Version JAB/3

EGT1
ENGINEERING TRIPOS PART IB

Wednesday 5 June 2024   2.00 to 4.10

Paper 2

STRUCTURES

Answer not more than ***four*** *questions, which may be taken from either section.*

All questions carry the same number of marks.

The ***approximate*** *number of marks allocated to each part of a question is indicated in the right margin.*

Answers to questions in each section should be tied together and handed in separately.

Write your candidate number ***not*** *your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

10 minutes reading time is allowed for this paper at the start of the exam.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

You may not remove any stationery from the Examination Room.

SECTION A

1 Figure 1 shows a weightless pin-jointed truss subjected to a horizontal force *H* and a vertical force *V*. The truss has pin supports at A and G. The unloaded structure comprises members I to XI. All members have the same axial stiffness $AE = 3\times10^5$ kN. All behaviour is linear elastic and the truss is initially stress-free.

(a) Show that the truss is statically indeterminate. [3]

(b) Calculate the support reactions at A and G, using bar II as the redundant bar. [15]

(c) Calculate the bar forces under the loads *H* and *V*. [7]

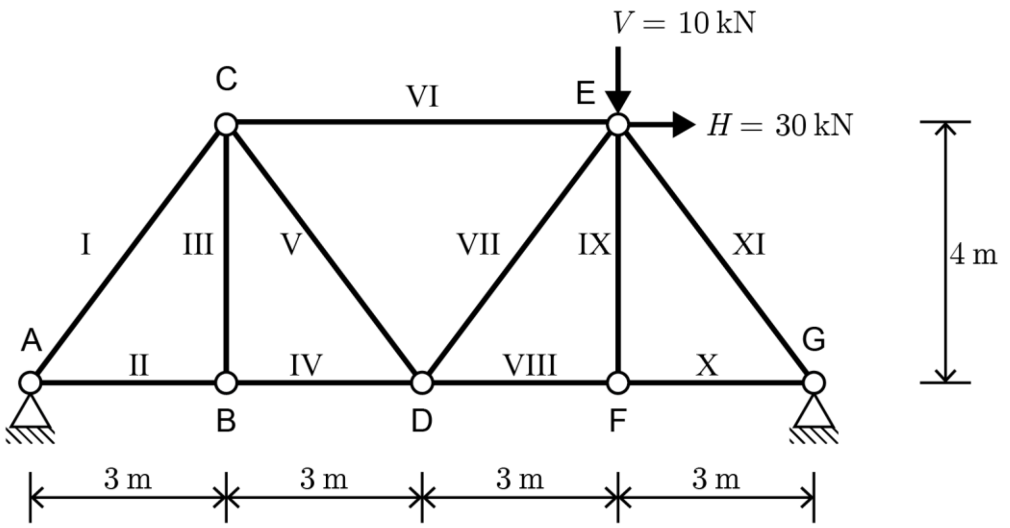


Figure 1

2 The mast shown in Fig. 2(a) is 5 m tall. Its cross-section is shown in Fig. 2(b). It is fabricated from reclaimed steel sections, namely two semi-circular sections, joined by two flat steel plates. Two equal and opposite horizontal forces F = 10 kN are applied to the mast by a horizontal spar. The uniaxial yield stress of the steel is 500 MPa.

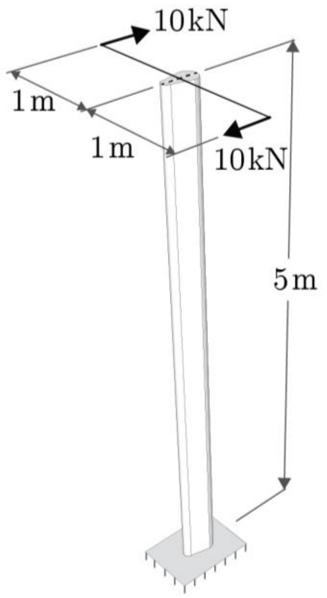
(a) Using elastic thin-walled theory, determine the maximum shear stress acting on the section. [5]

(b) Using the Tresca yield criterion, determine the factor of safety against yield for the mast. [5]

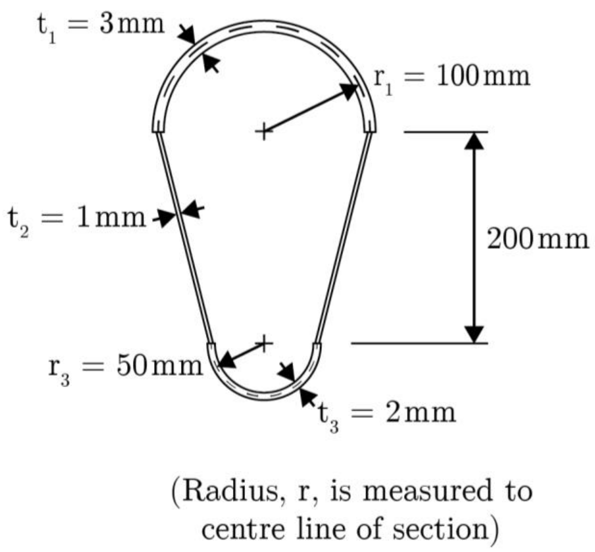
(c) Calculate the angle through which the spar will rotate under the applied loads. [10]

(d) The designer requires that the maximum angle of rotation of the spar just before the onset of inelastic behaviour is 5°. Show that this cannot be achieved. [3]

(e) Suggest how the mast might be changed to meet the designer's requirements. [2]



(a)



(b)

Figure 2

3 The weightless portal frame shown in Fig. 3 is pinned at support points A and B. Joints C and E are rigid. All members have flexural rigidity EI, are axially rigid, and behave elastically. A vertical force is applied to member CE and a horizontal force is applied at point E. The unloaded frame is unstressed.

(a) Draw a feasible deflected shape for the frame under the applied forces P. Annotate your diagram to highlight any salient points. [3]

(b) Derive expressions for the vertical reactions at A and B. [4]

(c) Derive expressions for the horizontal reactions at A and B. [12]

(d) Draw the bending moment diagram for the entire frame, annotating salient points. [4]

(e) Verify that the deflected shape drawn in part (a) is valid, by comparing it to the bending moment diagram drawn in part (d). [2]

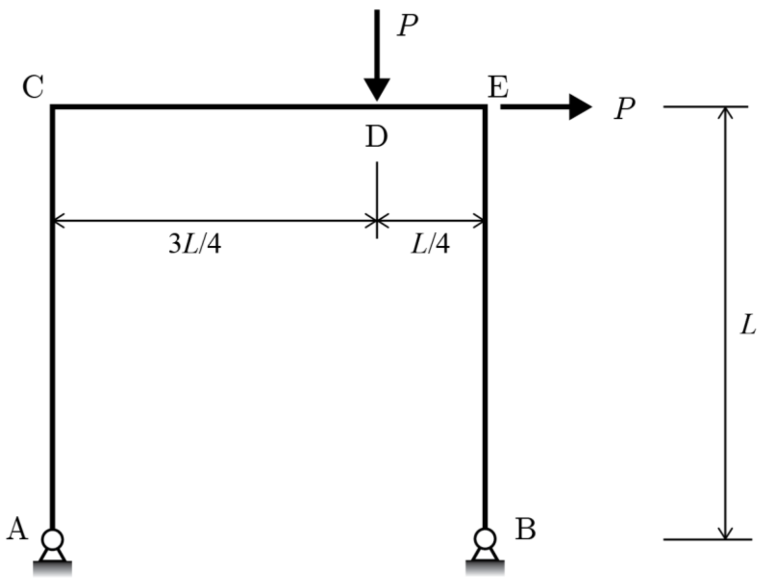


Figure 3

SECTION B

4 Figure 4(a) shows a pitched roof portal frame designed to carry a horizontal load H and vertical load V at the points shown. The portal frame is made of members which all have a plastic moment capacity M_p = 10 kNm.

(a) Sketch three possible collapse mechanisms for the frame. [3]

(b) Draw an interaction diagram of the collapse loads for these collapse mechanisms, for positive H and V. [10]

(c) If the loading requirement is H = 5 kN and V = 10 kN, calculate the safety factor against collapse, considering the mechanisms in part (a). [3]

(d) To increase the safety factor, the apex of the frame is reinforced, as shown in Fig. 4(b). The reinforcement prevents a plastic hinge from forming within 1 m horizontally of the apex. Calculate the effect that this reinforcement will have on the safety factor for the loading condition specified in part (c). [9]

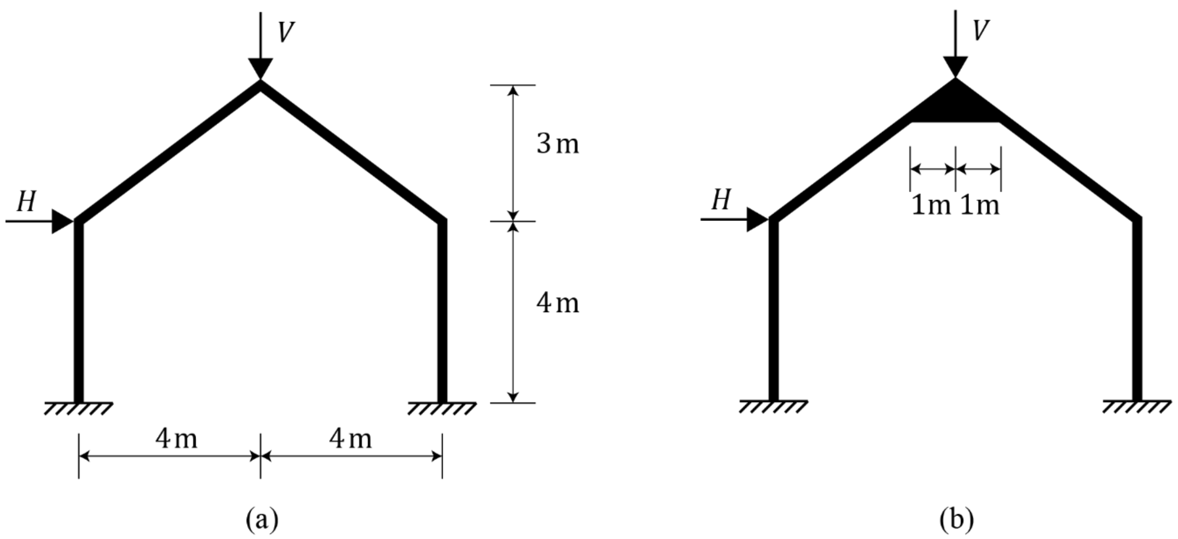


Figure 4

5 Figure 5(a) shows a square slab of side length $4a$ subject to four vertical forces of magnitude W. The slab has a plastic moment capacity per unit length of m. The slab is supported on four walls, giving a simple support on all four sides.

(a) Estimate the value of W to cause collapse of the slab, using the suggested collapse mechanisms shown in Figs 5(b) and (c). [3]

(b) During the life of the structure, one of the support walls collapses, so the slab is now only supported on three sides. Estimate the value of W that will now cause collapse of the slab, considering two collapse mechanisms which differ from those in part (a). [11]

(c) As a remedial measure, it is suggested that the missing line support is replaced by a point support in the middle of the side that collapsed. Carry out a calculation to estimate how effective this point support will be, considering one collapse mechanism. [11]

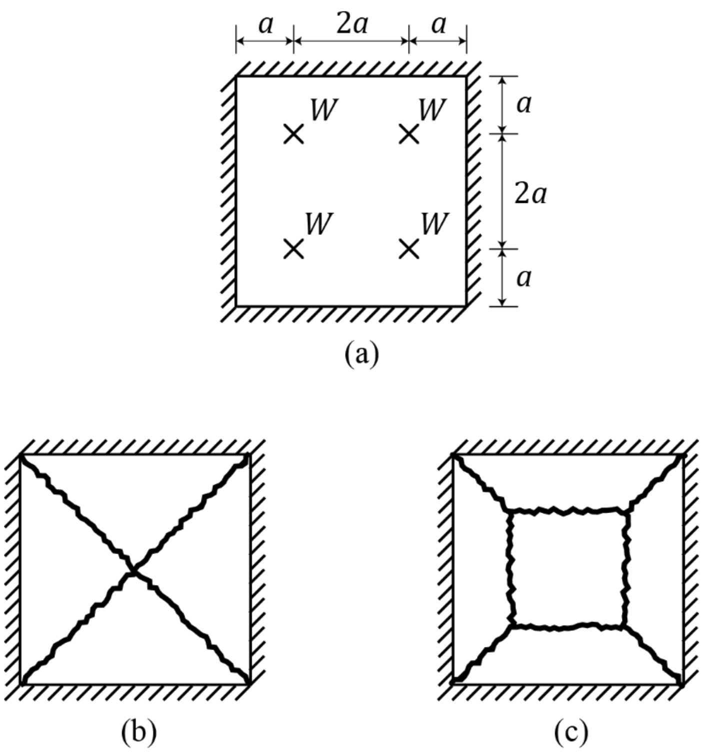


Figure 5

6 Figure 6(a) shows a weightless beam of length $6L$ subject to three vertical forces of magnitude W, two forces acting down and one acting up. The beam has a plastic moment capacity of M_p.

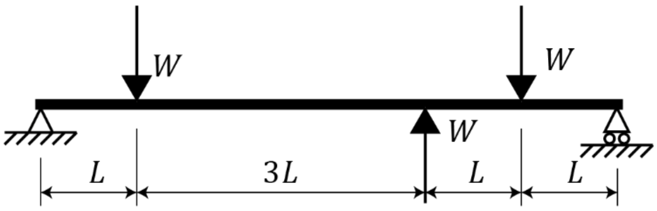
(a) Draw a bending moment diagram for the beam, and hence calculate the value of W at which the beam will collapse. [3]

(b) The centre of the beam is now supported by a vertical cable of length H, diameter d, and made of material with a yield stress σ_y, as shown in Fig. 6(b).

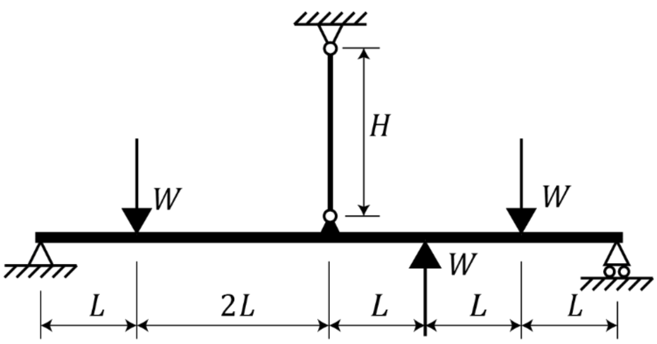
(i) Explain why the value of H does not affect the collapse load of the beam. [6]

(ii) Show that the load calculated in (a) will not cause this beam to collapse. [3]

(iii) If the diameter of the cable is varied, above a certain value the collapse load of the beam will not change. Find this value of the diameter, and the maximum collapse load of the beam. [13]



(a)



(b)

Figure 6

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