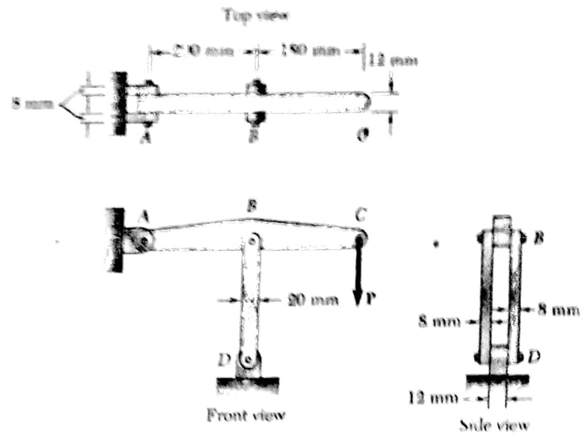
Faculty of Engineering
Prod. & Mech. Design Eng. Dept.

1[st] Term - 2018/2019

Strength of Materials
20 Marks – 1 Hour.

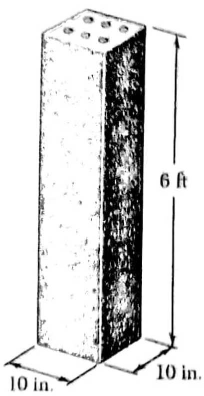
Second Midterm

Mid-Term Exam



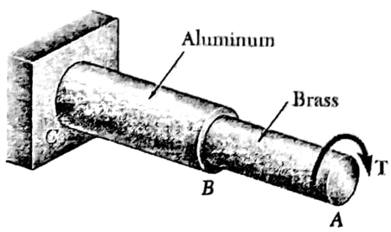
Question 1: [8 Marks]

In the structure shown, an 8-mm-diameter pin isused at A, and 12-mm-diameter pins are used at $B$and D. Knowing that the ultimate shearing stress is 100 MPa at all connections and that the ultimate normal stress is 250 MPa in each of the two links joining B and D, determine the allowable load **P** if an overall factor of safety of 3.0 is desired.



Question 2: [6 Marks]

The concrete post ($E_c = 3.6\times10^6$ psi and $\alpha_c = 5.5\times10^{-6}/°F$) is reinforced with six steel bars, each of $\frac{7}{8}$-in. diameter ($E_s = 29\times10^6$ psi and $\alpha_s = 6.5\times10^{-6}/°F$). Determine the normal stresses induced in the steel and in the concrete by a temperature rise of 65°F.



Question 3: [6 Marks]

The *solid* rod BC has a diameter of 30 mm and is made of an aluminum for which the allowable shearing stress is 25 MPa. Rod AB is *hollow* and has an outer diameter of 25 mm; it is made of a brass for which the allowable shearing stress is 50 MPa. Determine (a) the largest inner diameter of rod AB for which the factor of safety is the same for each rod, (b) the largest torque that can be applied at A.

Best Wishes

Associate Prof. Dr. Noha Fouda

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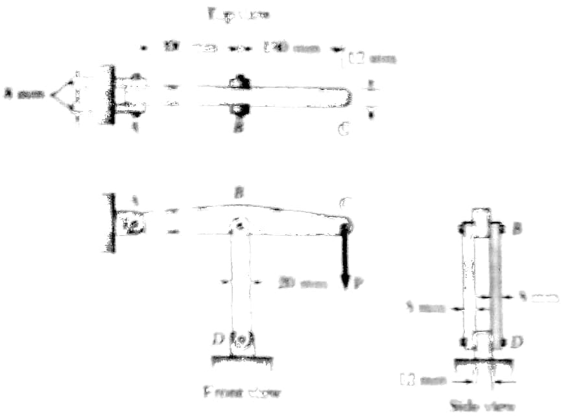
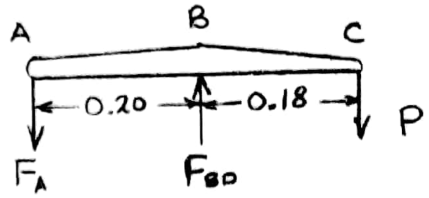


PROBLEM 1

In the structure shown, an 8-mm-diameter pin is used at A, and 12-mm-diameter pins are used at B and D. Knowing that the ultimate shearing stress is 100 MPa at all connections and that the ultimate normal stress is 250 MPa in each of the two links joining B and D, determine the allowable load $\mathbf{P}$ if an overall factor of safety of 3.0 is desired.

SOLUTION

Statics: Use ABC as free body.



$$+\circlearrowleft \Sigma M_B = 0: \quad 0.20\,F_A - 0.18\,P = 0 \qquad P = \frac{10}{9}F_A$$

$$+\circlearrowleft \Sigma M_A = 0: \quad 0.20\,F_{BD} - 0.38\,P = 0 \qquad P = \frac{10}{19}F_{BD}$$

Based on double shear in pin A: $A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.008)^2 = 50.266 \times 10^{-6}\,\mathrm{m}^2$

$$F_A = \frac{2\tau_U A}{F.S.} = \frac{(2)(100 \times 10^6)(50.266 \times 10^{-6})}{3.0} = 3.351 \times 10^3\,\mathrm{N} \qquad 2$$

$$P = \frac{10}{9}F_A = 3.72 \times 10^3\,\mathrm{N}$$

Based on double shear in pins at B and D: $A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.012)^2 = 113.10 \times 10^{-6}\,\mathrm{m}^2$

$$F_{BD} = \frac{2\tau_U A}{F.S.} = \frac{(2)(100 \times 10^6)(113.10 \times 10^{-6})}{3.0} = 7.54 \times 10^3\,\mathrm{N} \qquad 2$$

$$P = \frac{10}{19}F_{BD} = 3.97 \times 10^3\,\mathrm{N}$$

Based on compression in links BD: For one link, $A = (0.020)(0.008) = 160 \times 10^{-6}\,\mathrm{m}^2$

$$F_{BD} = \frac{2\sigma_U A}{F.S.} = \frac{(2)(250 \times 10^6)(160 \times 10^{-6})}{3.0} = 26.7 \times 10^3\,\mathrm{N} \qquad 2$$

$$P = \frac{10}{19}F_{BD} = 14.04 \times 10^3\,\mathrm{N}$$

Allowable value of P is smallest, $\therefore P = 3.72 \times 10^3\,\mathrm{N}$ 1

$P = 3.72$ kN ◀

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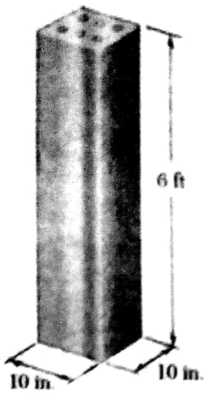
PROBLEM 2



The concrete post ($E_c = 3.6\times10^6$ psi and $\alpha_c = 5.5\times10^{-6}/°F$) is reinforced with six steel bars, each of $\frac{7}{8}$-in. diameter ($E_s = 29\times10^6$ psi and $\alpha_s = 6.5\times10^{-6}/°F$). Determine the normal stresses induced in the steel and in the concrete by a temperature rise of 65°F.

SOLUTION

$$A_s = 6\frac{\pi}{4}d^2 = 6\frac{\pi}{4}\left(\frac{7}{8}\right)^2 = 3.6079 \text{ in}^2$$

$$A_c = 10^2 - A_s = 10^2 - 3.6079 = 96.392 \text{ in}^2$$

Let P_c = tensile force developed in the concrete.

For equilibrium with zero total force, the compressive force in the six steel rods equals P_c.

Strains: $\varepsilon_s = -\dfrac{P_c}{E_sA_s} + \alpha_s(\Delta T) \qquad \varepsilon_c = \dfrac{P_c}{E_cA_c} + \alpha_c(\Delta T)$

Matching: $\varepsilon_c = \varepsilon_s \qquad \dfrac{P_c}{E_cA_c} + \alpha_c(\Delta T) = -\dfrac{P_c}{E_sA_s} + \alpha_s(\Delta T)$

$$\left(\frac{1}{E_cA_c} + \frac{1}{E_sA_s}\right)P_c = (\alpha_s - \alpha_c)(\Delta T)$$

$$\left[\frac{1}{(3.6\times10^6)(96.392)} + \frac{1}{(29\times10^6)(3.6079)}\right]P_c = (1.0\times10^{-6})(65)$$

$$P_c = 5.2254\times10^3 \text{ lb}$$

$$\sigma_c = \frac{P_c}{A_c} = \frac{5.2254\times10^3}{96.392} = 54.210 \text{ psi} \qquad \sigma_c = 54.2 \text{ psi}$$

$$\sigma_s = -\frac{P_c}{A_s} = -\frac{5.2254\times10^3}{3.6079} = -1448.32 \text{ psi} \qquad \sigma_s = -1.448 \text{ ksi}$$

Q3

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Solid BC $\tau = \frac{Tc}{J}$ $J = \frac{\pi}{2} c^4$

$\tau_{all} = 25 * 10^6$ pa

$c = \frac{1}{2} d = 0.015$ m

$T_{all} = \frac{\pi}{2} c^3 \tau_{all} = \frac{\pi}{2} (0.015)^3 (25 * 10^6)$

$= 132.536$ N-m 2

Hollow AB $\tau_{all} = 50 * 10^6$ pa

$T_{all} = 132.536$ N-m

$c_2 = \frac{1}{2} d_2 = \frac{1}{2}(0.025) = 0.125$ m

$c_1 = ??$

$T_{all} = \frac{J \tau_{all}}{c_2} = \frac{\pi}{2} (c_2^4 - c_1^4) \frac{\tau_{all}}{c_2}$ 2

$c_1^4 = c_2^4 - \frac{2 T_{all} c_2}{\pi \tau_{all}}$

$= 0.0125^4 - \frac{2(132.536)(0.0125)}{\pi (50 * 10^6)}$

$c_1 = 7.59 * 10^{-3}$ m $= 7.59$ mm 1

a $d_1 = 2c_1 = 15.18$ mm 1

b allowable torque $T_{all} = 132.5$ N.m

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