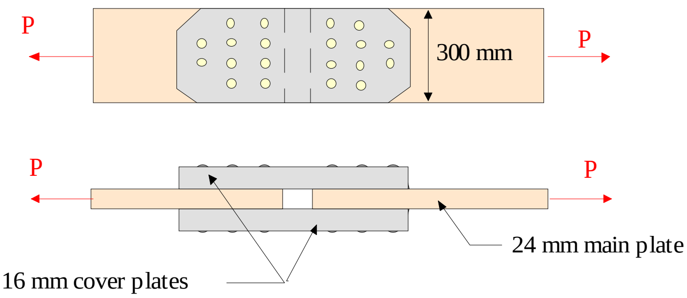
Rivet Example

Determine the allowable tensile force that the multi-riveted joint shown can transmit. All rivets are nominally 24 mm in a 26 mm diameter hole. The design stresses are

$(\sigma_{all})_{tension} = 160 \text{ MPa}$,

$(\tau_{all})_{shear} = 110 \text{ MPa}$,

$(\sigma_{all})_{bearing} = 350 \text{ MPa}$

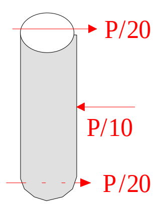


Solution

Rivet Shear

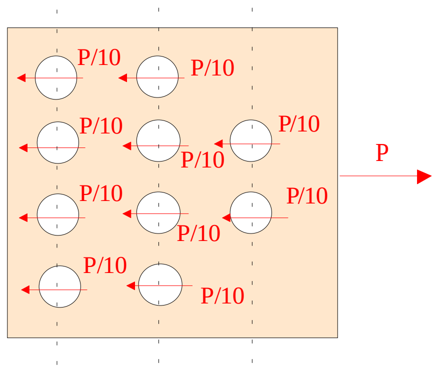
Consider a Free Body Diagram of the main plate. The cross-sectional area of each rivet is

$$A_r = \frac{\pi}{4} d^2 = \frac{\pi}{4}(0.024)^2 = 452.4 \times 10^{-6} \text{ m}^2$$



Since there are 10 rivets on each side of the main plate, and each one is in double shear, the shear force for each rivet is $P/20$. Since $(\tau_{all})_{shear} = 110 \text{ MPa}$ for each rivet

$$110 \times 10^3 = \frac{F_s}{A_r} = \frac{P/20}{452.4 \times 10^{-6}}$$



Row 3 Row 2 Row 1

Solving,

$P = 110 \times 10^6 \left(452.4 \times 10^{-6}\right)(20) = 995.28 \text{ kN}$ The applied force required to fail the rivets in shear is

$$P = 995 \text{ kN}$$

Bearing Failure : Main Plate: With 10 bearing surfaces in double shear and $(\sigma_{all})_{bearing} = 350 \text{ MPa}$

$$P = F_B = 10\left(350 \times 10^6\right)(0.024)(0.24) = 2016 \text{ kN}$$

Cover plate: With 20 bearing surfaces in single shear

$$P = F_B = 20\left(350 \times 10^6\right)(0.024)(0.016) = 2688 \text{ kN}$$

Tension Failure: Main Plate: In the section of the main plate where there are no rivet holes, and having $(\sigma_{all})_{tension} = 160 \text{ MPa}$, we find

$$P = F_T = (0.024)(0.30)\ 160 \times 10^6 \ = 1152 \text{ kN}$$

In the sections of the plate where there are holes, the area that can support load can be given as

$$A = t(w - nd)$$

where

t = plate thickness (24 mm), w = plate width (300 mm), n = number of holes, d = hole diameter (26 mm)

Row 1: $A = 0.024\left[0.300 - 2(0.026)\right] = 5.952 \times 10^{-3} \text{ m}^2$

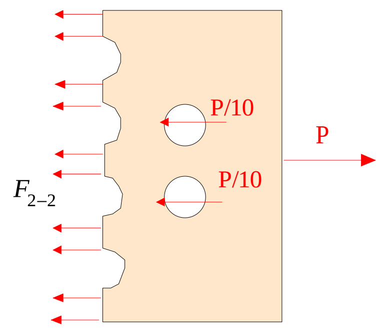
$$P = F_{1-1} = 160 \times 10^6 \left(5.952 \times 10^{-3}\right) = 952.3 \text{ kN}$$

Row 2: $A = 0.024\left[0.300 - 4\left(0.026\right)\right] = 4.704 \times 10^{-3} \text{ m}^2$

$$F_{2-2} + 2(P/10) = P \quad \Rightarrow \quad F_{2-2} = \frac{4}{5}P$$

$$F_{2-2} = \frac{4}{5}P = 160 \times 10^6 \left(4.704 \times 10^{-3}\right) = 752.6 \text{ kN}$$

$$P = 941 \text{ kN}$$



Row 3: $A = 0.024\left[0.300 - 4\left(0.026\right)\right] = 4.704 \times 10^{-3} \text{ m}^2$

$$F_{3-3} + 6(P/10) = P \quad \Rightarrow \quad F_{2-2} = \frac{2}{5}P$$

$$F_{3-3} = \frac{2}{5}P = 160 \times 10^6 \left(4.704 \times 10^{-3}\right) = 752.6 \text{ kN}$$

$$P = 1881 \text{ kN}$$

Cover Plate: For the cover plates, the area is $A = 0.016\left[0.300 - n\left(0.026\right)\right]$. Following the same procedure as with the main plate, we would determine, for each row

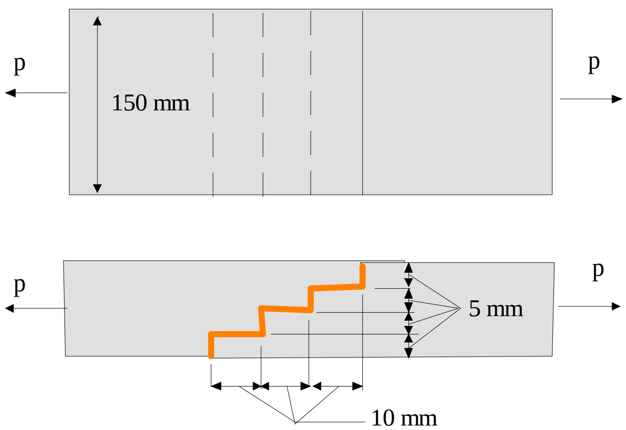
Row 1: $P = 1280 \text{ kN}$
Row 2: $P = 1254.5 \text{ kN}$
Row 3: $P = 2509 \text{ kN}$

Therefore, the maximum load that can be applied to the joint is the smallest force we have determined

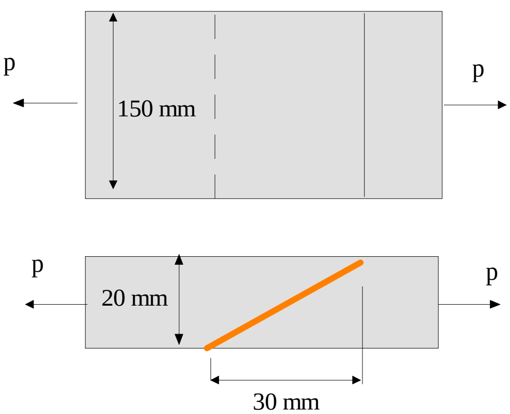
$$P = 941 \text{ kN}$$

Adhesive Example

Two joints are being considered for an application in which an adhesive with an allowable shear stress of $\tau_{all} = 10\ \text{MPa}$ is being used. Determine the allowable load that can be applied to each joint shown if the factor of safety for the joint is required to be 2.5.



Joint 1



Joint 2

Joint 1: $A_s = 3(0.01)(0.15) = 4.5\times10^{-3}\ \text{m}^2$

$$\tau_d = \frac{\tau_{all}}{2.5} = 4\ \text{MPa}$$

$$4\ \text{MPa} = \frac{\text{P}}{\text{A}_\text{s}} = \frac{P}{4.5\times10^{-3}} \quad \Rightarrow \quad P = 18\ \text{kN}$$

Joint 2: $A_s = 0.150\sqrt{(0.020)^2 + (0.030)^2} = 5.41\times10^{-3}\ \text{m}^2$

From equilibrium considerations of the joint

$$S = P\cos\theta \quad \left(\theta = 33.7^{\text{o}}\right)$$

$$S = 0.832P$$

$$4\ \text{MPa} = \frac{S}{A} = \frac{0.832P}{5.41\times10^{-3}} \quad \Rightarrow \quad P = 26\ \text{kN}$$