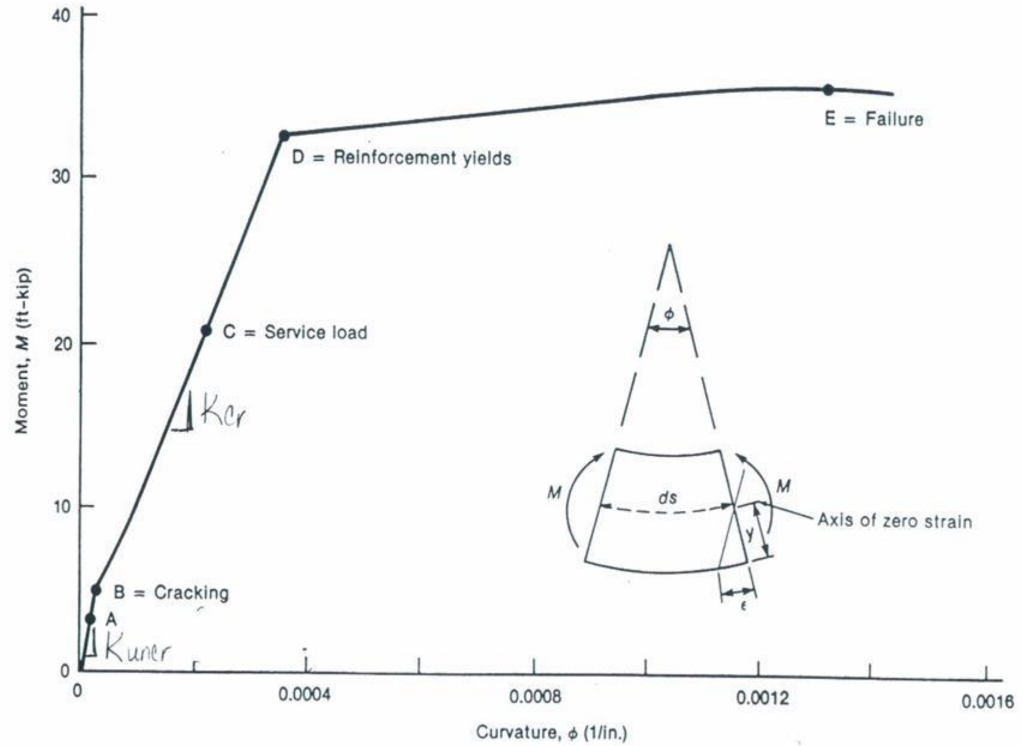
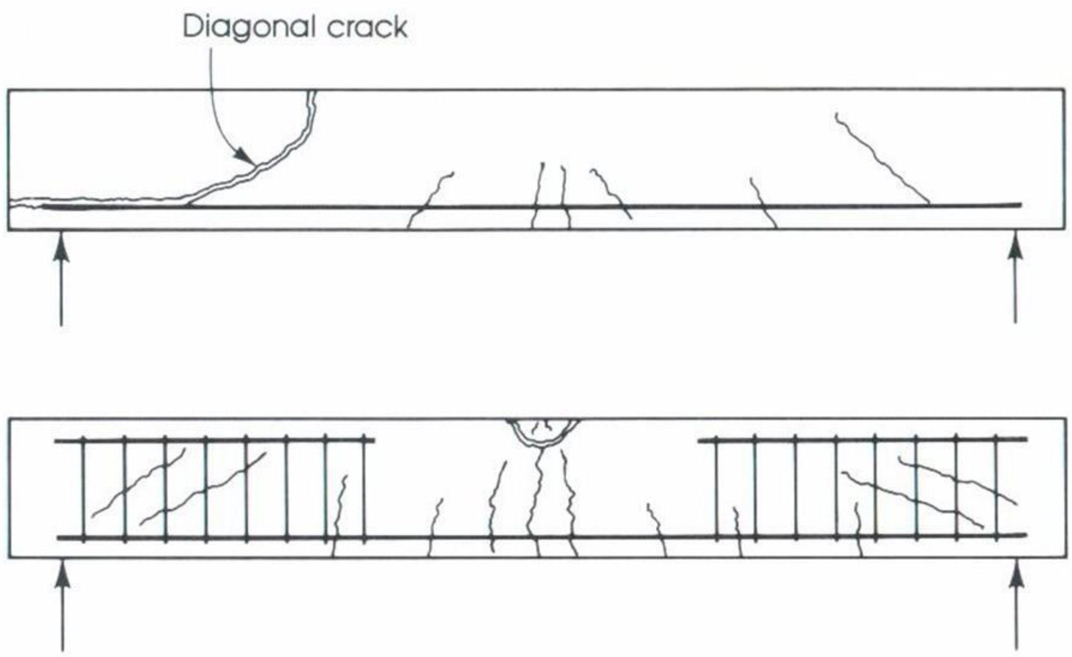


Fig. 4-7
Moment–curvature diagram for test beam.

Flexural Stress

The beam fails first in shear and the second beam fails in bending moment.



Flexural Stress

There are three types of flexural failure of a structural member.

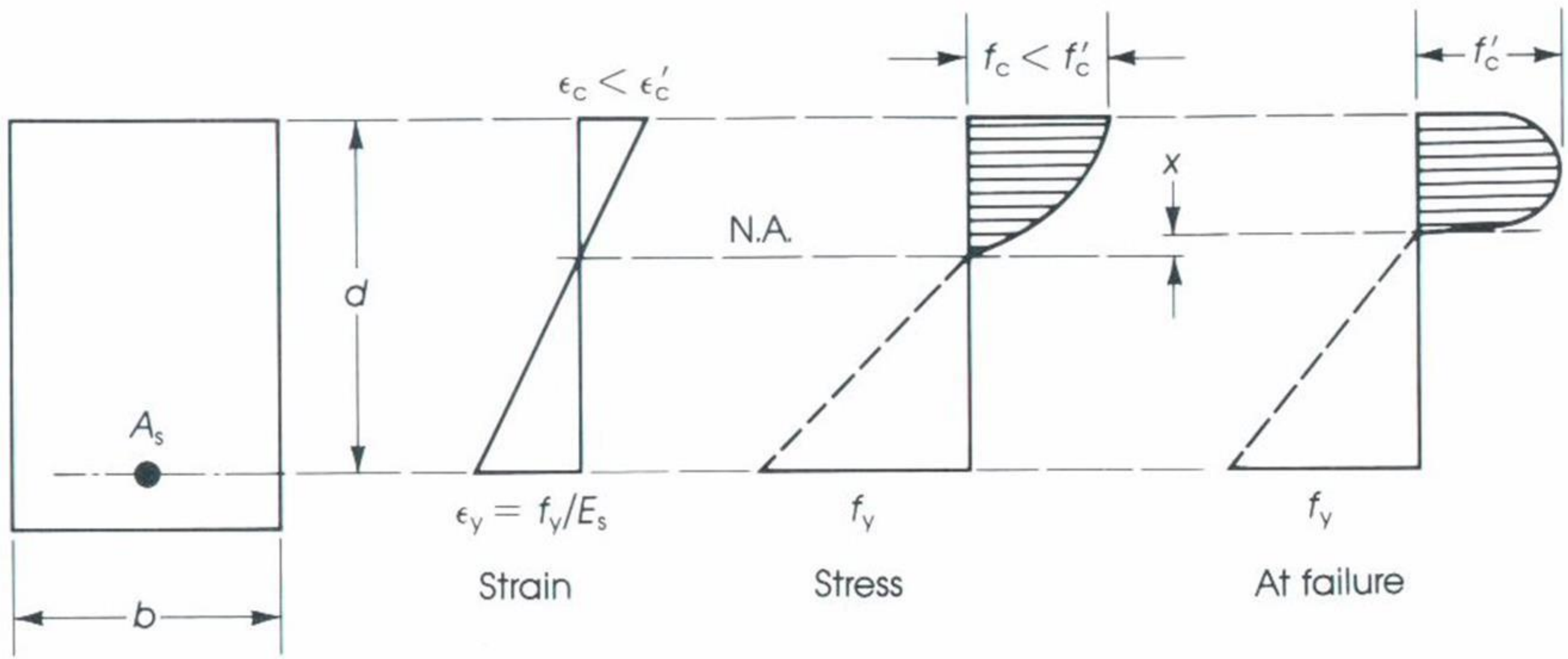
Steel may reach its yield strength before the concrete reaches its maximum. (**Under-reinforced section**).

Steel reaches yield at same time as concrete reaches ultimate strength. (**Balanced section**).

Concrete may fail before the the yield of steel due to the presence of a high percentage of steel in the section. (**Over-reinforced section**).

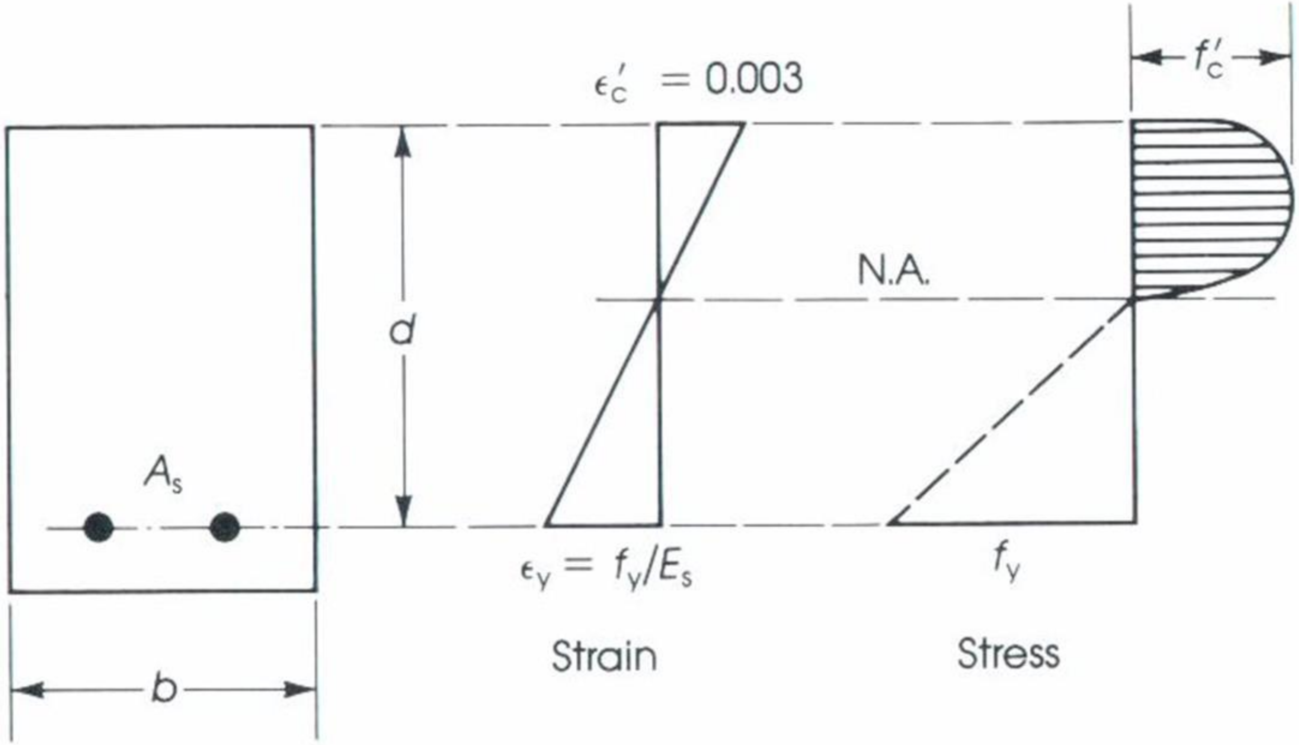
Flexural Stress

Steel may reach its yield strength before the concrete reaches its maximum. (**Under-reinforced section**).



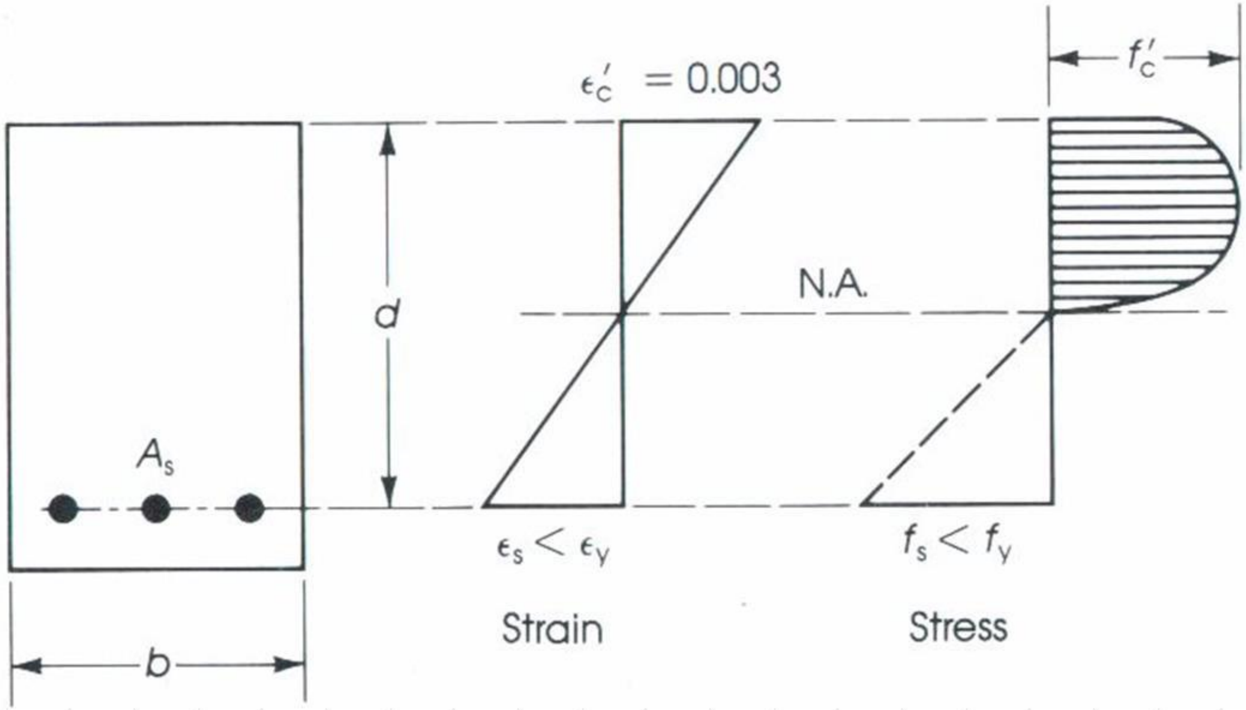
Flexural Stress

- Steel reaches yield at same time as concrete reaches ultimate strength. (**Balanced section**).



Flexural Stress

Concrete may fail before the the yield of steel due to the presence of a high percentage of steel in the section. (**Over-reinforced section**).



Flexural Stress

Additional Assumptions for design (for simplification)

- Tensile strength of concrete is neglected for calculation of flexural strength.
- Concrete is assumed to fail in compression, when ε_c (concrete strain) = ε_{cu} (limit state) = 0.003
- Compressive $\sigma-\varepsilon$ relationship for concrete may be assumed to be any shape that results in an acceptable prediction of strength.