Version FAM/3

EGT3
ENGINEERING TRIPOS PART IIB

Wednesday 29 April 2015 14.00 to 15.30

Module 4D10

STRUCTURAL STEELWORK

Answer not more than ***three*** *questions.*

All questions carry the same number of marks.

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

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
Attachment: 4D10 Structural Steelwork Data Sheets (9 pages)
Engineering Data Book

10 minutes reading time is allowed for this paper.

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

1 (a) Explain why it is appropriate to take account of restrained warping torsion when considering the lateral-torsional buckling of an I-beam, even if the support conditions allow complete freedom to warp. Illustrate your answer with a sketch. [20%]

(b) Describe some of the difficulties that may be encountered if one tries to develop a theory of elastic-plastic interaction in lateral-torsional buckling along lines similar to the Perry-Robertson approach to Euler column buckling. [20%]

(c) Figure 1 shows an 18 m beam of S275 steel and 610×229 UB 125 section. Lateral deflections and twist rotations are prevented at 6 m intervals, as denoted by the large crosses at A, B, C and D. Loads of 100 kN and 70 kN are applied via secondary beams at points B and C respectively. These are ultimate design loads that already include all load factors and all allowances for self-weight.

Assuming the yield stress is 275 MPa for all components, determine if the beam is adequate to carry the loads shown. [60%]

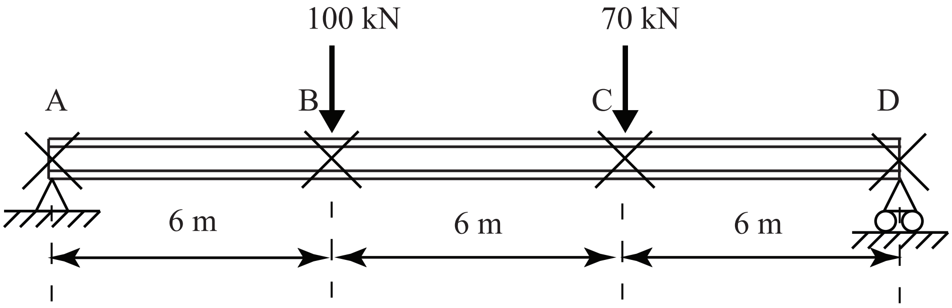

Fig. 1

2 A 254×254 UC 89 beam column of S275 steel is 8 m long. It is simply supported at its ends with respect to major axis flexure.

There are lateral braces at its ends and at midspan. Each brace prevents lateral movement due to minor axis flexure and twist rotation of the section where the brace connects. The midspan brace does not prevent major axis flexure.

The beam column will be loaded with some combination of axial compression N and equal-and-opposite major axis end moments M.

Assume the yield stress is 275 MPa for all parts of the section.

(a) Check the compactness of the various parts of the section. [10%]

(b) Using the bilinear "half web fraction" approximation, construct the local plastic capacity envelope on an (M,N) diagram. [10%]

(c) On your (M,N) diagram, also construct two strength envelopes associated with global behaviour, one for major axis flexure and one for minor axis flexure, each of which may interact with lateral-torsional buckling and plasticity effects. You may assume that each envelope is linear between points on the M and N axes. [60%]

(d) Estimate the maximum equal-and-opposite major axis end moments that may be applied coexistent with an axial load of 1000 kN. [20%]

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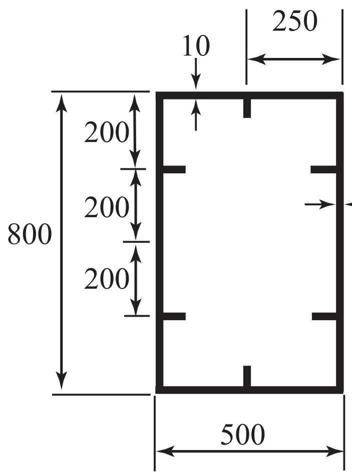
3 The cross-section of a box girder, constructed from plate steel of grade S355, is shown in Fig. 2(a). This box girder is used to support a uniformly distributed load of 80 kN/m over a simply-supported span of 12.2 m, as shown in Fig. 2(b). This is a factored load and includes an allowance for self-weight. There is concern about the adequacy of the girder in the midspan region and stiffeners have been added, as shown.

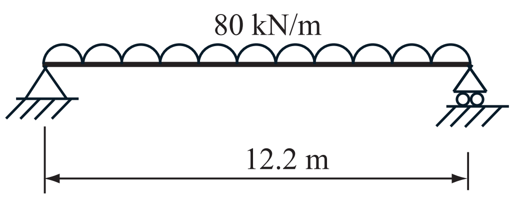
(a) Assuming that all stiffeners are properly designed and that global buckling is prevented, determine whether the stiffened midspan section is sufficient to support the load. [70%]

(b) The uniformly distributed load is then varied by the load cycle shown in Fig. 3. Assuming that the welds are Class D, estimate how many of these cycles the welds between the girder and its stiffeners can take before fatigue failure occurs. [30%]



All dimensions in mm.
All stiffeners 80 x 20 mm.

(a)



(b)

Fig. 2

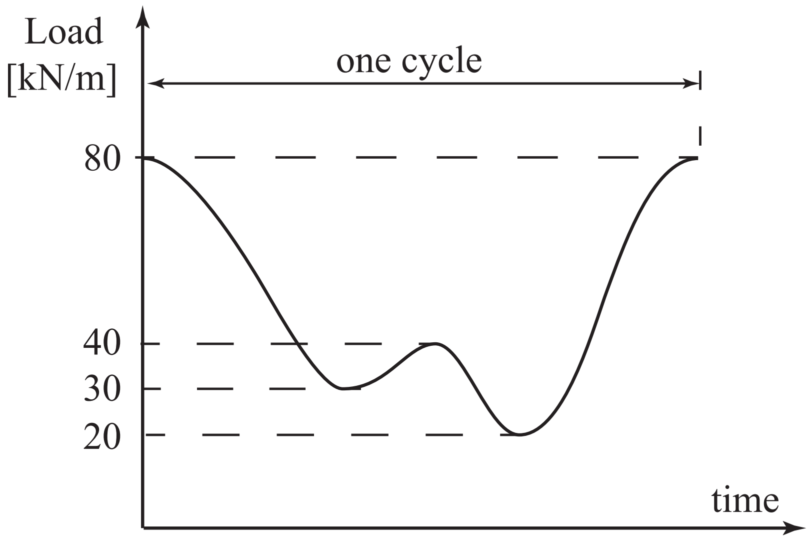


Fig. 3

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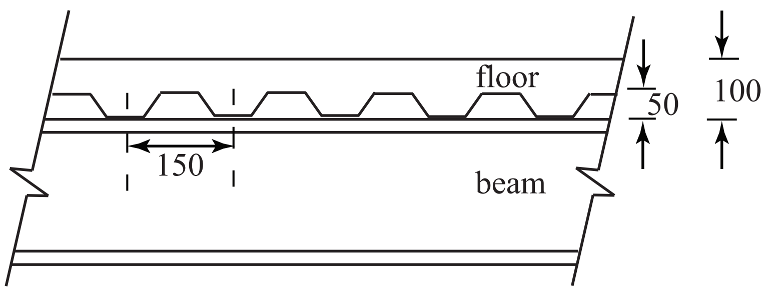
4 A composite floor is designed to carry a uniformly distributed imposed load of 5 kPa, permanent services of 2 kPa and its self-weight. The partial safety factors are 1.5 for imposed loads and 1.35 for permanent loads. The floor consists of a concrete slab of maximum thickness 100 mm which includes a 50 mm trough as shown in Fig. 4. The concrete has a design strength $f_{cd} = 30$ MPa and its density is 2400 kg m^{-3}. The slab is supported by 406 × 178 UB 60 beams of S355 steel. These beams are at 3.2 m centres and orthogonal to the deck troughs. The beams are 12 m long, and are simply supported at the ends. The slab does not extend beyond the ends of the beams.

(a) Assuming full composite action, show that the floor can carry the specified loading of permanent and imposed loads. [50%]

(b) Calculate the number of 65 mm × 13 mm shear studs needed for each beam to achieve full composite action. [20%]

(c) Estimate the maximum deflection under short-term application of the imposed load and check the serviceability limit state, assuming a maximum allowable deflection of span/250. [30%]



All dimensions in mm.
(Drawing not to scale).

Fig. 4

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