ENGINEERING TRIPOS PART IB

Monday 5 June 2000 2 to 4

Paper 2

STRUCTURES

*Answer not more than **four** questions.*

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.*

(TURN OVER

1 A tank is being designed to contain liquefied gas of density ρ at an average internal pressure p relative to the outside atmosphere. The tank is cylindrical, of length L and diameter D, with a wall thickness t ($<<D$). It will be mounted with its axis horizontal and will be simply supported at its ends. The ends of the tank are closed.

(a) By considering *only* the cylindrical portion of the tank, and ignoring effects due to its self-weight, determine:

(i) the magnitude and location of the maximum bending stress due to the weight of the liquid; [4]

(ii) the stresses due to p. [4]

(b) If $L = 20$ m, $D = 2$ m, $\rho = 1000$ kgm^{-3}, $p = 2$ MPa and the tank is to be made from a material which obeys von Mises yield criterion with a yield stress of 400 MPa, suggest a suitable value of t if the tank is to have a safety factor of 2 against failure by considering the stresses on the underside of the tank at the centre. [9]

(c) Why is the underside more likely to govern the thickness of the tank than the top? [3]

2 A cranked beam is made from an aluminium box section 20 mm × 10 mm (external dimensions) with 1 mm top and bottom flanges and 0.5 mm side walls, as shown in Fig. 1. The two legs of the crank are 300 mm long (as measured along the centreline) and the beam is mounted horizontally, as a cantilever. A 10 kg weight is hung from the tip of the cantilever.

(a) Determine the tip deflection under the loading specified. [6]

(b) Calculate the torque, shear force and bending moment at the root of the cantilever. Hence determine the state of stress at point A, immediately below the top flange on the inside of the beam at the root of the cantilever. [8]

(c) Draw a Mohr's circle of stress at point A, and determine the magnitudes and directions of the principal stresses. Make a sketch of the beam at the root of the cantilever and show clearly the two principal directions. [6]

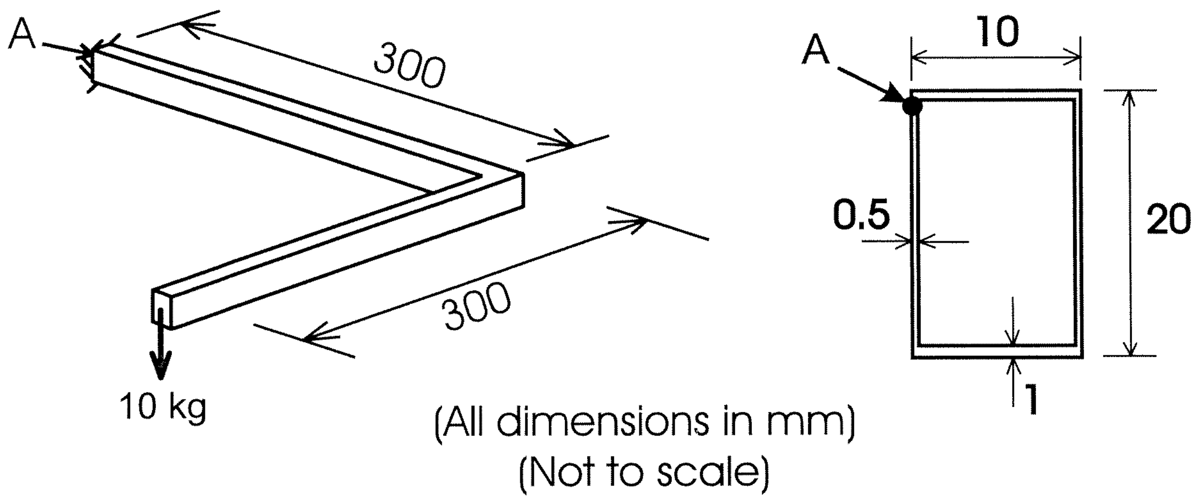

Fig.1

3 A pitched roof portal frame, as shown in Fig. 2, has a uniform fully plastic moment M_p. It is subjected to two loads V and H.

(a) Sketch three possible critical mechanisms of plastic collapse for positive V and H. [3]

(b) Plot an interaction diagram between V and H showing the collapse loads corresponding to the mechanisms from (a). [10]

(c) If $V = 5H$, determine the value of V at collapse. [3]

(d) The designer wishes to investigate the effects of replacing the fixed support at A with a pinned connection. Show how your interaction diagram in (b) above would be modified in this case and calculate the new value of V at collapse. [4]

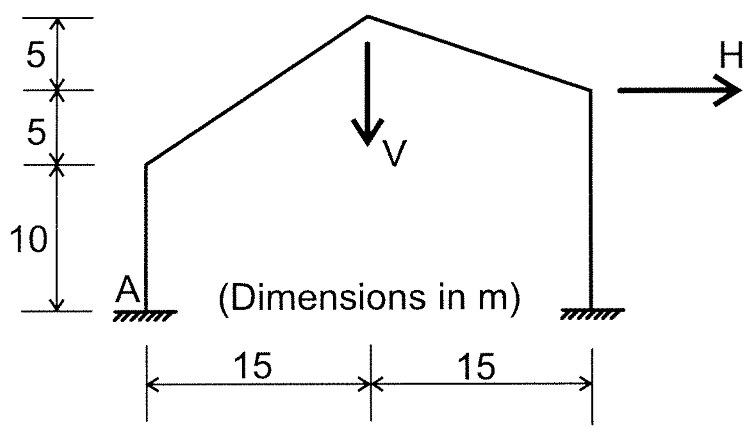

Fig. 2

4 A square slab is simply supported on two sides AB and AD, as shown in Fig. 3. There is a column support at C but the sides BC and DC are otherwise unsupported. The sides are of length L and it is loaded by a uniformly distributed load w everywhere. A copy of the figure is provided on which you may draw, and **which should be handed in as part of your answer**.

(a) Draw, on the copy of the figure, the yield line pattern if the slab collapses by a mechanism that has three axes of rotation as shown, that is symmetrical about the line AC, and where the yield lines intersect at the centre of the slab. [3]

(b) Determine the collapse load if the slab has a moment capacity of m per unit length in sagging bending everywhere. The relevant dimensions can be determined to sufficient accuracy by a graphical construction. [14]

(c) For the same collapse mechanism, determine the collapse load if the slab were built-in along the side AB with a moment capacity of $m/2$ in hogging bending. [3]

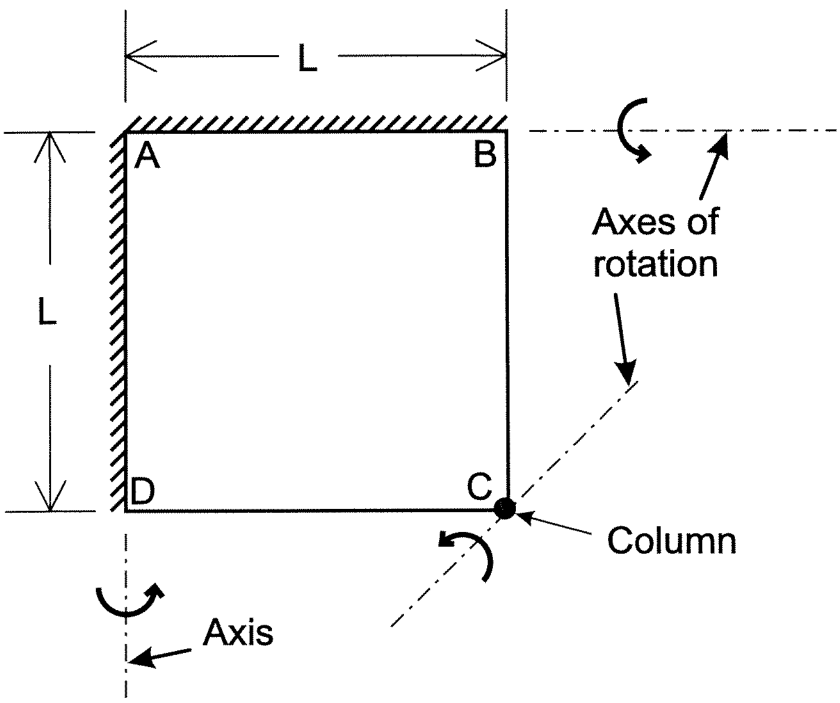

Fig.3

(TURN OVER

5 A propped cantilever, of length L, is loaded over its central third by a distributed load of intensity q, as illustrated in Fig.4. It was initially unstressed.

(a) Calculate the support reaction at the simply supported end. [6]

(b) Show that the maximum deflection occurs at a distance $0.56L$ from the clamped end. [8]

(c) Find the magnitude of the maximum deflection. [6]

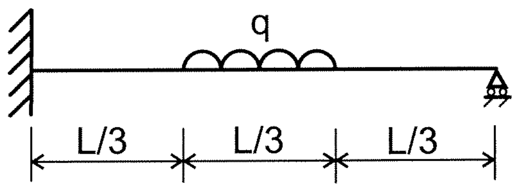

Fig. 4

6 A Ferris wheel to celebrate the Millennium is shown in front and side elevations in Fig. 5. The axle ABC is supported on two struts, BD and BE, and two sets of cables BF and CF. C is above the mid-point of DE . The wheel weighs 10 MN and its centre of gravity is 5m from B towards A. The connections at B, C, D, E and F can all be regarded as pins, and the weights of all components other than the wheel can be regarded as negligible.

(a) Show that the force in each of the two struts BD and BE is 11.45 MN. [8]

(b) The struts are to be made of circular steel tubes of thickness t and radius to mid-thickness r . If the r/t ratio is to be 20, determine the required value of r to provide a factor of 2 reserve against buckling for a perfect strut. [8]

(c) If the struts are made with an imperfection in straightness of Length/1000, calculate the expected lack of straightness when the wheel is in position. [4]

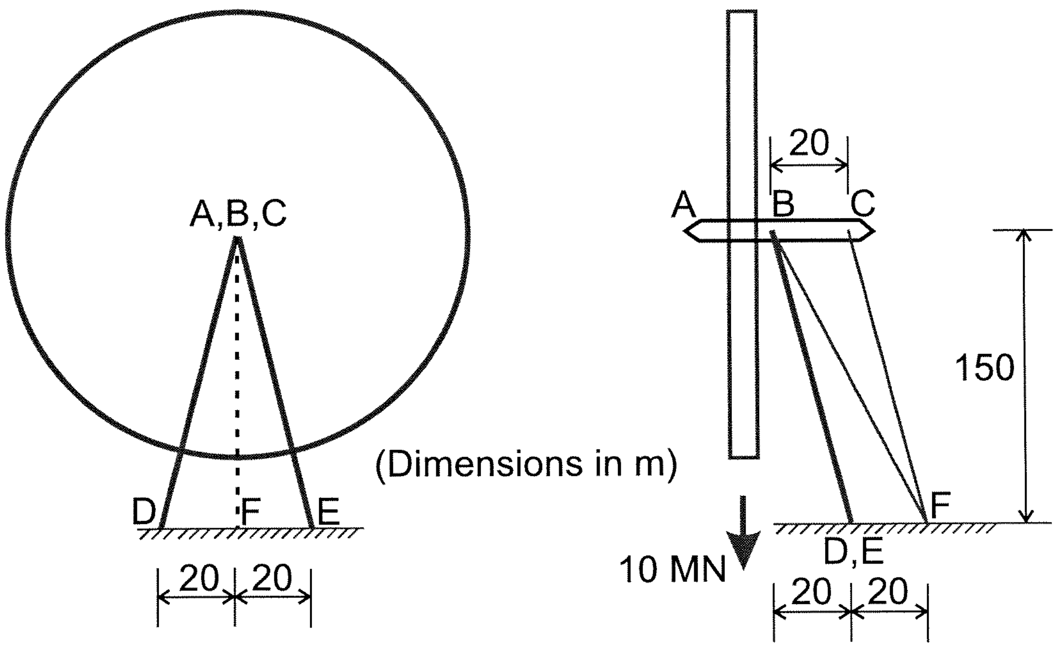

Fig. 5

END OF PAPER