ENGINEERING TRIPOS PART IIB

Monday 22 April 2013 9.30 to 11

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.*

Attachment: Structural Steelwork Data Sheets (9 pages).

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

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1 (a) Show that the lowest root $\sigma = \sigma_L$ of the Perry-Robertson equation

$$(\sigma_y - \sigma)(\sigma_E - \sigma) = \eta\sigma\sigma_E$$

may be expressed as

$$\sigma_L = \chi\sigma_y$$

where $\chi = \dfrac{1}{\Phi + \sqrt{\Phi^2 - \lambda^2}}$, $\Phi = \dfrac{1 + \eta + \lambda^2}{2}$ and $\lambda = \sqrt{\dfrac{\sigma_y}{\sigma_E}}$.

[25%]

(b) The buckling resistance curves in Data Sheet DS1 fall away to the right, approaching an inverse square law. This is related to the fact that the Euler load for a column of length L varies as $1/L^2$. However the critical moment for lateral torsional buckling of a beam of length L falls away as $1/L$ for large L. Explain then the rationale as to why the DS1 buckling resistance curves are applicable to lateral torsional buckling, even though lateral torsional buckling moments do not approach an inverse square law with increasing length.

[25%]

(c) Figure 1 shows a beam with a 12 m clear span. Its supports A and C provide full fixity in all local degrees of freedom. The beam has 457 × 152 × 74 UB cross-section throughout, oriented such that the web of the beam is in the plane of the diagram. It has been manufactured by hot rolling and is of Grade S275 steel. Side beams connect to the main beam AC at the intermediate point B. These side beams - denoted by the small cross in the diagram - prevent any lateral deflection or twist rotation at B. A factored point load of 100 kN is applied at B as shown.

Ignore self-weight and assume that all components are at least Class 2 (compact) with 275 MPa yield stress. Any reduction of moment capacity due to shear effects may also be ignored. Determine if the member is adequate to carry the applied load.

[50%]

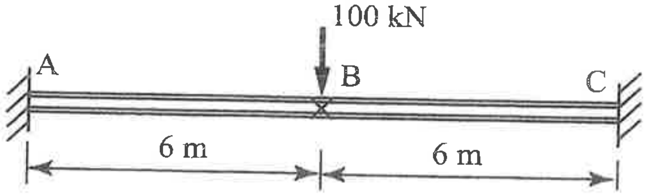

Fig. 1

2 (a) Assuming that equal and opposite major axis end moments will be applied and that no minor axis moments will be applied, construct the interaction diagram showing the strength envelopes for combined axial and major axis moment effects for a 305 × 305 × 158 Universal Column. The column has an effective length of 2.8 m for major axis elastic flexural buckling and 3.5 m for both minor axis elastic flexural buckling and lateral torsional buckling. The beam is of Grade S235 steel. You may assume that all components are at least Class 2 (compact) with 235 MPa yield stress. Your diagram should have axial loads in kN on the *y* axis and major axis moments in kNm on the *x* axis.

Your diagram should show:

(i) the local plastic capacity envelope (for which you may use the half web fraction bilinear approximation); [20%]

(ii) two further lines that delineate the strength envelopes relating to major axis and to minor axis buckling (each of which may interact with lateral torsional buckling). You may assume that these lines are straight between relevant points on the *x* and *y* axes. [60%]

(b) On the same diagram, add corresponding lines for the case where the applied major axis end moments are of equal magnitude but are in the same direction. [20%]

3 A box girder bridge is to be constructed from S355 steel as a uniform rectangular cross-section that is continuous over three supports with two spans each of 20 m. One ultimate limit state load case is a uniformly distributed load of 500 kNm^{-1} over the full 40 m bridge length, as illustrated schematically in Fig. 2. There is no need to consider the case where only a single span is loaded.

The cross-section is 3 m deep and 8 m wide with a uniform wall thickness of 10 mm. Longitudinal stiffeners, each 80 mm by 10 mm, are welded within the cross-section at 1 m centres to both the webs and flanges. Transverse cross-frames are welded in the cross-section at 2 m centres throughout both spans, including over each of the three supports.

(a) Sketch the shear force and the bending moment diagrams under the given ultimate load. [10%]

(b) Determine the location of the most highly loaded:

(i) longitudinal stiffener,

(ii) flange panel, and

(iii) web panel

in the bridge and check the adequacy in each case at the ultimate load. [80%]

(c) Suggest any simple changes to the bridge design that may be required. No further calculations are necessary. [10%]

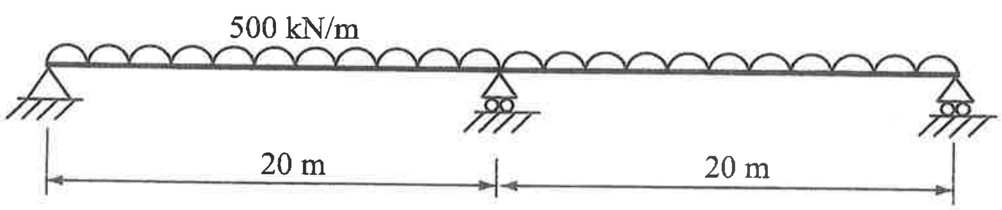

Fig. 2

4 A crash barrier post is illustrated schematically in Fig. 3. It is to be constructed from a vertical 250 × 250 × 5 mm square hollow section in S235 steel. The post is intended to resist a horizontal design load of 100 kN applied 1 m above the moment-resisting base connection. The base detail consists of two angle cleats on either side of the post, each connected into the post webs with a group of 6 bolts. Each group of bolts is arranged in a 2 × 3 array, with a single horizontal spacing of 150 mm and vertical spacings of 100 mm as illustrated. The bolts are working in pure shear.

(a) Determine the effective cross-section of the post and check its adequacy at the maximum design bending moment. [40%]

(b) Determine which bolt is the most heavily loaded, and determine the size of Grade 4.6 bolt that is required. [40%]

(c) Make any further checks of the design that may be necessary. [20%]

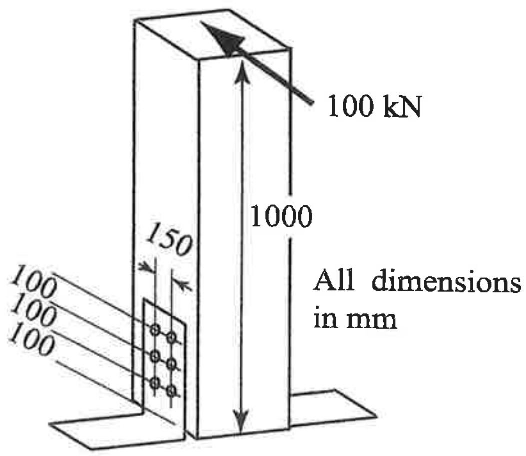

Fig. 3

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Answers:

1. 295.3kNm > 150kNm applied

2. a) 4723kN, 630kNm, 514kNm

   b) 4676kN, 4062kN, 598kNm

   c) 617 kNm

3. a) A,C 3750 kN, B +/-6250kN
   25 MNm at B, 14.07 MNm at 7.5m from A, C
   b) i) in bottom flange at B, T-section can carry 596 kN (< 913kN required)
   ii) in bottom flange at B. Strength 0.24 < 1. Stability 0.76 <1
   iii) in lowest web at B. Strength 0.32 < 1. Stability 1.19 > 1.

4. a) 70 kNm strength
   b) 92kN, M36 grade 4.6