higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

STRENGTH OF MATERIALS AND STRUCTURES N6

(8060076)

21 April 2021 (X-paper)
09:00–12:00

REQUIREMENTS: Hot-rolled structural steel sections (BOE 8/2)

Nonprogrammable calculators may be used.

This question paper consists of 6 pages and a formula sheet of 2 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. Questions can be answered in any order but keep subsections together.
5. All calculations must have at least THREE steps (formula, substitution and answer with SI unit).
6. Draw a line after each completed subsection.
7. Start each question on a new page.
8. Use $g = 9{,}81\ \mathrm{m/s^2}$.
9. Write neatly and legibly.

QUESTION 1: THICK CYLINDERS

A cylinder with closed ends has an internal diameter of 100 mm and a wall thickness of 50 mm. The cylinder is simultaneously subjected to an internal pressure of 100 MPa and an external pressure of 40 MPa. Young's modulus is 200 GPa and Poisson's ratio is 0,3.

Calculate:

1.1 The resultant hoop stresses at both diameters (6)

1.2 The resultant internal diameter (2)

1.3 The resultant external diameter (2)

1.4 The resultant thickness of the cylinder wall (1)
[11]

QUESTION 2: TENSION IN CABLES

A steel-core aluminium conductor with a length of 150 m has a weight of 60 N/m and is supported between two supports. The turning point of the cable is 62 m from the shortest support measured along the length of the cable. The total cross-sectional area of the cable is 500 mm^2 and the steel core area is 50 mm^2. The maximum allowable stress in the steel and aluminium is 42 MPa and 14 MPa respectively.

Calculate:

2.1 The maximum tension allowed in the cable (2)

2.2 The difference in height between the two supports (4)

2.3 The horizontal distance of the highest support from the turning point (1)

2.4 The horizontal distance from the longest support where the tension is 7 800 N (4)
[11]

QUESTION 3: BENDING AND DEFLECTION OF BEAMS

A simply supported beam is 4 m long and carries a concentrated load in the centre of the beam. The stress in the beam is limited to 80 MPa and the deflection is not allowed to be more than 10 mm. Young's modulus for the material is 200 GPa. The beam is made up by welding two channel profiles 200 × 75 × 25,3 kg/m toe to toe.

Calculate:

3.1 The second moment of area about both axes (3)

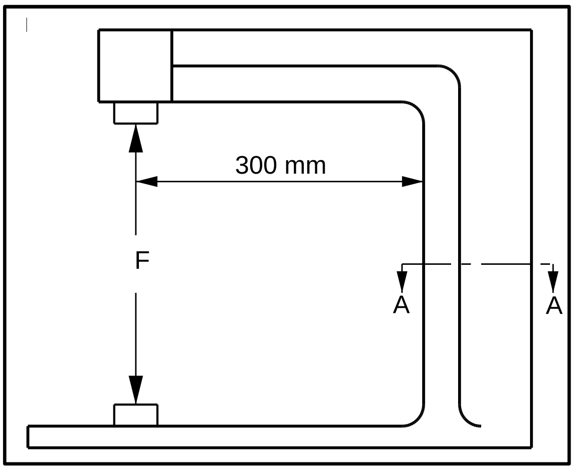
3.2 The maximum concentrated load this beam may carry (including its own weight) (5)

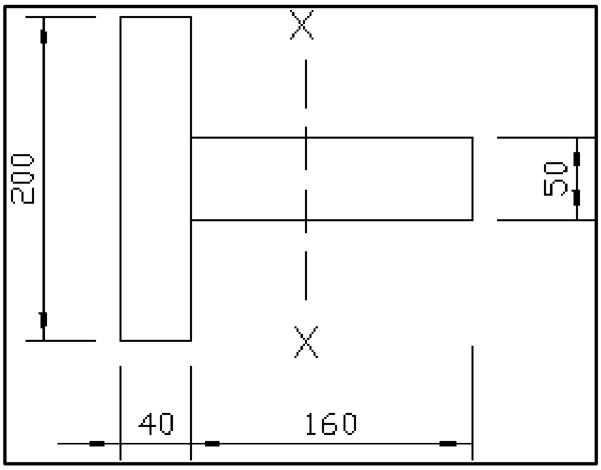
3.3 The actual stress and deflection in the beam for this load (2)

3.4 The force in a prop that is placed in the middle of the beam and 2 mm lower than the supports to prevent some of the deflection (2)
[12]

QUESTION 4: DIRECT AND BENDING STRESSES

Refer to the steel-press frame shown below. All dimensions are in mm.





SECTION A-A

Calculate:

4.1 The position of the X-X axis (3)

4.2 The second moment of area of the profile about the X-X axis (3)

4.3 The magnitude and nature of the direct stress in the frame if F is 40 kN (2)

4.4 The resultant stresses in the frame in magnitude and nature (6)
[14]

QUESTION 5: RETAINING WALLS

A retaining wall with a trapezium shape retains water to the full height of 6 m. The top of the wall is 2 m wide and the base is 3 m. The density of the wall material is 2 100 kg/m^3.

Calculate:

5.1 The lateral force of the water and the vertical reaction of the ground (4)

5.2 The force moments and weight moments about the toe (3)

5.3 The safety factor for overturning and state whether it is within the minimum limit (2)

5.4 The position of the vertical reaction from the toe and state whether tension will occur in the wall giving a reason why or why not (3)

5.5 The minimum ground-bearing pressure required underneath the wall (3)

[15]

QUESTION 6: FOUNDATIONS

A parallel flange H-section 356 × 406 × 340 kg/m with a length of 4 m is used as a column which supports an eccentric load of 50 kN. The load is carried on the Y-Y axis and is 100 mm outside the flange. The column must be placed on the foundation in such a position that the ground pressure of 30 kPa is evenly spread underneath the foundation.

Calculate:

6.1 The length of the sides for the square foundation (2)

6.2 The direct stress at the base of the column (2)

6.3 The eccentric distance the column must be placed from the foundation centre (4)

6.4 Make a neat, labelled sketch of the column in the eccentric position (4)

[12]

QUESTION 7: REINFORCED CONCRETE

A rectangular steel-reinforced concrete beam with a width of 400 mm must support a bending moment of 174 kNm. The steel reinforcing consists of a number of 20 mm diameter rods. The cover beneath the reinforcement is 30 mm. The allowable stress is 140 MPa and 7 MPa for steel and concrete respectively. Assume the modular ratio as 15.

Calculate:

7.1 The total depth dimension of the beam (6)

7.2 The number of 20 mm steel rods required (4)

7.3 The bending moment carried by each material (4)
[14]

QUESTION 8: STRUCTURAL FRAMEWORKS

The legs of a tripod are each 6 m long and placed to form an isosceles triangle ABC with AB = AC = 5 m and BC = 6 m. The tripod supports a load of 30 kN from the apex.

8.1 Draw, to scale 1 cm:1 m, a side and top view of the tripod to determine the apex. (4)

8.2 Draw, to scale 1 cm: 5 kN, vector diagrams to determine the force in each leg. (4)

8.3 Tabulate the answers showing both magnitude and nature. (3)
[11]

TOTAL: 100

FORMULA SHEET

Any applicable equation or formula may be used.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$M_s = \sigma_s \, A_s \, (d - n)$

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

$$M_{Maks/Max} = M_s + M_c$$

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

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

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

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

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

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

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

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

Replace D^3 with $\dfrac{D^4 - d^4}{D}$