ENGINEERING TRIPOS PART IIA
ENGINEERING TRIPOS PART IIB

Monday 26 April 2010 2.30 to 4

Module 4D8

PRESTRESSED CONCRETE

Answer ***one*** *question from Section A and* ***two*** *questions from Section B. Questions from Section A carry* ***twice*** *as many marks as questions from Section B.*

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

Attachments: None

STATIONERY REQUIREMENTS
Single-sided script paper
Graph paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

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

cjb03

SECTION A

1 A prestressed concrete railway sleeper is to be designed to carry a 100 kN wheel load on each rail simultaneously. The rails are spaced at 1500 mm centres. The overall length of the sleeper is 2500 mm. When the track has been newly laid, the reaction from the ground is assumed to be uniformly spread over a distance of 350 mm on either side of the rail, as shown in Fig. 1 (a). After settlement of the ballast, the ground reaction is assumed to be spread uniformly over the gap between the rails, as shown in Fig. 1(b).

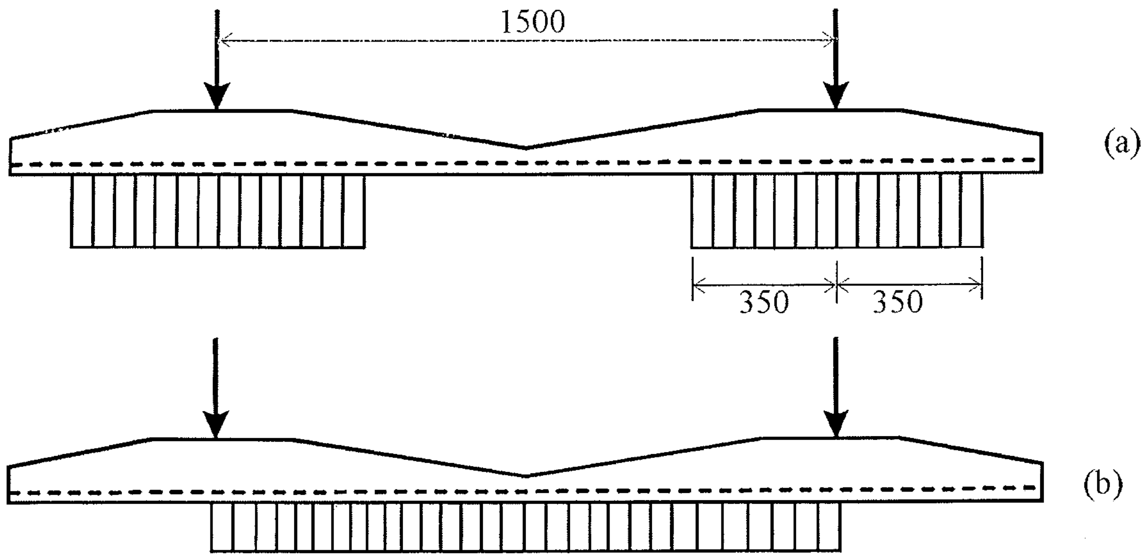
The method of fabrication requires that the prestressing tendons be straight and a fixed distance above the bottom of the sleeper, which must be flat, but the profile of the top surface may vary.

The overall width of the sleeper is fixed at 300 mm and it has a rectangular cross-section; the permissible stresses in the concrete are 20 N/mm^2 in compression and zero in tension. Ignore the effects of loss of prestress and the self-weight of the sleeper.

(a) Sketch the bending moment diagrams for the two loading cases and determine the maximum and minimum bending moments at the centre of the sleeper and under the rail. [20%]

(b) Design suitable cross-sections at the centre and under the rail. [30%]

(c) Draw Magnel diagrams for both cross-sections and hence determine a suitable prestress force and its location. [50%]



(all dimensions in mm)

Fig. 1

2 A beam 1000 mm deep and 500 mm wide has a single straight post-tensioning tendon, of area 2500 mm^2 placed at the lower Kern point. The tendon is stressed to 1000 N/mm^2 after immediate losses and application of the beam's own dead load. The tendon has an ultimate strength of 1600 N/mm^2. The concrete has a Young's modulus of 30 kN/mm^2, a cube strength of 60 N/mm^2 and a tensile strength of 4 N/mm^2. The concrete weighs 23.6 kN/m^3. The beam is simply supported over a span of 15 m and is subjected to a uniformly distributed load.

(a) Calculate the ultimate load that the beam can carry. [40%]

(b) Plot, to scale and on graph paper, the load vs. central deflection of the beam. Show clearly which parts of your plot are accurately calculated and which parts are approximate. [30%]

Note on your diagram:

(i) the load to cause zero deflection, [10%]
(ii) the limits of applicability of stress design, and [10%]
(iii) the ultimate load. [10%]

SECTION B

3 A three-span prestressed concrete bridge, of uniform section, is built as a pair of balanced cantilevers with prestressing cables (force P_1) in the top flange. The outer ends of the two pieces are then supported on rollers (taking upward or downward force). The tips of the cantilevers are now joined with in-situ concrete at the centre and prestressing cables are placed across the joint and stressed (Fig. 2(a)). These cables have a constant eccentricity *(e)* below the centroid of the beam, and carry a force P_2.

(a) Explain why the cables originally placed in the top flange do not cause any secondary moments. [20%]

(b) Determine the secondary moments induced in the bridge, taking the flexural stiffness of the piers as negligibly small in comparison with that of the bridge deck. Couples of 1000 kNm applied at the ends of the new cable induce end reactions of 18 kN as shown in Fig. 2(b). Draw a diagram of the total bending moment induced in the beam by the prestressing force P_2 . [60%]

(c) Why do designers deliberately choose to induce sagging secondary moments in this way?

[20%]

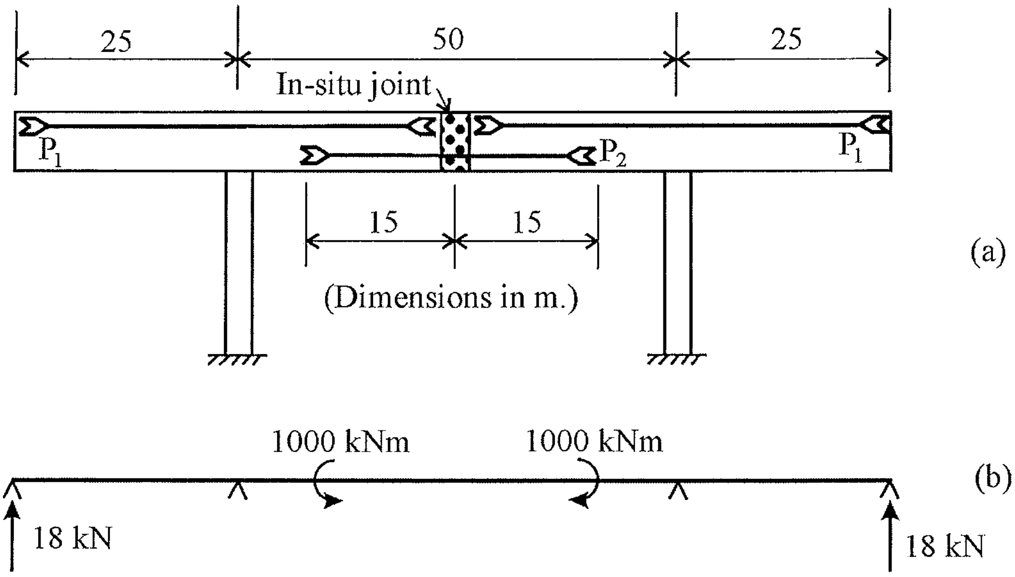


Fig. 2

4 For each of the following statements, say whether they are always true, always false, or true in certain circumstances only. Write a short statement to justify your answer in each case.

(a) Prestressed concrete is cheaper than reinforced concrete. [25%]

(b) Prestressed concrete is stiffer than reinforced concrete. [25%]

(c) Reinforced concrete is more durable than prestressed concrete. [25%]

(d) The use of untensioned reinforcement does not alter the design procedures for prestressed concrete. [25%]

5 Which of the following statements regarding losses of prestress are true or false? In each case, write a single sentence justifying your conclusion.

(a) Friction losses in prestressing cables are reduced by the use of flexible ducts. [12.5%]

(b) Friction losses in continuous beams are increased when the cable profile induces secondary moments. [12.5%]

(c) Friction losses are increased by the presence of untensioned reinforcement. [12.5%]

(d) Improving the bond between cable and duct by the use of strong grout reduces the friction losses. [12.5%]

(e) Creep losses are increased by the presence of untensioned reinforcement. [12.5%]

(f) Losses due to anchorage slip are more important in long tendons than in short tendons. [12.5%]

(g) Losses due to elastic shortening can be ignored for pretensioned beams because the tendons are stressed before the concrete is placed. [12.5%]

(h) Losses due to relaxation of steel are worse for post-tensioned beams than for pretensioned beams. [12.5%]

END OF PAPER