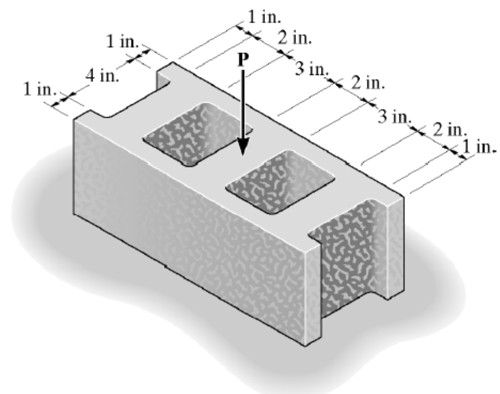
HW 14 SOLUTIONS

***1–40.** The cinder block has the dimensions shown. If the material fails when the average normal stress reaches 120 psi, determine the largest centrally applied vertical load **P** it can support.



Cross section Area :

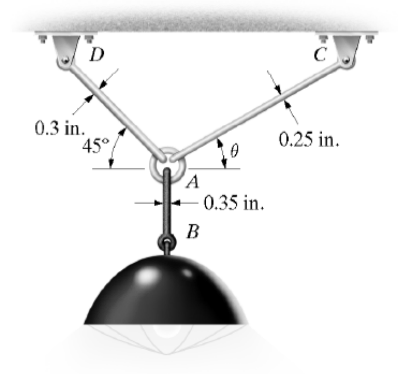
$$A = 6(14) - 2[4(1) + 3(4)] = 52 \text{ in}^2$$

Average Normal Stress :

$$\sigma_{allow} = \frac{P_{allow}}{A}; \qquad 120 = \frac{P_{allow}}{52}$$

$P_{allow} = 6240 \text{ lb} = 6.24 \text{ kip}$ **Ans**

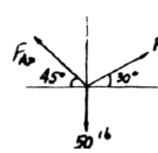
1–42. The 50-lb lamp is supported by three steel rods connected by a ring at A. Determine which rod is subjected to the greater average normal stress and compute its value. Take $\theta = 30°$. The diameter of each rod is given in the figure.



$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{AC}\cos 30° - F_{AD}\cos 45° = 0$

$+\uparrow \Sigma F_y = 0; \qquad F_{AC}\sin 30° + F_{AD}\sin 45° - 50 = 0$

$$F_{AC} = 36.60 \text{ lb}, \qquad F_{AD} = 44.83 \text{ lb}$$



Rod *AB* :

$$\sigma_{AB} = \frac{50}{\frac{\pi}{4}(0.35)^2} = 520 \text{ psi}$$

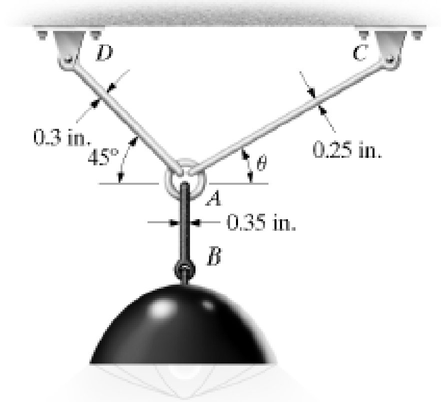
Rod *AD* :

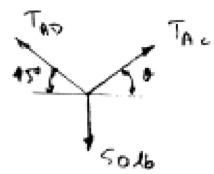
$$\sigma_{AD} = \frac{44.83}{\frac{\pi}{4}(0.3)^2} = 634 \text{ psi}$$

Rod *AC* :

$$\sigma_{AC} = \frac{36.60}{\frac{\pi}{4}(0.25)^2} = 746 \text{ psi}$$ **Ans**

*1–44. The 50-lb lamp is supported by three steel rods connected by a ring at A. Determine the angle of orientation θ of AC such that the average normal stress in rod AC is twice the average normal stress in rod AD. What is the magnitude of stress in each rod? The diameter of each rod is given in the figure.





$$\sigma_{AD} = \frac{T_{AD}}{\frac{\pi}{4}(0.3)^2}; \qquad T_{AD} = (0.070686)\sigma_{AD}$$

$$\sigma_{AC} = 2\sigma_{AD} = \frac{T_{AC}}{\frac{\pi}{4}(0.25)^2}; \qquad T_{AC} = (0.098175)\sigma_{AD}$$

$$\xrightarrow{+} \Sigma F_x = 0; \qquad -T_{AD}\cos 45° + T_{AC}\cos\theta = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad T_{AC}\sin\theta + T_{AD}\sin 45° - 50 = 0 \qquad (2)$$

Thus

$$-(0.070686)\sigma_{AD}(\cos 45°) + (0.098175)\sigma_{AD}(\cos\theta) = 0$$

$$\theta = 59.39° = 59.4° \qquad \textbf{Ans}$$

From Eq. (2) :

$$(0.098175)\sigma_{AD}\sin 59.39° + (0.070686)\sigma_{AD}\sin 45° - 50 = 0$$

$$\sigma_{AD} = 371.8 \text{ psi} = 372 \text{ psi} \qquad \textbf{Ans}$$

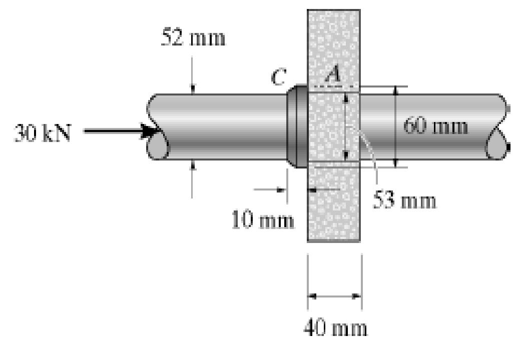
Hence,

$$\sigma_{AC} = 2(371.8) = 744 \text{ psi} \qquad \textbf{Ans}$$

And,

$$\sigma_{AB} = \frac{T_{AB}}{\frac{\pi}{4}(0.35)^2} = \frac{50}{\frac{\pi}{4}(0.35)^2} = 520 \text{ psi} \qquad \textbf{Ans}$$

1–45. The shaft is subjected to the axial force of 30 kN. If the shaft passes through the 53-mm diameter hole in the fixed support A, determine the bearing stress acting on the collar C. Also, what is the average shear stress acting along the inside surface of the collar where it is fixed connected to the 52-mm diameter shaft?



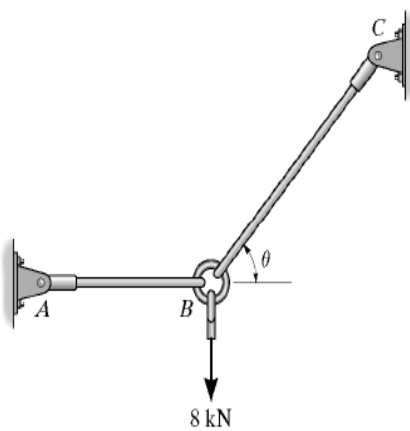
Bearing Stress :

$$\sigma_b = \frac{P}{A} = \frac{30(10^3)}{\frac{\pi}{4}(0.06^2 - 0.053^2)} = 48.3 \text{ MPa} \qquad \textbf{Ans}$$

Average Shear Stress :

$$\tau_{avg} = \frac{V}{A} = \frac{30(10^3)}{\pi(0.052)(0.01)} = 18.4 \text{ MPa} \qquad \textbf{Ans}$$

1–57. Rods AB and BC have diameters of 4 mm and 6 mm, respectively. If the vertical load of 8 kN is applied to the ring at B, determine the angle θ of rod BC so that the average normal stress in each rod is equivalent. What is this stress?



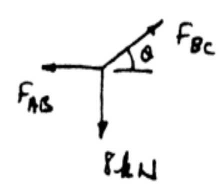
$$F_{AB} = \sigma A_{AB} = \sigma(\pi)(0.002)^2$$
$$F_{BC} = \sigma A_{BC} = \sigma(\pi)(0.003)^2$$

$$\xrightarrow{+} \Sigma F_x = 0; \qquad \sigma(\pi)(0.003^2)\cos\theta - \sigma\pi(0.002^2) = 0 \qquad (1)$$
$$+\uparrow \Sigma F_y = 0; \qquad \sigma\pi(0.003^2)\sin\theta - 8(10^3) = 0 \qquad (2)$$

From Eq. (1) :

$$\cos\theta = \left(\frac{0.002}{0.003}\right)^2$$

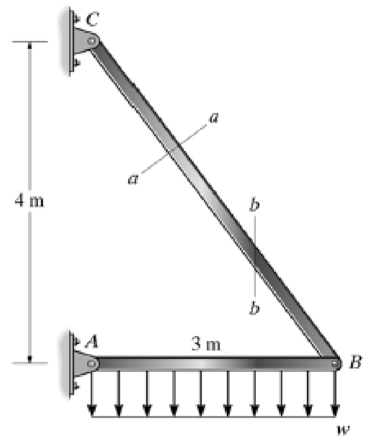
$$\theta = 63.6° \qquad \textbf{Ans}$$



From Eq. (2) :

$$\sigma = \frac{8(10^3)}{\pi(0.003)^2 \sin 63.6°} = 316 \text{ MPa} \qquad \textbf{Ans}$$

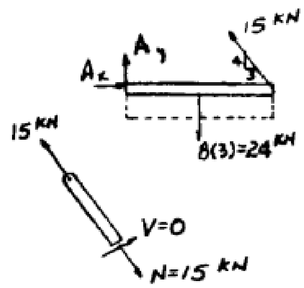
*1–64. The two-member frame is subjected to the distributed loading shown. Determine the average normal stress and average shear stress acting at sections a–a and b–b. Member CB has a square cross section of 35 mm on each side. Take $w = 8$ kN/m.



At setion $a-a$:

$$\sigma_{a-a} = \frac{15(10^3)}{(0.035)^2} = 12.2 \text{ MPa} \qquad \textbf{Ans}$$

$$\tau_{a-a} = 0 \qquad \textbf{Ans}$$



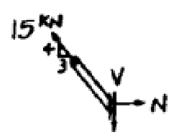
At section $b-b$:

$$\xrightarrow{+} \Sigma F_x = 0; \qquad N - 15(3/5) = 0; \qquad N = 9 \text{ kN}$$

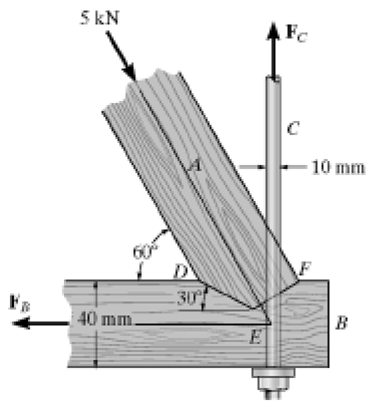
$$+\downarrow \Sigma F_y = 0; \qquad V - 15(4/5) = 0; \qquad V = 12 \text{ kN}$$

$$\sigma_{b-b} = \frac{9(10^3)}{(0.035)(0.035/0.6)} = 4.41 \text{ MPa} \qquad \textbf{Ans}$$

$$\tau_{b-b} = \frac{12(10^3)}{(0.035)(0.035/0.6)} = 5.88 \text{ MPa} \qquad \textbf{Ans}$$



1–65. Member A of the timber step joint for a truss is subjected to a compressive force of 5 kN. Determine the average normal stress acting in the hanger rod C which has a diameter of 10 mm and in member B which has a thickness of 30 mm.



Equations of Equilibrium :

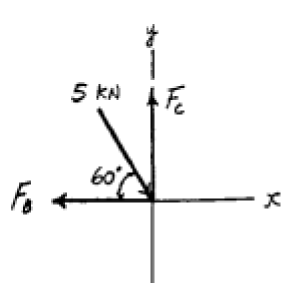
$\xrightarrow{+} \Sigma F_x = 0;\quad 5\cos 60° - F_B = 0 \qquad F_B = 2.50 \text{ kN}$

$+\uparrow \Sigma F_y = 0;\quad F_c - 5\sin 60° = 0 \qquad F_c = 4.330 \text{ kN}$

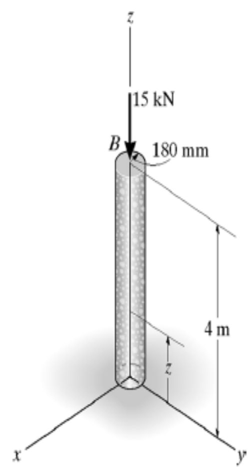
Average Normal Stress :

$$\sigma_B = \frac{F_B}{A_B} = \frac{2.50(10^3)}{(0.04)(0.03)} = 2.08 \text{ MPa} \qquad \textbf{Ans}$$

$$\sigma_C = \frac{F_C}{A_C} = \frac{4.330(10^3)}{\frac{\pi}{4}(0.01^2)} = 55.1 \text{ MPa} \qquad \textbf{Ans}$$



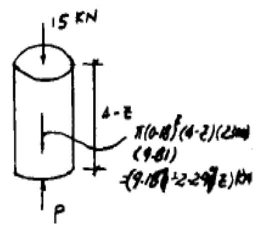
1–75. The column is made of concrete having a density of $2.30\ \mathrm{Mg/m^3}$. At its top B it is subjected to an axial compressive force of 15 kN. Determine the average normal stress in the column as a function of the distance z measured from its base. *Note:* The result will be useful only for finding the average normal stress at a section removed from the ends of the column, because of localized deformation at the ends.



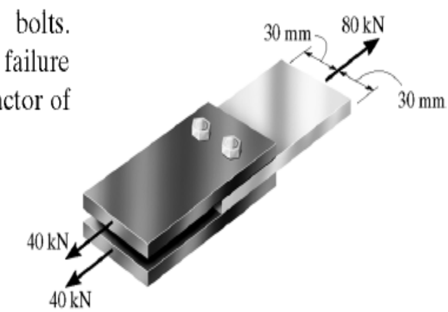
$$+\uparrow \Sigma F_y = 0 \qquad P - 15 - 9.187 + 2.297z = 0$$

$$P = 24.187 - 2.297z$$

$$\sigma = \frac{P}{A} = \frac{24.187 - 2.297z}{\pi(0.18)^2} = (238 - 22.6z)\ \mathrm{kPa} \qquad \textbf{Ans}$$



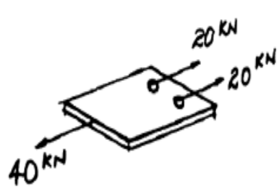
1–81. The joint is fastened together using two bolts. Determine the required diameter of the bolts if the failure shear stress for the bolts is $\tau_{fail} = 350$ MPa. Use a factor of safety for shear of F.S. = 2.5.



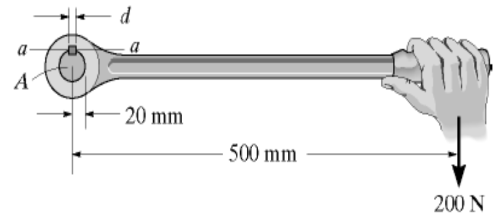
$$\frac{350(10^6)}{2.5} = 140(10^6)$$

$$\tau_{allow} = 140(10^6) = \frac{20(10^3)}{\frac{\pi}{4}d^2}$$

$$d = 0.0135\ \mathrm{m} = 13.5\ \mathrm{mm} \qquad \textbf{Ans}$$

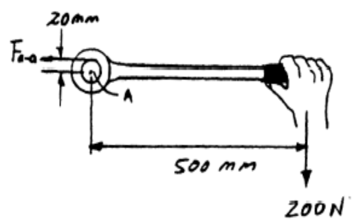


1–83. The lever is attached to the shaft A using a key that has a width d and length of 25 mm. If the shaft is fixed and a vertical force of 200 N is applied perpendicular to the handle, determine the dimension d if the allowable shear stress for the key is $\tau_{allow} = 35$ MPa.



$\circlearrowleft + \Sigma M_A = 0;\quad F_{a-a}(20) - 200(500) = 0$

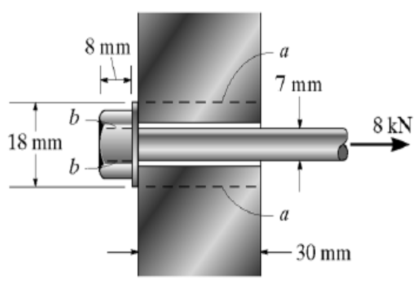
$F_{a-a} = 5000$ N



$\tau_{allow} = \frac{F_{a-a}}{A_{a-a}};\quad 35(10^6) = \frac{5000}{d(0.025)}$

$d = 0.00571$ m $= 5.71$ mm **Ans**

***1–112.** The long bolt passes through the 30-mm-thick plate. If the force in the bolt shank is 8 kN, determine the average normal stress in the shank, the average shear stress along the cylindrical area of the plate defined by the section lines a–a, and the average shear stress in the bolt head along the cylindrical area defined by the section lines b–b.



$$\sigma_s = \frac{P}{A} = \frac{8(10^3)}{\frac{\pi}{4}(0.007)^2} = 208 \text{ MPa} \quad \textbf{Ans}$$

$$(\tau_{avg})_a = \frac{V}{A} = \frac{8(10^3)}{\pi(0.018)(0.030)} = 4.72 \text{ MPa} \quad \textbf{Ans}$$

$$(\tau_{avg})_b = \frac{V}{A} = \frac{8(10^3)}{\pi(0.007)(0.008)} = 45.5 \text{ MPa} \quad \textbf{Ans}$$