Fig. 4.26  Reinforced concrete beam.
\[ x = \frac{b x (x/2) + m A_s (d)}{b x + m A_s} = \frac{A_1 y_1 + A_2 y_2 + \ldots}{A_1 + A_2 + \ldots} \]

\[ b x^2 + m A_s x = \frac{b x^2}{2} + m A_s d \]

\[ \frac{b x^2}{2} + m A_s x - m A_s d = 0 \]

**Prob Sample 4.4**

\[ b = 12'' \text{, } n = 8.06 \text{, } A_s = 0.614''^2 \text{, } d = 4'' \]
4.7 STRESS CONCENTRATIONS

$\sigma_{\text{true}} = \sigma_{305} (K)$

$\sigma_{\text{max}} = K \sigma_{305}$

Fig. 4.27 Stress-concentration factors for flat bars with fillets under pure bending.†

Fig. 4.28 Stress-concentration factors for flat bars with grooves under pure bending.†

Grooves 10 mm deep are to be cut in a steel bar which is 60 mm wide and 9 mm thick (Fig. 4.29). Determine the smallest allowable width of the grooves if the stress in the bar is not to exceed 150 MPa when the bending moment is equal to 150 N·m.

**Fig. 4.29**

\[ D = 60 \]

4.29 \( \sigma = \frac{K(Mc)}{I} \) from page 246

\[ 305 \]
SAMPLE PROBLEM 4.3

\[ \bar{y} = \frac{A_1 y_1 + A_2 y_2 + \cdots}{A_1 + A_2 + \cdots} \]

SOLUTION

b. Stress in Steel. Along the top edge \( c_1 = 0.120 \text{ m} \). From the transformed section we obtain an equivalent stress in wood, which must be multiplied by \( n \) to obtain the stress in steel.

\[ \sigma_s = n \frac{M_{c_1}}{I} = (16) \frac{50 \times 10^3 \text{ N} \cdot \text{m}}{2.19 \times 10^{-3} \text{ m}^4} (0.120 \text{ m}) \]

\[ \sigma_s = 43.8 \text{ MPa} \]
\[ \bar{y} = \frac{(3 \times 2 \text{ m})(0.02 \text{ m})[0.31 \text{ m}]}{(3.2 \text{ m})(0.02 \text{ m})} + \frac{(0.470)(0.30)(0.30)}{2} + (0.470)(0.3) \]

\[ \Rightarrow \bar{y} = 0.2 \text{ m} \]

\[ I = \frac{bh^3}{12} + \frac{bh^3}{12} + Ad^2 + Ad^2 \]
SAMPLE PROBLEM 4.4

A concrete floor slab is reinforced by $\frac{5}{8}$-in.-diameter steel rods placed 1.5 in. above the lower face of the slab and spaced 6 in. on centers. The modulus of elasticity is $3.6 \times 10^6$ psi for the concrete used and $29 \times 10^6$ psi for the steel. Knowing that a bending moment of 40 kip \cdot in. is applied to each 1-ft width of the slab, determine (a) the maximum stress in the concrete, (b) the stress in the steel.

\[
A_S = 2.36 \pi \left( \frac{\pi}{4} \left( \frac{5}{8} \right)^2 \right)
\]

\[
\frac{E_S}{E_C} = \frac{29}{3.6} = 8.06
\]

\[
M = 40 \text{ kip in.}
\]

\[
\sigma = \frac{M c}{I}
\]

\[
I = \frac{bh^3}{12} + bh\left(\frac{h}{2}\right) + 4.95(2.55)^2
\]
Pop Quiz

STEEL
Douglas Fir

M = \frac{29 \times 10^3 \text{ksi}}{1.9 \times 10^3 \text{ksi}} = 15.26

Transformed section into woods

\bar{I} = \frac{(152.6 \text{ in})(22\text{ in})^3}{12} - \frac{(142.6 \text{ in})(20\text{ in})^3}{12} = 40,340 \text{ in}^4

\sigma = \frac{M_{all}}{I} = \frac{M_{all}}{I_{transformed}}
For wood: \( F_{\text{all}} = \frac{7.2 \text{ ksi comp}}{1.2} = 6.0 \text{ ksi} \)

\[
M_{\text{all}} = \frac{(6.0 \text{ ksi})(40,340 \text{ in}^4)}{10 \text{ in}} = \frac{24,200 \text{ in} \cdot \text{lb}}{10 \text{ in}^2} = 2017 \text{ kft}
\]

For steel: \( F_{\text{all}} = \frac{36 \text{ ksi}}{1.6} = 22.5 \text{ ksi} \)

\[
M_{\text{all}} = \frac{(22.5 \text{ ksi})(40,340 \text{ in}^4)}{(15,26)(11\text{''})} = \frac{5407 \text{ in} \cdot \text{lb}}{15,26} = 5407 \text{ in} \cdot \text{lb} = 5407 \text{ in} \cdot \text{lb}
\]

Check: \( C_{\text{steel}} = \frac{M_{\text{c}}}{I} \)

\[
= \frac{5407 \text{ in} \cdot \text{lb}(11\text{''})}{40,340 \text{ in} \cdot \text{lb}} = 22.5 \text{ ksi}
\]
4.12 ECCENTRIC AXIAL LOADING IN A PLANE OF SYMMETRY

Fig. 4.42 Member with eccentric loading.

Fig. 4.43 Internal forces in member with eccentric loading.
Pop Quiz

\[ M = 10 \text{ in.k} \]

\[ \Gamma = \frac{(10 \text{ in.k}) (1')}{(6 \text{ in})(2 \text{ in})^{\frac{3}{12}}} \]
Pop Quiz

\[ \sigma = \frac{10 \text{ (lb/in.\textsuperscript{2})}}{6.23/12} \]

T.G. - Nice Job.

L^3