EM319 – Mechanics of Solids

Quiz #1, Fall 2004

Time: 7-9pm, Tuesday, September 28

Place: ESB 115

Name: __________________________

Unique number (circle one): 13055  13060  13065  13070

Closed books, notes, and homework.

Formulas:

\[ \sigma = \frac{P}{A}, \quad \varepsilon = \frac{\delta}{L}, \quad \sigma = E\varepsilon, \quad \varepsilon' = -\nu\varepsilon, \quad \tau = G\gamma, \quad G = \frac{E}{2(1+\nu)}, \]

\[ \delta = \frac{PL}{EA}, \quad \delta = \int d\delta = \int_0^L \frac{N(x)dx}{E(x)A(x)}, \quad \varepsilon_\tau = \alpha \Delta T, \]

\[ \sigma_\theta = \sigma_0 \cos^2 \theta, \quad \tau_\theta = -\sigma_0 \sin \theta \cos \theta \]
1. A circular steel bar of length $L$ and diameter $d$ is loaded in tension. The load $P$ and the elongation $\delta$ are measured simultaneously as the load increases, and they are plotted as below. Given: $L = 50$mm, $d = 10$mm, $P_1 = 30$kN, $P_2 = 40$kN, $P_3 = 60$kN, $\delta_1 = 0.1$mm.

(a) What is the Young’s modulus of the steel? (10 points)
(b) If the Poisson’s ratio of the steel is 0.3, what is the diameter of the bar under the load $P = 10$kN? (10)
(c) If the bar is designed within the proportional limit and the factor of safety is set to be 1.5, what is the allowable load? (5)

Answer: (a) 191 GPa; (b) 9.998mm; (c) 20 kN.
2. A horizontal rigid bar ABCD is pinned at end A and supported by two cables at B and C (see figure). The cables have the effective modulus $E = 140$ GPa, the nominal diameter $d = 20$ mm ($d_B = d_C = d$), the effective area 173 mm$^2$, and the length $L = 800$ mm. A bolt of diameter $d_A = 10$ mm are used at A to pin the bar (see figure). The total length of the bar is 5 m (i.e., $b = 1$m).

(a) Determine the vertical displacement of the end D subjected to a vertical load $P = 100$ kN at the end. (20)

(b) If the allowable tensile stress in the cable is 900 MPa and the allowable shear stress in the bolt A is 400 MPa, what is the allowable vertical load at the end D? (15)

Answer: (a) 4.1 mm; (b) 125.6 kN.
3. A copper bar AB of length 40 inch is placed in position at room temperature with a gap of 0.008 inch between the end A and a rigid restraint (see figure). For copper, elastic modulus \( E = 16 \times 10^6 \) psi and coefficient of thermal expansion \( \alpha = 10 \) ppm/°F.

(a) Calculate the length and the axial stress (if any) in the bar when the temperature rises by 10°F. (10)

(b) Re-calculate the length and the axial stress (if any) in the bar when the temperature rises by 50°F. (15)

(c) What is the maximum permissible temperature rise if the allowable compressive stress in the bar is 8000 psi and the allowable shear stress in the bar is 3000 psi? (15)

Answer: (a) \( L = 40.004 \) in and \( \sigma = 0 \); (b) \( L = 40.008 \) in and \( \sigma = 4800 \) psi; (c) 57.5°F.