The University of Sydney

CIVL3206 Steel Structures 1

School of Civil Engineering

Semester 2, 2006

Time Allowed: 3 hours + 20 minutes reading time

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).

Q 1 Tension Members (20 marks)

a) Explain the phenomenon of “shear lag” with respect to tension capacity of a member at a connection, and how it is considered by various values of the connection correction factor k_t. It is expected that possibly two paragraphs of text, plus diagrams might be suitable to answer this question.

b) Consider the simply supported Warren truss shown in Figure 1. There are 10 panels, each 2.1 m in length, to give a total span of 21 m. The truss uses T-sections for the chords and double angles for the diagonals. The truss is designed to resist a downwards UDL of 19 kN/m, which may be simplified as a set of point loads acting on the panel points of the truss. 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 connections.

i) Since the chords are 20 m long, two separate T-sections spliced together will be needed for each chord. **Sketch a possible splice connection for the T chords and hence determine an appropriate value for k_t.**

ii) **Which chord (top or bottom) is in tension? Determine the design axial tension N^*** for this chord using an appropriate method of analysis.

iii) Use the attached page of section properties for Grade 300 T-sections to **determine the T-section of least mass** that will be suitable for the tension design of the bottom chord. Compression in the bottom chord should not be considered. Please include **the design section capacity in tension (φN_t) of the selected section.**

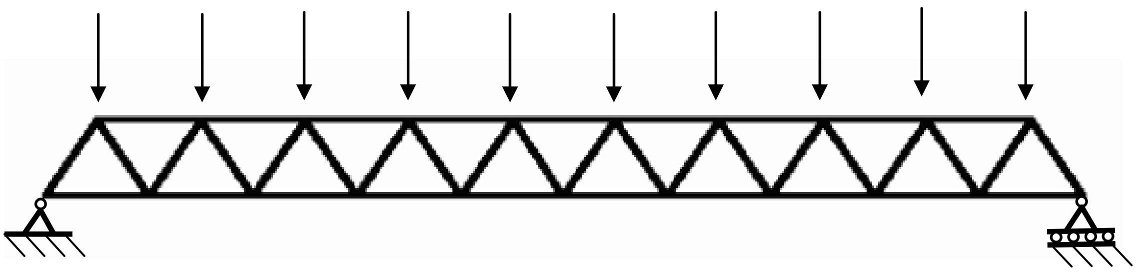

Figure 1

Q 2 Bending (25 Marks)

a) For a typical low rise portal frame structure (such as the one considered in the design assignment), UB sections are more commonly used for the columns compared to UC sections. **Explain why the typical shape of a UB compared to a UC makes it more suitable for use as a column in such a structure.** Use of diagrams and reference to different types of buckling would assist the answer. Calculations are not necessary, but identification of loads, key equations or parameters may be useful.

b) A beam ABC is built in at both ends and subjected to a distributed load w = 3.0 kN/m applied downwards to the top flange. The top flange is fully restrained along its entire length. The Bending Moment Diagram (BMD) and Shear Force Diagram (SFD) are as shown in Figure 2. The beam is being bent about the *x*-axis.

i) Determine a suitable size UB based on bending section capacity (ϕM_{sx}) alone.

ii) For the beam determined in (a), is the shear capacity and combined bending and shear capacity adequate at the ends?

iii) Use Clause 5.3.2.4 of AS 4100 to determine whether the beam determined in (a) is adequately braced in the end regions where hogging occurs and the bottom (unrestrained) flange is in compression. The equation that describes the bending moment distribution is $M = \frac{w}{2}\left(Lx - x^2 - \frac{L^2}{6}\right)$.

iv) For the beam determined in (a), what is the maximum value of *w* based on lateral buckling considerations (ϕM_{bx}) if there are no restraints within the span, and full restraint is provided at the supports only.

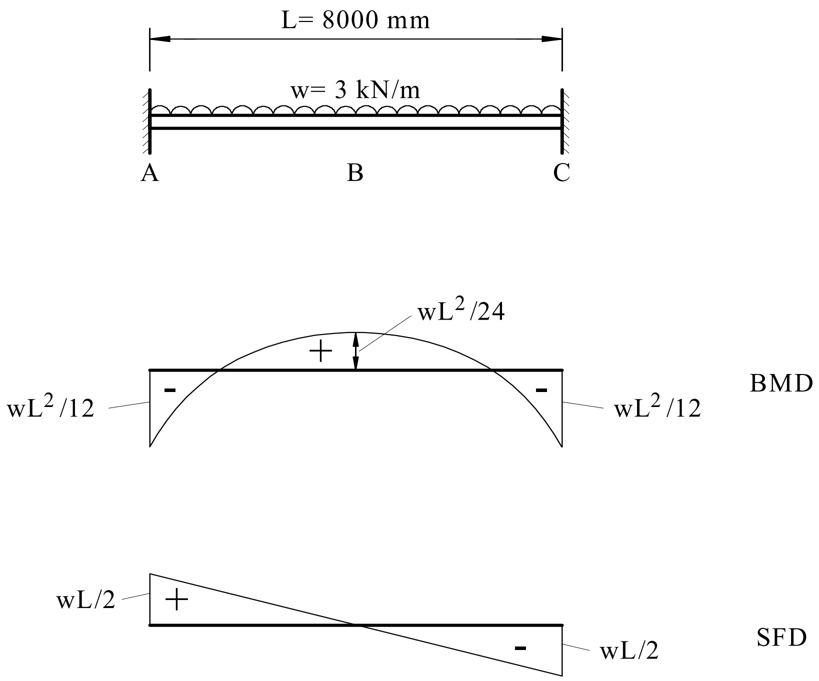

Figure 2

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

Q3 Compression Members (25 Marks)

a) **Explain why bamboo cane is a very efficient member for use as an axially loaded column.** Use of diagrams and reference to different types of buckling would assist the answer. Calculations are not necessary, but identification of key equations or parameters may be useful.

b) Consider the frame shown in Figure 3. All columns are 200UC52.2 and all beams are 250UB25.7 in Grade 300 steel. The columns are 4 m apart in the north-south and 3 m apart in the east-west directions and each storey is 3.3 m in height. The beam column connections in the north-south direction are flexible, and the connections are rigid in the east-west direction. There is cross bracing in the north-south direction. The column base plate connections should be considered as pinned in both directions. The webs of all columns are oriented east-west and all beams are oriented such that the flanges are horizontal.

i) **Determine the effective length of Column 1 for buckling in the north-south direction. Is this buckling about the *x* or *y* axis?**

ii) **Determine the effective length of Column 1 for buckling in the east-west direction. Is this buckling about the *x* or *y* axis?**

iii) **Determine the design member capacity (φN_c) of Column 1. Is the column adequate for design axial compressions of $N^*_{Col\ 1}$ = 600 kN?**

If required, any relevant values should be taken from the OneSteel product tables.

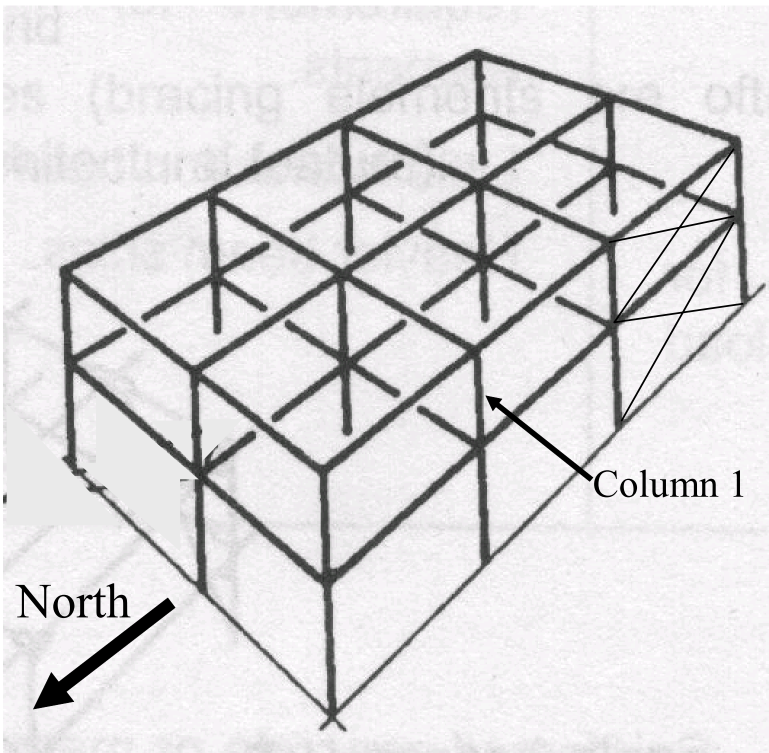

Figure 3

Q4 Combined actions (15 Marks)

a) Explain the difference between the two types of second-order effects, *P*-δ and *P*–Δ, and how second-order effects can be accounted for in the analysis of structures.

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. At most two paragraphs of text would be required.

b) A rectangular portal frame ABCD subjected to a design load combination is shown in Figure 4(a). All members are oriented such that the planes of the webs of the section are in the plane of the frame shown. 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) **Does the structural analysis program used draw the BMD on the tension or compression side of the structure? Explain briefly.**

ii) **Determine the in plane member strength (ϕM_{ix}) of member BC** and hence establish if Cl 8.4.2.2 of AS 4100 is satisfied. It should be assumed that the effective length factor for compression for in-plane buckling of BC is k_e = 0.8. If required, the values of Z_{ex} and k_f may be taken from the OneSteel product literature.

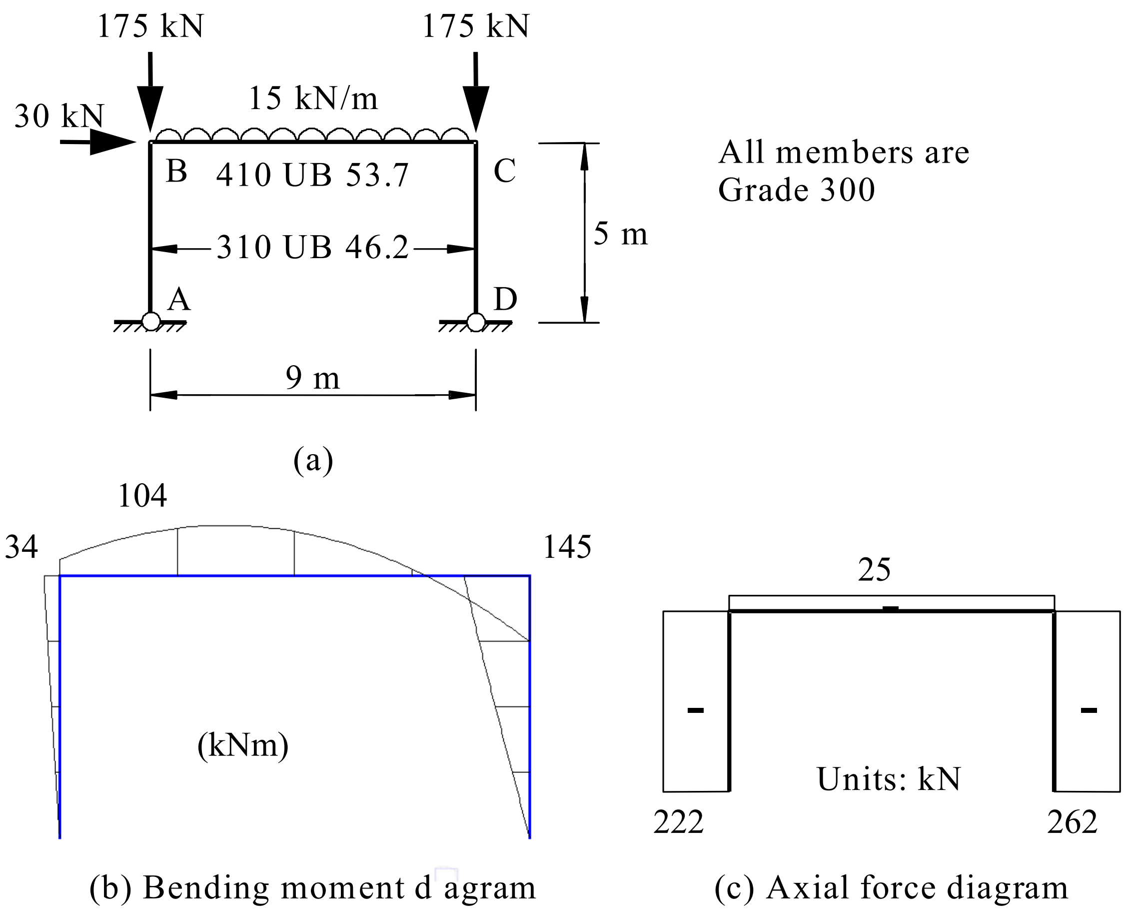

Figure 4

Q5 Connections (15 Marks)

(a) **What does the capacity reduction factor, φ, account for in limit states design? Explain why there are different φ factors for different failure modes. It would be useful to make specific reference to different φ factors applying to the design of SP and GP welds.**

(b) An engineer is assessing the tensile strength of a bracing connection in which a 200×200×20 EA (Grade 300) is bolted to a 25 mm thick gusset plate (Grade 300 to AS/NZS 3678) by 5 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 ϕN_t = 1750 kN). **What is the critical failure mode of the connection?**

(iii) The engineer changes the bolts to Grade 4.6 bolts (but still M20). **How many Grade 4.6 bolts would be required to ensure the same capacity as calculated in part (ii) above?**

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

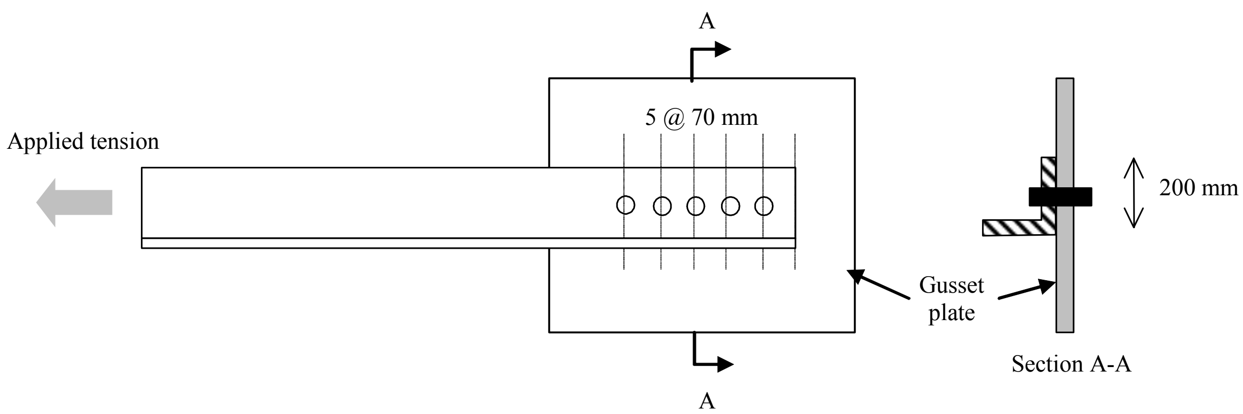

Figure 5

This is the end of the questions in this examination paper. The next 4 pages should contain OneSteel product information on UB, EA & T.