



The University of Sydney

Department of Civil Engineering

CIVL2201 Structural Mechanics

Semester 1, 2002

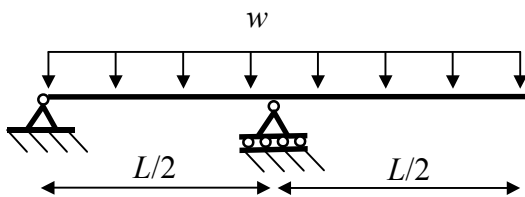
Time Allowed: 3 hours

Instructions to Candidates

- (a) **This paper contains 3 parts: A, B, & C. Part A has 4 questions (Q 1 – Q 4, 35 %), Part B has 4 questions (Q 5 – Q 8, 50 %), and Part C has 2 questions (Q 9 - Q 10, 15 %).**
- (b) All questions may be attempted.
- (c) Suitable working, diagrams and explanations are required for each question.
- (d) Marks may be deducted for work that is not satisfactorily set out.
- (e) **Units are important.**
- (f) Programmable and non-programmable calculators may be used.
- (g) Read the questions carefully before answering.
- (h) **Annotated copies of the “Structural Mechanics Lecture Notes” may be taken into the exam, but no other written material is permitted.** Other sheets of paper may not be inserted into the set of lecture notes.
- (i) Students are reminded that satisfactory exam performance is an essential criterion in this course, and a combined mark of 65 % for three of the four questions is required in Part A, and a combined mark of 50 % for three of the four questions is required in Part B.

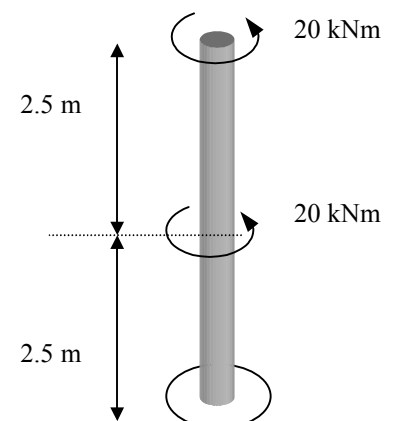
Part A – Basic Questions

- 1) The diagram below shows an overhanging beam of total length L , with a uniformly distributed load, w . The beam is made from steel with an elastic modulus $E_{\text{steel}} = 200000 \text{ MPa}$. The effects of self-weight are negligible compared to effects of the applied loading, w .
 - a) Draw the free body diagram of the beam clearly showing the support reactions. Calculate the value of the support reactions.
 - b) Draw the bending moment diagram (BMD) and shear force diagram (SFD). Clearly indicate the values of bending moment and shear force at the supports and the free edge. At what locations do the maximum and minimum values of bending moment and shear force occur, and what are their values?
 - c) The steel beam is replaced by an identical aluminium beam ($E_{\text{aluminium}} = 70000 \text{ MPa}$). The effects of self-weight are still negligible. Without performing any calculations, how will the BMD be affected? Briefly justify the answer.



Question 1 is worth 10 marks

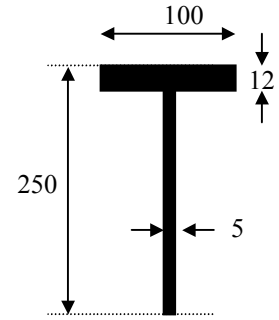
- 2) A column is made from 2 rigidly connected circular hollow sections each 2.5 m in length and loaded as shown in the diagram. Each section of the pole has an outer diameter of 300 mm, and thickness 6 mm, but the material varies. The bottom half is made from steel ($G_{\text{steel}} = 80000 \text{ MPa}$), and the top half is made from aluminium ($G_{\text{aluminium}} = 30000 \text{ MPa}$). The bar is rigidly connected to a support at the base, and free at the top.



- (a) Draw the twisting moment diagram.
- (b) Determine the torsion constant, J , of the circular hollow section. Is this value affected by the material (steel or aluminium) (yes/no only required)?
- (c) What is the total twist rotation of the top with respect to the fixed base?
- (d) Would the total twist rotation at the top relative to the fixed base increase or decrease if the materials were swapped (steel in the top half, aluminium in the bottom)? Briefly explain your answer.

Question 2 is worth 9 marks

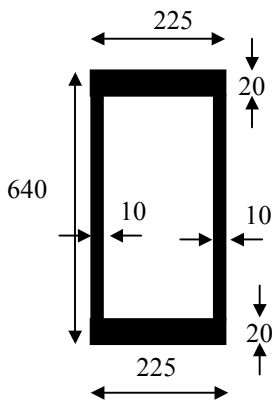
- 3) Consider the following T-section, the dimensions of which are shown in the diagram. The section is symmetric about the stem of the T.
- Calculate the location of the centroid and show this location on a diagram.
 - Calculate the second moment of area (I_x) of the section about the horizontal centroidal axis. Give the answer in both metric and imperial units (assume 1 inch = 25.4 mm).
 - All the dimensions are doubled. How will I_x be affected? Calculations are not required. Briefly justify your answer.



All dimensions are in mm

Question 3 is worth 9 marks

- 4) Consider the box section which is shown below. The second moment of area about the minor (vertical) centroidal axis is $I_y = 176.7 \times 10^6 \text{ mm}^4$. The steel has a yield stress of 340 MPa.
- Calculate elastic section modulus for bending about the minor y – axis (Z_y). (I_y is given – so it does not need to be calculated).
 - Calculate the bending moment (about the y - axis) that will cause first yield of the section.
 - Draw the stress and strain distributions in the cross-section which correspond to the answer in (b) above.
 - With the aid of a diagram, describe briefly how the second moment area I_y could be determined experimentally.



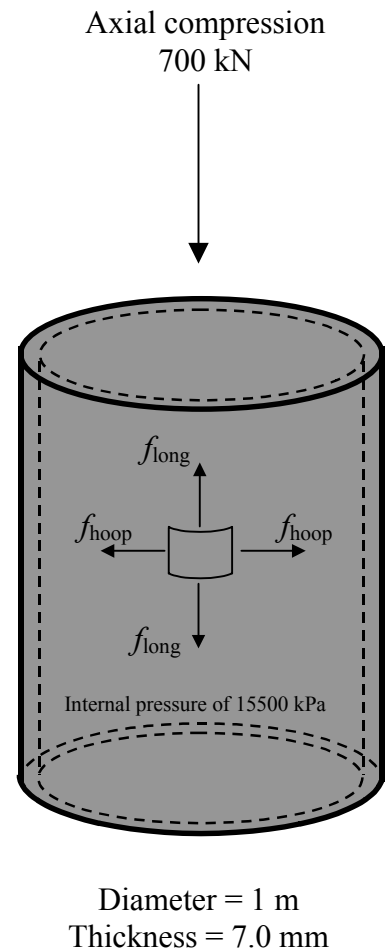
All dimensions are in mm

Question 4 is worth 7 marks

Part B – Intermediate Questions

5) Consider a closed cylindrical pressure vessel. The vessel has an outer diameter of 1 m and a thickness of 7 mm, and is subjected to an internal pressure of 15500 kPa. In addition the vessel is subjected to a vertical compressive load of 700 kN.

- Calculate the hoop stress and longitudinal stress experienced by a typical element within the vessel as shown in the attached diagram.
- Draw the Mohr's circle that represents the stresses calculated in a) above. (If you have not been able to answer part a), you may assume that $f_{\text{hoop}} = +1150 \text{ MPa}$ and $f_{\text{long}} = +500 \text{ MPa}$. Note that these are *not* the correct answers to part a).). What are the principal stresses?
- Assuming the pressure vessel is made from a material with yield stress $f_y = 1100 \text{ MPa}$, determine whether the material has yielded according to both Tresca's and von Mises' yield criteria.
- The design engineer is concerned about the value of hoop stress in the pressure vessel, and wants to change the design of the vessel without changing the pressure. State one way in which the hoop stress could be halved without reducing the pressure in the vessel.

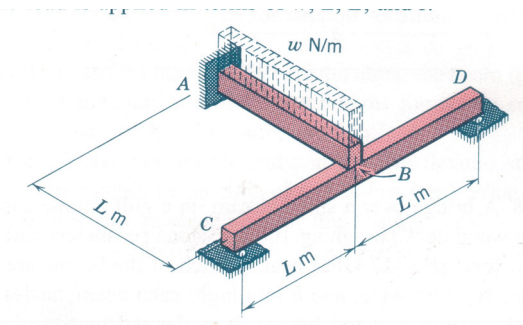


Question 5 is worth 13 marks

- 6) A uniformly distributed load w is supported by two beams arranged as shown. Beam AB is a cantilever fixed at A, while beam CD is simply supported. Before the load is applied, the cantilever is *just* in contact with CD, ie initially there is no reaction force between the two beams before w is applied. The load w acts on AB only. Both beams have the same cross-sectional area (A), second moment of area (I) and elastic modulus (E). Any effects of self-weight should be ignored.

Hints: compatibility, FBDs, standard cases.

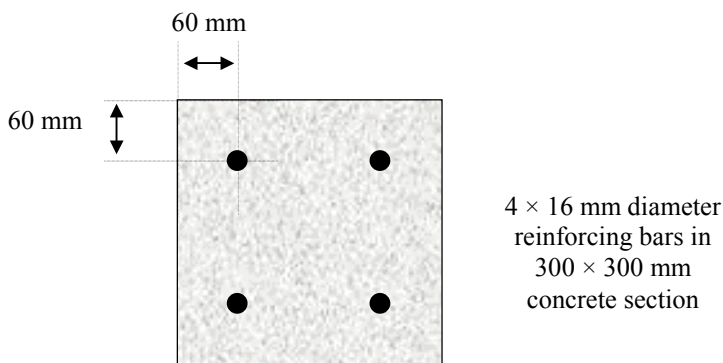
- (a) Briefly outline a strategy for solving this problem and the reasoning behind the method.
- (b) Determine the vertical deflection at B, in terms of w , L , E and I .



(Source: Riley, Sturges & Morris, *Statics and Mechanics of Materials*, John Wiley, 1995)

Question 6 is worth 12 marks

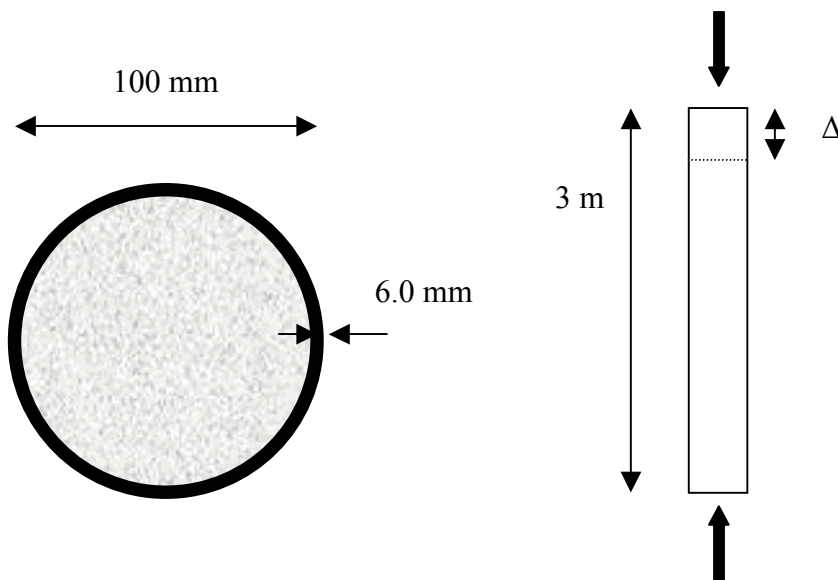
- 7) A concrete beam, with square cross-section $300 \text{ mm} \times 300 \text{ mm}$ is symmetrically reinforced with 4 steel reinforcing bars, each of diameter 16 mm. The centre of each reinforcing bar is located 60 mm from closest edges of the concrete beam. The beam is bending about its horizontal centroidal axis and is sagging. It can be assumed that $E_{\text{concrete}} = 40 \text{ GPa}$ and $E_{\text{steel}} = 200000 \text{ MPa}$ and that both materials exhibit linear elastic behaviour. The concrete cracks if the tensile stress in the concrete exceeds 6 MPa. Consider the cross-section of the beam that is experiencing the greatest positive bending moment just as the concrete is about to crack.
- Draw the strain distribution across the section (values required). For the steel reinforcement it is sufficient to give the strain at the centre of the reinforcing bar.
 - Draw the stress distribution across the section (values required). For the steel reinforcement it is sufficient to give the stress at the centre of the reinforcing bar.
 - What is the bending moment that will cause the concrete to crack?
 - Explain composite action with particular reference to the bending behaviour of a reinforced concrete beam such as the one shown below.



Question 7 is worth 13 marks

8) Concrete Filled Tubes (CFT) are frequently used in composite construction. Once filled, the CFT acts compositely. Consider the CFT shown below. The tube has outer diameter 100 mm and thickness 6 mm. The member is used as a column, 3 m in length, and is subjected to an axial compression. It can be assumed that $E_{\text{concrete}} = 40 \text{ GPa}$ and $E_{\text{steel}} = 200000 \text{ MPa}$, and that both materials behave linear elastically. The design engineer wants to ensure that the total axial shortening of the column does not exceed 3.2 mm under its design axial compression.

- Calculate the axial strains and stresses in the steel and the concrete when the column experiences its maximum permitted shortening.
- What is the maximum axial load the column can carry while ensuring the column does not exceed its maximum permitted shortening?
- The steel tube is replaced by another steel tube which is only 5 mm thick but with the same outer diameter of 100 mm. The cross-sectional area of the steel is therefore reduced by the same amount that the cross sectional area of concrete is increased. Assuming that the same load as calculated in (b) above is applied, would the following increase or decrease (compared to the original case)? Calculations are not required, but some justification of the answers is required.
 - Steel strain
 - Steel stress
 - Concrete strain
 - Concrete stress
 - Total axial shortening

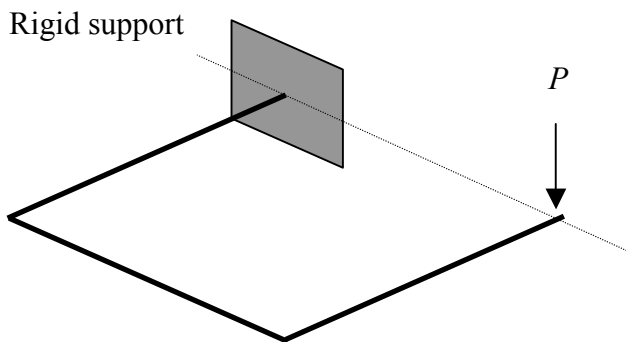


Question 8 is worth 12 marks

Part C – Advanced Questions

The questions in this section are designed for students who seek to obtain a mark of Distinction or higher. They are not necessarily mathematically difficult, but require more thinking, visualisation, and application than the other questions. The majority of marks will be awarded to completed questions, and only minor marks will be awarded to partially answered questions – ie it is better to complete one question fully, than half complete 2 questions.

- 9) The squared U-shaped structure is made up of three components, each of length L . The structure lies in a horizontal plane and each segment is perpendicular to the adjacent segment. There is a vertical load P at the free end of the structure. The support is completely fixed, preventing deflection in every direction, and rotation about any axis. Draw the bending moment and twisting moment diagrams for the structure.



Question 9 is worth 7 marks

- 10) Engineers have discovered a new material in which the elastic modulus in tension is one half of the elastic modulus in compression. This material is used to make a beam with rectangular cross-sectional dimensions of $100 \text{ mm} \times 50 \text{ mm}$. Consider a cross section that is resisting a positive bending moment of 600 kNm . Draw the strain and stress distributions on the cross section (values required where appropriate). The beam is bending about its strong axis.

Question 10 is worth 8 marks

This is the end of the examination paper.