higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

STRENGTH OF MATERIALS AND STRUCTURES N6

(8060076)

6 December 2023 (X-paper)
09:00–12:00

REQUIREMENTS: Hot-rolled structural steel tables BOE8/2

Drawing instruments and nonprogrammable calculators may be used.

This question paper consists of 6 pages and a formula sheet of 3 pages.

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STRENGTH OF MATERIALS AND STRUCTURES N6
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer all the questions.
2. Read all the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Start each question on a new page.
5. Use only a black or blue pen.
6. Write neatly and legibly.

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QUESTION 1: THICK CYLINDERS

Two hollow cylinders were shrunk together to form a compound cylinder with an inner diameter of 100 mm and an outer diameter of 400 mm. This caused an intermediate pressure at the common diameter of 250 mm. After the cylinders were shrunk together, an internal pressure of 30 MPa was applied to the compound cylinder causing the resultant hoop stress at the inner diameter to be 10 MPa (tensile).

Calculate the following:

1.1 The resultant stresses in the inner cylinder at 250 mm (state the natures) (8)

1.2 The resultant stresses in the outer cylinder at 250 mm and 400 mm (state the natures) (8)

[16]

QUESTION 2: TENSION IN CABLES

The supports of a suspension bridge are 1 000 m apart and differ 10 m in length. Each cable supports 1 kN/m. The turning point of the cable is a horizontal distance of 490 m and a vertical distance of 120 m from the lowest support.

Calculate the following:

2.1 The tension in the cable at the turning point (1)

2.2 The maximum tension in the cable (2)

2.3 The minimum diameter of a cable if the tensile stress is limited to 180 MPa (2)

2.4 The vertical reaction at the highest support if the cable passes over a frictionless pulley and the slope of the anchor cable is 60° (3)

2.5 The bending moment on the highest support if the support is 150 m high (3)

[11]

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QUESTION 3: BENDING AND TWISTING OF SHAFTS

A solid shaft with a diameter of 100 mm is subjected to a maximum torque of 6 kNm as well as a bending moment. The shear stress in the shaft is limited to 45 MPa and the principal stress is limited to 80 MPa.

Calculate the following:

3.1 The maximum bending moment by considering the shear stress limit (3)

3.2 The maximum bending moment by considering the principal stress limit (5)

3.3 The maximum allowed bending moment – state a reason for your answer (2)

3.4 The actual stresses in the shaft (3)

[13]

QUESTION 4: BENDING AND DEFLECTION

A parallel flange I-section 406 × 178 × 74,8 kg/m is simply supported over a total length of 3 m. The maximum allowable bending stress in the material is 150 MPa and Young's modulus is 200 GPa. The deflection is limited to 8 mm.

Calculate the following:

4.1 The maximum distributed load that can be supported (consider both limits) (6)

4.2 The actual stress and deflection due to the calculated distributed load (2)

4.3 The force in a prop if it is placed in the middle of the beam and if it is 2 mm lower than the supports (2)

[10]

QUESTION 5: COMBINED DIRECT AND BENDING STRESS

A column with a weight of 1 200 N and a diameter of 150 mm supports its own weight as well as an eccentric load 30 mm from its centre. Due to the combined loading, the maximum resultant compressive stress in the column is 215 kPa.

Calculate the following:

5.1 The magnitude of the eccentric load (7)

5.2 The minimum resultant stress in the column in magnitude and nature (4)

5.3 The position of the neutral axis from the centroid.
Represent these values on a stress distribution diagram to show the neutral axis. (3)

[14]

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QUESTION 6: SHEAR STRESS IN BEAMS

An I-beam with dimensions of 100 mm × 150 mm is used as a beam with the longest dimension vertical. The thickness of the material is 10 mm. The beam is subjected to a shear force of 15 kN.

Calculate the following:

6.1	The average shear stress	(2)
6.2	The second moment of area about the XX-axis	(2)
6.3	The shear stresses in the flange and web at the junction	(3)
6.4	The maximum shear stress	(2)
6.5	Draw the shear stress distribution diagram across the section.	(4)

[13]

QUESTION 7: CLOSE-COILED HELICAL SPRINGS

A safety buffer must stop a loaded goods carriage with a kinetic energy of 1 kJ. The buffer consists of 15 identical springs placed in parallel, each with a stiffness of 2 kN/m and a spring index of 10. The shear stress in the wires may not exceed 80 MPa and the modulus of rigidity is 75 GPa.

Calculate the following:

7.1	The compression of the buffer	(2)
7.2	The diameter of the spring wire by using Wahl's factor	(5)
7.3	The number of coils in each spring	(2)
7.4	The length of a fully compressed spring if it has two inactive coils	(1)

[10]

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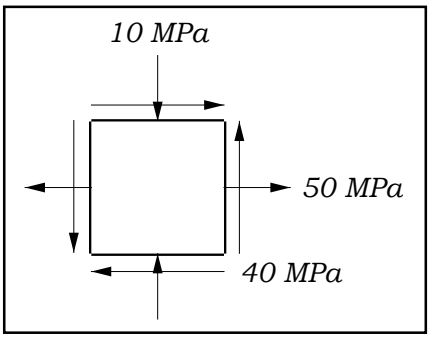
QUESTION 8: TRANSFORMATION OF STRESS

The in-plane stresses on an element are shown below:



8.1 Construct Mohr's circle for the element shown.
Determine the maximum shear stress as well as the principal stresses and planes from the diagram.
Use a scale of 1 cm = 10 MPa. (10)

8.2 Sketch the element in the transformed position to indicate the angle of the principal plane. (3)

[13]

TOTAL: 100

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FORMULA SHEET

Any applicable equation or formula may be used.

$$\sigma_R = a - \frac{b}{x^2} \qquad \sigma_H = a + \frac{b}{x^2} \qquad p_i \frac{\pi}{4} d = \sigma_L \frac{\pi}{4}\left(D^2 - d^2\right)$$

$$F_\mu = \mu p_c \pi D_c L \qquad \varepsilon = \frac{\sigma_H - \nu\sigma_R}{E} \qquad \delta d = \frac{d\left[\sigma_H - \nu\sigma_R\right]}{E}$$

$$\Delta d = \delta d_2 - \delta d_1 \qquad \Delta d = \frac{D_c\left(\sigma_{H2} - \sigma_{H1}\right)}{E}$$

****

$$M = \frac{Wab}{L}$$

$$\theta = \frac{WL^2}{2EI} \qquad \Delta = \frac{WL^3}{3EI} \qquad M = WL$$

$$\theta = \frac{wL^3}{6EI} \qquad \Delta = \frac{wL^4}{8EI} \qquad M = \frac{wL^2}{2}$$

$$\theta = \frac{WL^2}{16EI} \qquad \Delta = \frac{WL^3}{48EI} \qquad M = \frac{WL}{4}$$

$$\theta = \frac{wL^3}{24EI} \qquad \Delta = \frac{5wL^4}{384EI} \qquad M = \frac{wL^2}{8}$$

****

$$T_e = \frac{\pi D^3 \tau}{16} \qquad D_s^3 = \frac{D^4 - d^4}{D} \qquad T_e = \sqrt{M^2 + T^2}$$

$$M_e = \frac{\pi D^3 \sigma}{32} \qquad M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$

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$F_H = wy_0$ $F_V = w\ell$ $F_T = wy$

$y^2 = y_0^2 + \ell^2$ $F_T^2 = F_V^2 + F_H^2$ $x = y_0 \ln\left[\frac{y+\ell}{y_0}\right]$

$F_V = wx$ $F_H = \frac{wx_1^2}{2d}$ $F_H = \frac{w(L-x_1)^2}{2(d+h)}$

$R_V = F_{Vc} + F_{Va}$ $R_H = F_{Hc} - F_{Ha}$ $M = (F_{Hc} - F_{Ha})H$

$\ell_1 = x_1 + \frac{2d_1^2}{3x_1}$ $\ell_2 = (L-x_1) + \frac{2(d+h)^2}{3(L-x_1)}$

****

$\tau_{ave} = \frac{V}{A}$ $\tau_{\max} = \frac{3V}{2A}$ $\tau_{\max} = \frac{4V}{3A}$

$\tau = \frac{VQ}{Ib}$ $Q = \sum ay$ $\tau = \frac{V(R^2 - y^2)}{3I}$

$q = \frac{VQ}{I}$ $p = \frac{F_b}{q}$ $\tau_{web} = \frac{(2\tau_{\max} + \tau_{\min})}{3}$

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$$\tau = K\left(\frac{8WD}{\pi d^3}\right) \qquad K_S = 1+\frac{1}{2C} \qquad K_W = \frac{4C-1}{4C-4}+\frac{0,615}{C}$$

$$\tau = \frac{xGd}{\pi D^2 n} \qquad x = \frac{8WD^3 n}{Gd^4} \qquad C = \frac{D}{d}$$

$$U = \frac{Wx}{2} \qquad U = \frac{kx^2}{2} \qquad U = \frac{4W^2 D^3 n}{Gd^4}$$

$$k = \frac{W}{x} \qquad k = \frac{Gd^4}{8D^3 n}$$

$$k_e = k_1 + k_2 \qquad k_e = \frac{k_1 k_2}{k_1 + k_2}$$

****

$$\sigma_{x'} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos(2\theta) + \tau_{xy}\ \sin(2\theta) \qquad \sigma_{y'} = \frac{\sigma_x + \sigma_y}{2} - \frac{\sigma_x - \sigma_y}{2}\cos(2\theta) - \tau_{xy}\ \sin(2\theta)$$

$$\tau_{x'y'} = -\frac{\sigma_x - \sigma_y}{2}\sin(2\theta) - \tau_{xy}\ \cos(2\theta) \qquad \sigma_1 = \left(\frac{\sigma_x + \sigma_y}{2}\right) + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_2 = \left(\frac{\sigma_x + \sigma_y}{2}\right) - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \qquad \tan 2\theta_p = \frac{\tau_{xy}}{\left(\frac{\sigma_x - \sigma_y}{2}\right)}$$

$$\tau_{\max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \qquad \tan 2\theta_s = -\left(\frac{\sigma_x - \sigma_y}{2\tau_{xy}}\right)$$

$$\tau_{\max} = \frac{\sigma_{yield}}{2 \times SF} \qquad \sigma_{y'} + \sigma_{x'} = \sigma_x + \sigma_y$$

$$C = \sigma_{ave} = \frac{\sigma_x + \sigma_y}{2} \qquad \mathrm{R} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

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