The University of Sydney

Faculty of Engineering

Department of Civil Engineering

Senior Year Examination

CIVL 3206 Steel Structures 1

Semester 2, 2000

Time Allowed: 3 hours

All questions should be attempted.

Suitable working, diagrams and explanations are required for each question.
Units are important.

Programmable and non-programmable calculators may be used.

READ THE QUESTIONS CAREFULLY BEFORE ANSWERING.

Annotated copies (but no inserts) of the following documents may be taken into the exam:
"Hot Rolled and Structural Steel Products - BHP"
"Structural Cold-Formed Hollow Sections and Profiles - BHP"
"Australian Standards for Civil Engineering Students - Part 2: Structural Engineering HB2.2"
"Australian Standard - Steel Structures - AS 4100"

The marks shown for each question on this paper correspond to the percentage of the examination paper and not the course.

Q1:	Tension Members	(15 marks)
Q2:	Bending	(20 marks)
Q3:	Compression Members	(20 marks)
Q4:	Combined Actions	(30 marks)
Q5	Connections	(15 marks)
		100 marks total

Q 1 Tension Members (15 marks)

a) Table 7.3.2 of AS 4100 gives different values of the tension correction factor k_t for unequal angles connected by the long leg or by the short leg.

Briefly explain why the correction factor is different for the two cases. There is no need to perform any calculations in answering this question. Including some diagrams may be useful in answering this question.

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b) Single 150 × 100 × 12 Unequal Angles in Grade 300 steel are being used as diagonal tension members in a truss. A typical UA member is connected to each chord of the truss using M20 bolts through the long leg of the UA only, and the pattern of 22 mm diameter bolt holes is shown in Figure 1 below. The capacities of the bolts in shear, and the ply in bearing do not need to be considered.

i) **Sketch two different fracture patterns** that may occur in the UA section in order to determine the net area (A_n).

ii) **What is the design section capacity in tension (ϕN_t) of the angle section?**

Remember to include units.

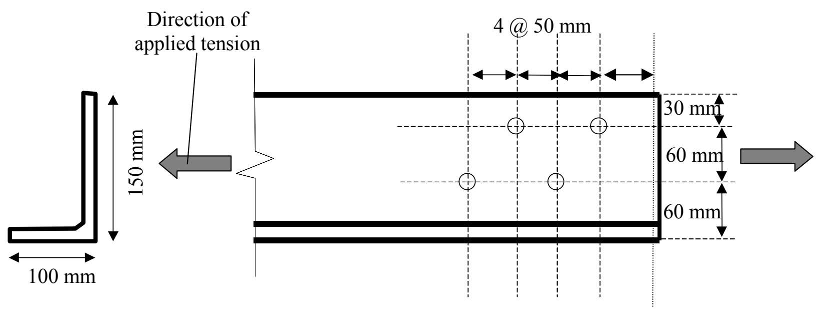

Figure 1: Bolt hole pattern in 150 × 100 × 12 UA Grade 300

Q 2 Bending (20 Marks)

a) **Explain briefly the meaning of the term "full lateral restraint", and what implications it has for the design of a beam to AS 4100.**

It may be appropriate to write some relevant equations in your response, but there is no need to perform any calculations.

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b) A simply supported beam of length L = 7 m is constructed from an 800WB122 section in Grade 300 steel, and is subjected to a uniformly distributed design load of w^* = 35 kN/m, 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.

ii) Figure 3 indicates that the web of the beam is in the vertical plane. **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 whether the beam is adequate 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 BHP product literature.

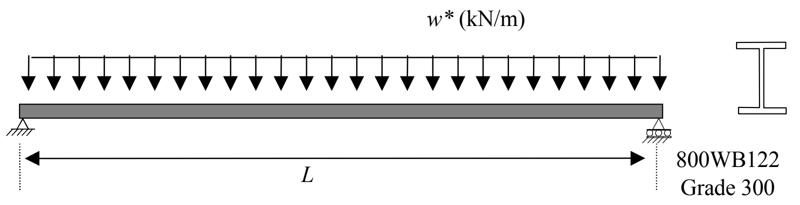

Figure 2: Simply Supported Beam Under Uniformly Distributed Load

Q3 Compression Members (20 Marks)

a) **Briefly explain the different behaviour of stub columns with form factor, $k_f < 1.0$ and $k_f = 1.0$ under axial compression.** A graph showing the axial load vs axial shortening of two specimens would assist the explanation greatly. Your experience in the "stub column" practical may be of assistance.

No calculations need to be performed in answering this question.

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b) An engineer is considering the behaviour of a truss that supports a roof under wind uplift loading conditions. The truss is shown in Figure 3. Fly bracing at every second panel point on the bottom chord of the truss prevents out-of-plane deflections. Out-of-plane deflections are also prevented at the end supports of the truss. The chords of the truss are constructed from Grade C450 cold-formed rectangular hollow sections (RHS), 150 × 50 × 2.5 C450 RHS. The *longer* face of the RHS is horizontal. At the middle of the truss, the design axial compression in the bottom chord of the truss is N^* = 200 kN.

i) **What is the effective length for *in-plane* buckling of the bottom chord?** For this orientation of the truss, **does in-plane buckling refer to major (x) axis or minor (y)axis buckling of the bottom chord?**

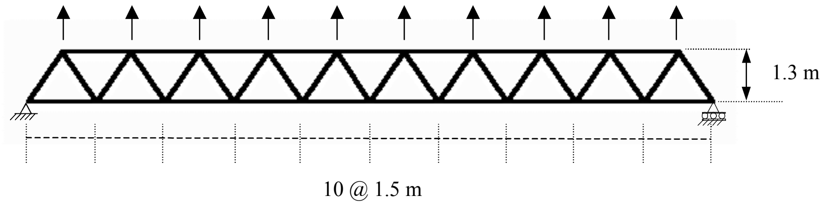
ii) **What is the effective length for *out-of-plane* buckling of the bottom chord?** For this orientation of the truss, **does out-of-plane buckling refer to major (x) axis or minor (y) axis buckling of the bottom chord?**

iii) **Determine the design member capacity in compression (ϕN_c) of the bottom chord, and hence state whether the bottom chord is adequate for the design axial compression.**

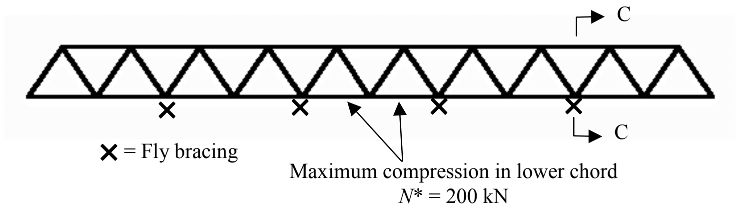
Clearly identify the values of all appropriate variables calculated and include the relevant units.

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

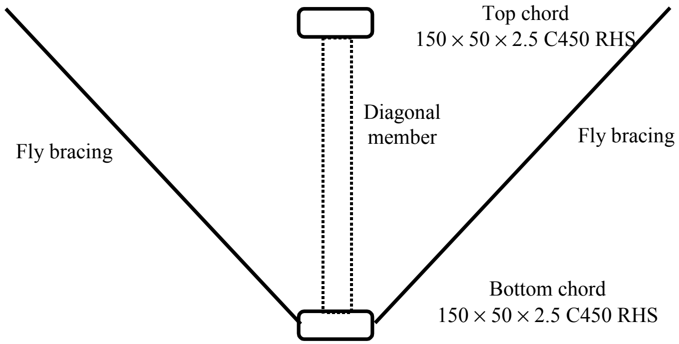
The diagram is on the next page.



(a) Truss Layout and Loading



(b) Location of fly bracing and analysis results



(c) Section C-C

Figure 3: Details of Roof Truss

Q4 Combined actions (30 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.

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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 connections between the beam and the column at B and C are rigid connections. The supports at A and D 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.

The columns are 310UB40.4 Grade 300 sections and are 5.0 m high, and the beam is a 410UB53.7 Grade 300 section and is 9.0 m in length.

The frame is subjected to a uniformly distributed load, and three point loads, as indicated in Figure 4(a).

Each member of the frame is braced so that no out-of-plane deflections can occur in the frame. Hence out-of-plane buckling may be ignored.

The values of bending moment in Figure 4(b) are given at the quarter points of each member.

The magnitude of the axial compression in the beam can be considered negligible.

The diagram and questions are on the next page.

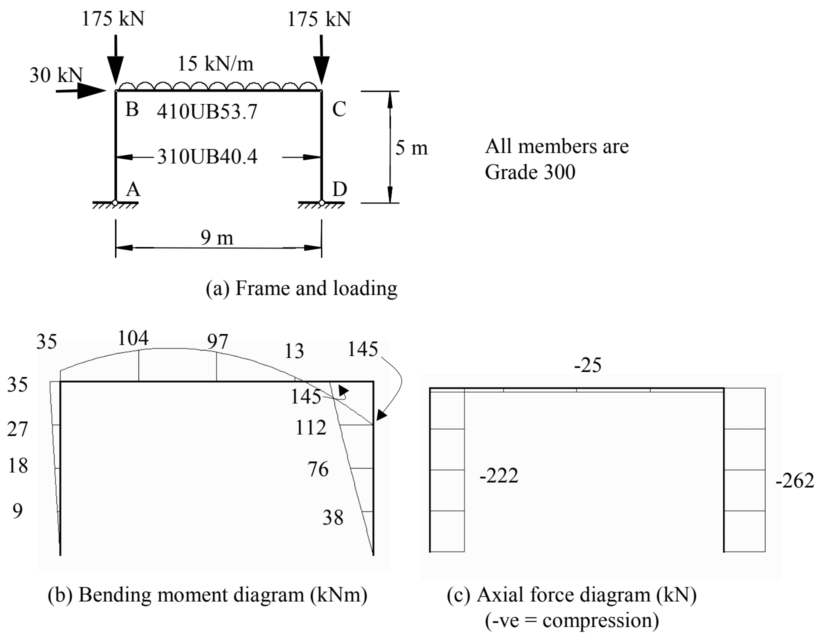

Figure 4: Dimensions, Loading and Design Action Effects for the Frame

i) **Are the columns AB and CD braced or sway columns?**

ii) **Determine the effective length of the column CD for in-plane buckling.** By symmetry the effective length of AB is the same as the effective length of CD.

iii) **What are the design actions, M_x* and N*, that apply to the design of column CD?**

iv) **Determine the section capacity (φM_{rx}) of the column CD for in-plane bending according to Clause 8.3.2 of AS 4100.**

v) **Determine the in-plane member capacity (φM_{ix}) of the column CD according to Clause 8.4.2.2 of AS 4100.**

vi) **Hence establish whether column CD is adequate according to the design rules of AS 4100.**

Clearly indicate the values and units of all appropriate capacities used in any intermediate calculations.

The values of Z_{ex} and k_f may be taken from the BHP product literature if necessary.

Q5 Connections (15 Marks)

a) **Briefly explain two methods of guaranteeing the specified pre-tension in a fully-tensioned high-strength bolt.**

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b) Two 150UC23.4 sections, Grade 300 to AS 3679, are connected with splice plates connected to the top and bottom flanges of each section, as shown in Figure 5. Each splice plate is Grade 300 to AS 3678, and is 120 mm wide and 16 mm thick. The splice plates are welded to the flanges of the UC section with longitudinal fillet welds. The fillet welds are SP Grade, made from E48XX electrode, and each weld has equal leg lengths of 6 mm. Each weld is 250 mm long, and eight (8) individual fillet welds are used to construct the splice connection. The UC sections are subject to a design axial tension N*.

It is not necessary to calculate the section capacity in tension (φN_t) of either the UC or the splice plates. For the UC section φN_t = 853 kN, and for each of the splice plates φN_t = 518 kN.

i) **What is the value of the capacity factor (φ) that applies to the design of the fillet weld? What is the design shear capacity per unit length (φv_w) of the weld?**

ii) **List the various failure modes that should be considered when calculating the design capacity of this connection.**

iii) **What is the maximum design tension (N*) to which the connection can be subjected? What is the controlling limit state for the connections?**

Remember to include units.

The diagram is on the next page.

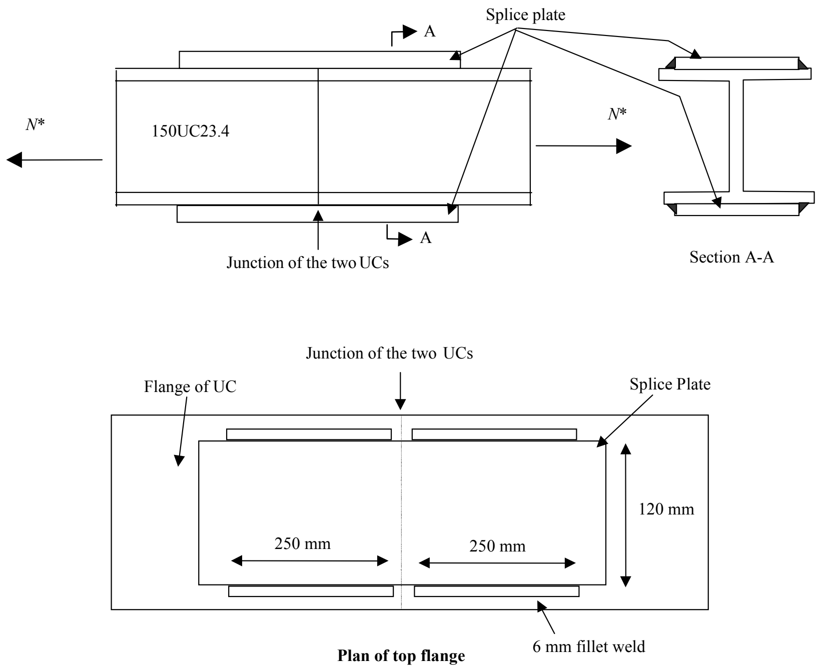

Figure 5: Welded UC Tension Splice

This is the end of the examination paper.