ENGINEERING TRIPOS PART IIA
ENGINEERING TRIPOS PART IIB

Thursday 4 May 2006 9 to 10.30

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	SPECIAL REQUIREMENTS
Single-sided script paper	Engineering Data Book
Graph paper	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

SECTION A

*Answer **one** question from this section.*

1 (a) A uniform elastic simply-supported beam is subjected to three loads, as shown in Fig. 1. Find the relationship between P_1 and P_2 such that the deflection at the centre is zero. [30%]

(b) A *continuous* prestressed concrete beam has a cable profile as shown in Fig. 2. The cable position s is measured positive downwards from the centroid of the section. Use the result of (a) to find a relationship between s_1 and s_2 such that the cable profile is concordant. [40%]

(c) A beam of the form shown in Fig. 2 has a constant prestressing force of 1000 kN and a cable profile defined by $s_1 = -0.6$ m and $s_2 = 0.4$ m. Use the result of (b) and a suitable linear transformation to find the secondary moments induced over the internal support. [30%]

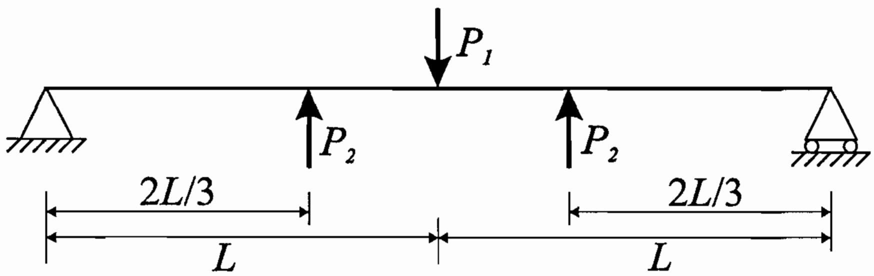

Fig. 1

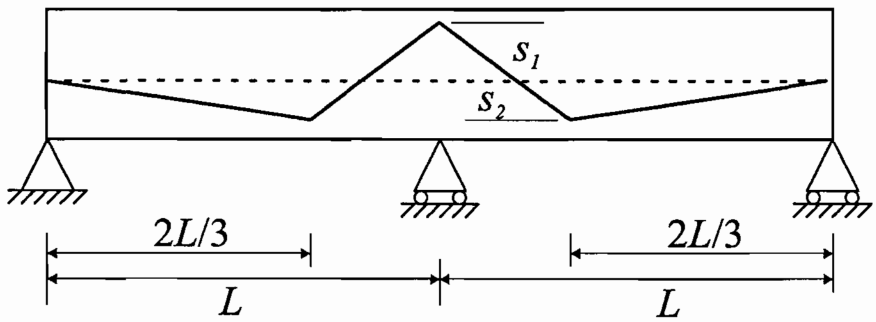

Fig. 2

2 A rectangular pretensioned beam 1000 mm deep and 500 mm wide has a single steel prestressing tendon of cross-sectional area 2500 mm^2 placed 350 mm above the soffit. Before the concrete was cast the cable was pretensioned to a stress of 800 MPa. Young's modulus for the steel is 200 GPa; for the concrete it is 25 GPa in the short term and 10 GPa in the long term. Over a long period of time the shrinkage strain of concrete is 300×10^{-6}.

(a) By considering compatibility of strain, derive relationships that will allow the determination of the stresses in the concrete at different stages. Use the effective modulus method and assume that no significant forces other than the prestress act on the beam. [30%]

(b) Determine the maximum compressive stress in the concrete and the tensile stress in the tendon

(i) immediately after transfer, and [10%]

(ii) after a long period of time. [30%]

(c) If there is a thermal gradient in the structure, more creep takes place at the top of the beam than at the bottom so that the long term modulus of concrete varies linearly from 8 GPa at the top to 12 GPa at the bottom. Suggest, without doing detailed numerical calculations, how the procedure used above would be modified. [30%]

SECTION B

*Answer **two** questions from this section.*

3 The precast U-beam shown in Fig. 3 is 1.5 m deep and its centroid is located 0.72 m above the soffit. The second moment of area of the precast beam is 0.203 m^4 and its cross-sectional area is 0.75 m^2. It carries a prestressing force of 7500 kN, the centroid of which is located 0.37 m above the soffit. A simply-supported bridge is made from such beams with a span of 30 m at 2 m centres, and an in-situ slab that is 0.2 m thick. The concrete weighs 24 kNm^{-3} and the modular ratio of the in-situ concrete to the precast concrete may be taken as 0.8. The beam is not propped.

(a) Calculate the stresses in the precast beam at mid-span when the in-situ concrete is still wet. [30%]

(b) Determine the maximum uniformly-distributed live load that can be carried by the composite beam so that no tensile stresses are caused in the soffit of the precast beam. [50%]

(c) Explain why the support is often the most critical cross-section for precast beams. What steps can be undertaken to reduce the problems that arise here? [20%]

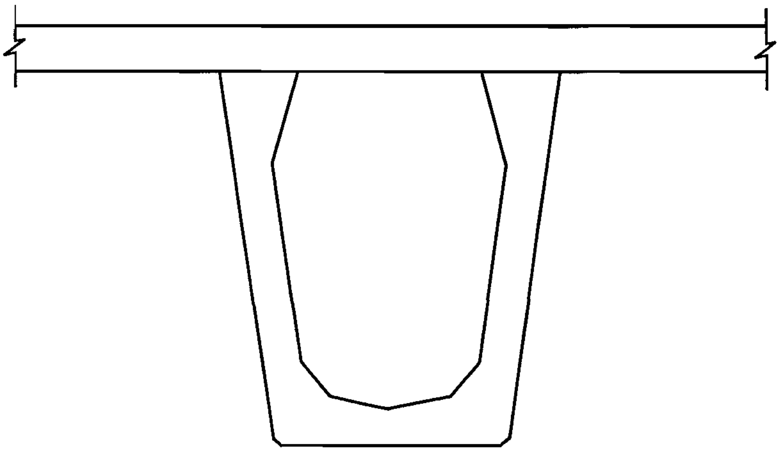

Fig. 3

4 Two post-tensioned prestressed concrete beams are identical, other than that one has bonded tendons and the other has unbonded tendons. They have an overall depth of 900 mm, a breadth of 400 mm, and a prestressing tendon of 1800 mm^2 at an eccentricity of 150 mm. The tendons are initially stressed to 800 MPa. The stress-strain curve for the steel is shown in Fig. 4. The beams are designed to be simply-supported at their ends and to be subjected to a uniformly-distributed load.

(a) Without doing detailed calculations, sketch typical load-deflection relations for the two beams, showing the complete behaviour from casting to failure. Indicate the reasons for all changes of slope on these curves, and discuss the similarities and differences. [40%]

(b) Why is a complete analysis of the unbonded beam more complicated than for the bonded beam? [30%]

(c) Perform an ultimate moment calculation for the unbonded beam, assuming a bond factor of 0.25. Ignore the effects of elastic strains in the concrete due to the prestress and assume that the concrete stress at failure is 30 MPa over the whole of the compression zone. [30%]

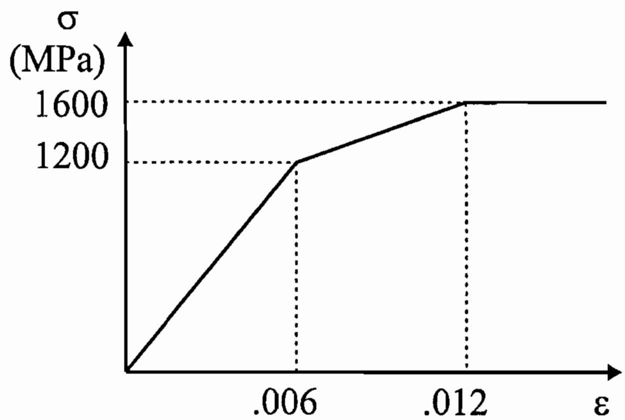

Fig 4.

(TURN OVER

5 Write an essay about **one** of the following:

(a) The development of prestressed concrete in the UK.

(b) The prestressing of Winterton House.

(c) The prestressing of the Athenian Trireme.

(d) The prestressing of steel structures, with particular reference to Foyle Bridge.

(e) The prestressing of spoked wheels and cartwheels.

[100%]

END OF PAPER

4D8 Prestressed Concrete – Examination 2006

Numerical answers

1. (a) $27P_1 = 46P_2$ (b) $8s_1 = -15s_2$ (c) 66.7 kNm (sagging)

2. (b)(i) 7.28 N/mm^2; 761 N/mm^2 (ii) 6.27 N/mm^2; 656 N/mm^2

3. (a) Bottom 8.3 N/mm^2; top 11.8 N/mm^2 (b) 14.2 kN/m^2

4. (c) 1102 kNm

C J Burgoyne
1st June 2006