higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

STRENGTH OF MATERIALS AND STRUCTURES N6

(8060076)

29 November 2022 (X-paper)
09:00–12:00

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. All calculations must have at least THREE steps (formula, substitution and answer with SI-unit).
5. Use g = 9,81 m/s^2.
6. Start each question on a new page.
7. Use only a black or a blue pen.
8. Write neatly and legibly.

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QUESTION 1: THICK CYLINDERS

A solid steel shaft with a maximum allowable stress of 160 MPa is pressed into a cast iron hub with a maximum allowable stress of 120 MPa. The hub has an internal and external diameter of 100 mm and 140 mm respectively. The coefficient of friction between the shaft and the hub is 0,25 and the length of the hub is 110 mm.

Calculate the following:

1.1 The maximum interference pressure on the contact of the shaft and the hub (8)

1.2 The frictional force between the shaft and hub (2)

1.3 The frictional torque between the hub and the shaft (1)

[11]

QUESTION 2: COMBINED BENDING AND DIRECT STRESS

A hollow cylindrical steel column of 4 m high has an external diameter of 2 m. The density of the steel material is 7 800 kg/m^3. A wind with a pressure of 2,5 kPa blows against the cylindrical column and the effective area that the wind is blowing against is 60% of the projected area.

Calculate the wall thickness of the cylindrical column so that no tensile stress is applied at the base of the column. **[12]**

QUESTION 3: BENDING AND DEFLECTION OF BEAMS

A cantilever shown in FIGURE1 is 6 m long and made of two channels placed back to back with the longest side vertical to form an 'I'. The beam is loaded with a uniform distributed load of 2 kN/m 2 metres from the fixed end as shown. The deflection and the bending stress may not exceed 11 mm and 120 MPa respectively. E = 200 GPa.

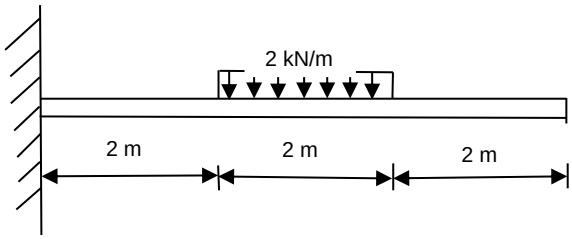

FIGURE 1

Calculate the following:

3.1 Select the lightest channel-section for the stress limit (5)

3.2 Select the lightest channel-section for the deflection limit (6)

3.3 Select the correct section to be used and state your reason why. (2)

[13]

QUESTION 4: TENSION IN CABLES

A cable with a weight of 12 N/m is suspended between two supports and support A is 5 m longer than support B. The maximum tension at the supports is 360 N. The length of the cable suspended between the supports is 40 m.

Calculate the following:

4.1 The sag of the cable (8)

4.2 The maximum slope of the cable (2)

[10]

QUESTION 5: FOUNDATIONS

A grillage foundation consists of four I-sections in the top tier and twelve I-sections in the bottom tier. The 800 mm × 800 mm square base plate is fixed to the top tier. The mass of the 4 m × 4 m square foundation is 20 tonnes and the ground bearing capacity is 160 kPa. The allowable bending stress on the I-section is 180 MPa.

Calculate the following:

5.1 The maximum bending moment on the top tier (3)

5.2 The suitable size parallel flange I-sections in the top tier (2)

5.3 The minimum width needed to space the I-sections in the top tier (2)

5.4 The suitable size parallel flange I-sections in the bottom tier (3)

5.5 The shear stress in the selected I-sections in the top tier (3)

5.6 The shear stress in the selected I-sections in the bottom tier (3)

[16]

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QUESTION 6: RETAINING WALLS

The retaining wall shown in FIGURE 2 supports soil with a density of 1 600 kg/m^3 and an angle of repose of 30°. The soil is overlapping onto the step of the wall. The wall material has a density of 2 200 kg/m^3. A surcharge of 2 kPa is placed on the soil in front of the wall and not overlapping onto the step.

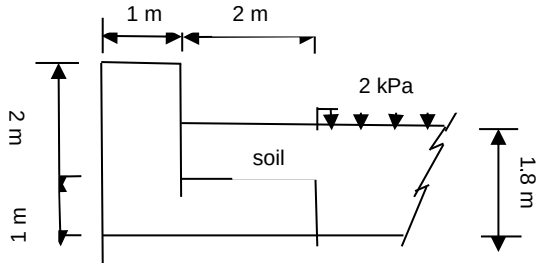

FIGURE 2

Calculate the following:

6.1 The vertical ground reaction underneath the wall (4)

6.2 The weight moments about the toe (2)

6.3 The force moments about the toe (3)

6.4 Whether the wall is safe against tension (4)

[13]

QUESTION 7: REINFORCED CONCRETE

A reinforced concrete T-beam has a flange of 1 m wide and 100 mm thick. The web is 600 mm deep and 80 mm thick. The effective depth of the reinforcement is 670 mm from the bottom of the beam and the beam is reinforced with five round bars of 20 mm. The Young modulus of elasticity for steel and concrete is 210 GPa and 14 GPa respectively. The maximum bending moment of the beam is 140 kNm.

Calculate the following:

7.1 The position of the neutral axis (4)

7.2 The maximum stress carried by steel and concrete (9)

[13]

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QUESTION 8: COMBINED BENDING AND TWISTING OF SHAFTS

A pulley with an effective diameter of 300 mm overhangs a bearing by 160 mm from the centre of the bearing. The maximum shear and principal stresses are 45 MPa and 100 MPa respectively. The belts are vertical and parallel, with the tension on the slack and tight sides 1 kN and 2,4 kN respectively.

Calculate the following:

8.1	The maximum equivalent torque of the shaft	(4)
8.2	The suitable size of the shaft using the shear stress limit	(2)
8.3	The maximum equivalent bending moment of the shaft	(2)
8.4	The suitable size of the shaft using the principle stress limit	(2)
8.5	The suitable size of the shaft for both limits and state the reason	(2)
		[12]

TOTAL: 100

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FORMULA SHEET

Any applicable equation or formula may be used.

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

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

$$\Delta d = D_c \left[\left(\frac{\sigma_{H1} - \nu_1 \sigma_{RC}}{E_1} \right) - \left(\frac{\sigma_{H2} - \nu_2 \sigma_{RC}}{E_2} \right) \right] \qquad \Delta d = \frac{D_c}{E}[\sigma_{H1} - \sigma_{H2}]$$

****

$$M = \frac{W\ a\ b}{L}$$

$$\theta = \frac{W\ L^2}{2\ E\ I} \qquad \Delta = \frac{W\ L^3}{3\ E\ I} \qquad M = W\ L$$

$$\theta = \frac{w\ L^3}{6\ E\ I} \qquad \Delta = \frac{w\ L^4}{8\ E\ I} \qquad M = \frac{w\ L^2}{2}$$

$$\theta = \frac{W\ L^2}{16\ E\ I} \qquad \Delta = \frac{W\ L^3}{48\ E\ I} \qquad M = \frac{W\ L}{4}$$

$$\theta = \frac{w\ L^3}{24\ E\ I} \qquad \Delta = \frac{5\ w\ L^4}{384\ E\ I} \qquad M = \frac{w\ L^2}{8}$$

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$F_w = \frac{1}{2}\rho\, g\, H^2$ $F_g = \frac{1}{2} C_\mu\, \rho\, g\, H^2$ $F_p = C_\mu\, p\, H$

$C_\mu = \frac{1 - Sin\phi}{1 + Sin\phi}$ $Vx + \Sigma F - M = \Sigma W - M$ $\sigma_r = \frac{V}{B} \pm \frac{6\,V\,e}{B^2}$

$\sigma_r = \frac{2\,V}{3\,x}$ (*x = distance from toe*)

$V.F./F.O.S. = \frac{\Sigma W - M}{\Sigma F - M}$ $V.F/F.O.S. = \frac{\sigma_{Ultimate}}{\sigma_{Max}}$ $V.F./F.O.S. = \frac{F_\mu}{\Sigma F - Forces}$

****

$M = \frac{W}{8}[L - \ell]$ $M = \frac{W}{8\,L}[L - \ell]^2$

$d = \frac{\sigma_1}{\rho\, g}\left[\frac{1 - Sin\phi}{1 + Sin\phi}\right]^2$ $SF = \frac{W}{2\,L}[L - \ell]$

****

$\frac{\sigma_s}{\sigma_c} = \frac{m(d-n)}{n}$ $\frac{b\,n^2}{2} = m\,A_s\,(d-n)$

$M = \frac{1}{2}\sigma_c\, b\, n\, \ell_a$ $M = \sigma_s\, A_s\, \ell_a$ $\ell_a = d - \frac{n}{3}$

$m\,A_s(d-n) = A_1\left(n - \frac{t}{2}\right) + A_2\left(\frac{n-t}{2}\right)$ $\sigma_{cl} = \frac{\sigma_c\,(n-t)}{n}$

$M_s = \sigma_s\, A_s\,(d-n)$ $M_c = \left[\frac{1}{2}\sigma_c\, b\, n\left(\frac{2}{3}n\right)\right] - \left[\frac{1}{2}\sigma_{cl}\,(b-e)(n-t)\left\{\frac{2}{3}(n-t)\right\}\right]$

$M_{Max} = M_s + M_c$

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

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

$F_V = wx$ $F_H = \frac{w L^2}{8 d}$ $\ell = L + \frac{8 d^2}{3 L}$

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

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

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

****

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

$T_e = \sqrt{M^2 + T^2}$ $T_e = \frac{\pi D^3}{16}\tau$

$\frac{\text{Vervang}}{\text{Replace}}\ D^3\ \frac{\text{met}}{\text{with}}\ \frac{D^4 - d^4}{D}$

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