The University of Sydney

CIVL3227 Steel Structures 1/CIVL3206 Steel Structures 1

Department of Civil Engineering

Semester 2, 2003

Time Allowed: 3 hours

Instructions to Candidates

(a) **Students should attempt all questions.**

(b) Suitable working, diagrams and explanations are required for each question.

(c) Marks may be deducted for work that is not satisfactorily set out.

(d) Units are important and answers with incorrect units will not be awarded full marks.

(e) Programmable and non-programmable calculators may be used.

(f) Read the questions carefully before answering.

(g) Annotated copies of AS 4100 (or the student edition HB2.2) may be taken into the exam, but no other written material is permitted. Additional pages are not to be inserted into AS 4100 (or HB 2.2).

(h) Students are reminded that satisfactory exam performance is an essential criterion in this unit of study, and a total mark of 40%, and minimum 50 % mark in at least 2 exam questions, is required.

(i) The exam is worth 55 % of the final assessment in the "structures" component of this unit of study.

(j) This paper contains 5 questions: Tension (15 %), Bending (25 %), Compression (20 %), Combined Actions (25 %), Connections (15 %).

Q 1 Tension Members (15 marks)

a) Clause 9.1.10.3 of AS 4100 states "When holes are staggered, the area to be deducted shall be the greater of—(a) the deduction for non-staggered holes; or (b) the sum of the areas of all holes in any zig-zag line extending progressively across the member or part of the member, less ($s^2_p t$ / $4s_g$) for each gauge space in the chain of holes", where s_p is the pitch and s_g is the gauge.

Use a diagram to explain the terms "pitch" and "gauge".

Would increasing the pitch in a set of staggered bolt-holes make failure through that staggered pattern more or less likely? Explain the answer (diagrams will help!).

b) A cold-formed circular hollow section is to be used as a bracing member in a frame to resist a design tensile load of 145 kN. The member will not experience compressive loads. The engineer has not yet designed the connections but assumes that 15 % of the gross cross sectional area may be lost due to the presence of bolt holes at the connection. Use the attached page of section properties for Grade C350 CHS to **determine the CHS of least mass** that will be suitable. Please include **the design section capacity in tension (φN_t) of the selected CHS section.**

There is no Figure 1, but students know they should draw diagrams!!

Q 2 Bending (25 Marks)

a) **Explain why the typical shape of a UB compared to a UC makes it more suitable for bending applications.** Use of diagrams would assist the answer.

b) A simply supported beam of length L = 7 m is constructed from an 410UB59.7 section in Grade 300 steel, and is subjected to a uniformly distributed design load of w, as illustrated in Figure 2. The load acts vertically downwards on the top flange of the beam.

i) **Draw the bending moment and shear force diagrams** for the entire beam clearly showing magnitude, units and location of the maximum shear force and maximum bending moment. **Is the beam bending about its major (x) axis or minor (y) axis?**

iii) **Which flange (top or bottom) is the critical flange and why?**

iv) The beam has full restraint at the supports only, but there is no lateral rotation restraint provided at the supports. **Calculate the effective length in bending, L_e, and the design member moment capacity, φM_b. Hence, determine the maximum value of w according to the design requirements of AS 4100.**

Clearly identify the values of all appropriate variables calculated and include the relevant units.

If required, the values of Z_{ex}, Z_{ey} and k_f may be taken from the OneSteel product literature.

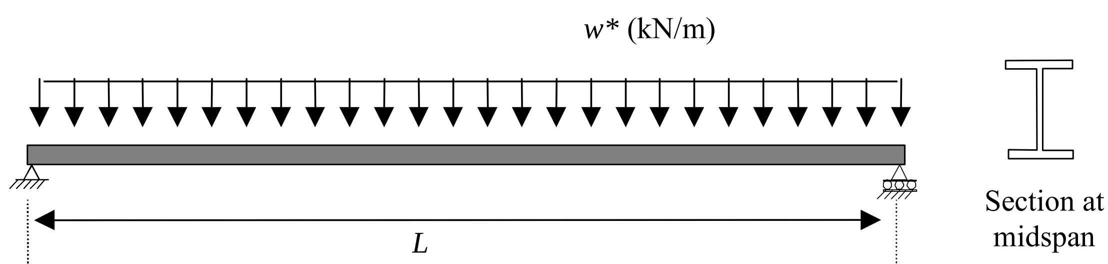


Figure 2: Simply Supported Beam Under Uniformly Distributed Load

Q3 Compression Members (20 Marks)

a) **Explain why the typical shape of a UC compared to a UB makes it more suitable for compression applications.** Use of diagrams would assist the answer.

b) OneSteel are planning to introduce a new ***heavily welded*** I section which is shown below.

The steel has a yield stress $f_y = 320$ MPa.
Geometric properties:
$I_x = 184\times10^6 mm^4$
$I_y = 10.3\times10^6 mm^4$
$A_g = 6778\ mm^2$

Determine the following:

- The form factor (k_f) (you will need to calculate this)
- The design section capacity (φN_s) for compression.
- Design member compression capacity (φN_c) assuming effective lengths in compression of L_{ex} = 7.5 m and L_{ey} = 4.0 m.

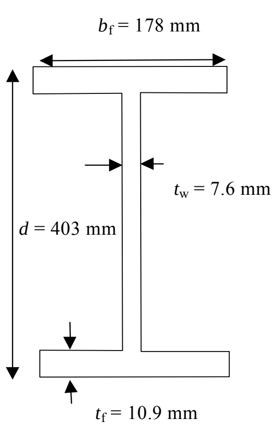


Figure 3: Proposed heavily welded section

Q4 Combined actions (25 Marks)

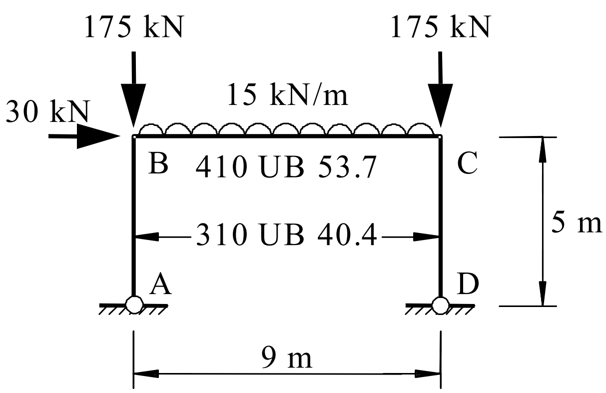
a) **Briefly explain the difference between a *first-order* and a *second-order* bending moment.**

It may be appropriate to write some relevant equations and draw some diagrams in your response, but there is no need to perform any numerical calculations. Directly quoting from AS 4100 is not considered an appropriate answer.

b) A rectangular portal frame ABCD subjected to a design load combination is shown in Figure 4(a). All members are bent about their major (x) axis in the plane of the frame. The beam column connections are rigid, while the column base plate connections are pinned. The bending moment and axial force diagrams obtained by conducting a *second order elastic analysis* of the frame are shown in Figures 4(b) and 4(c), respectively. Each member of the frame is sufficiently laterally braced such that buckling out of the plane of the frame is prevented.

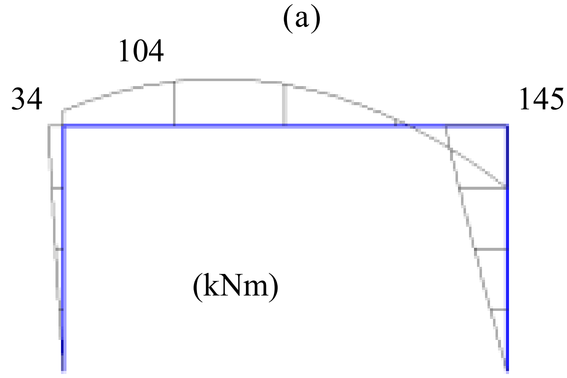
i) **Determine the effective length for in-plane buckling of member CD. Is this x or y axis buckling? Is this braced or sway? Without calculations would the effective length of AB be greater, smaller, or the same as the effective length of CD? Explain your answer.**

ii) **Determine the in plane member strength (ϕM_{ix}) of member CD** and hence establish if Cl 8.4.2.2 of AS 4100 is satisfied. If required, the values of Z_{ex} and k_f may be taken from the OneSteel product literature.

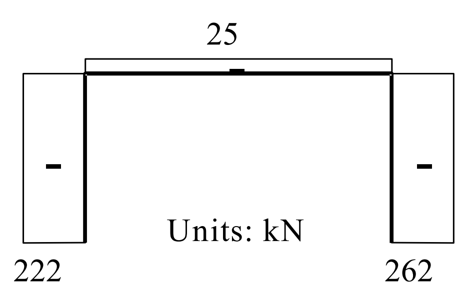


(a)

All members are Grade 300



(b) Bending moment d agram



(c) Axial force diagram

Figure 4

Q5 Connections (15 Marks)

(a) **Give two methods** of guaranteeing the specified pre-tension in a fully-tensioned high-strength bolt. Directly quoting from AS 4100 is not considered an appropriate answer. Use of diagrams would greatly assist the answer.

(b) A Grade 8.8 M20 bolt experiences both tension and shear (through the threaded cross-section). The bolt experiences a design shear force of $V_f^* = 35$ kN. **What is the maximum design tensile force (N_{tf}^*) the bolt can hold?**

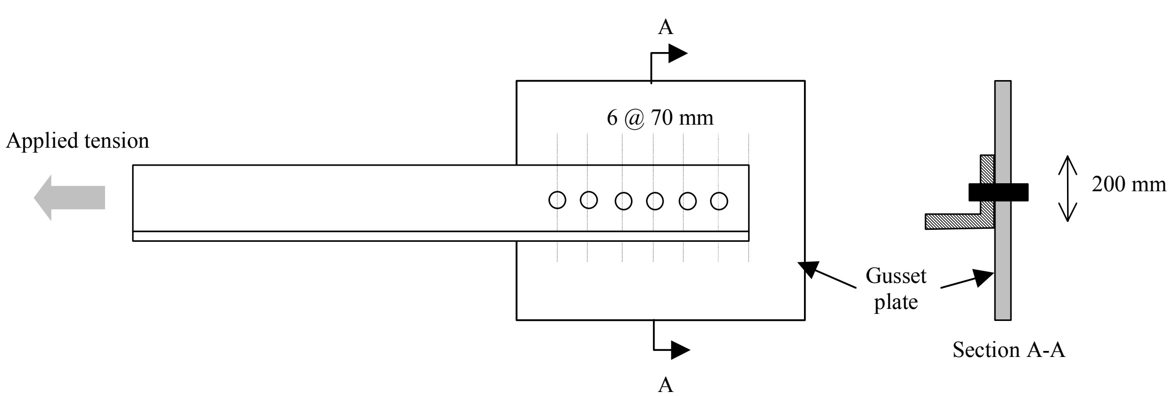
(c) An engineer is assessing the tensile strength of a bracing connection in which a 200×200×18 EA (Grade 300) is bolted to a 25 mm thick gusset plate (Grade 300 to AS/NZS 3678) by 6 bolts as shown in Figure 5. The bolt pitch is 70 mm. Grade 8.8 snug tight M20 bolts are used in this connection, and the plane between the gusset plate and angle coincides with the *threaded* part of the bolt.

(i) **List the various failure modes (and hence limit states) that should be considered when calculating the design capacity of this connection.**

(ii) **What is the design capacity of the connection?** (Students are *not* required to calculate the section capacity in tension of the angle. For the angle section $\phi N_t = 1750$ kN). **What is the critical failure mode of the connection?**

The following properties of an M20 bolt may be useful.

Core area, $A_c = 225$ mm^2.
Shank area, $A_o = 314$ mm^2.
Tensile stress area, $A_s = 245$ mm^2
Diameter of the hole, $d_h = 22$ mm



(a) Plan

Figure 5 (All dimensions in mm)

This is the end of the questions in this examination paper. The next 5 pages should contain OneSteel product information on UB, UC, EA & CHS.