The University of Sydney

CIVL3206 Steel Structures 1

Department of Civil Engineering

Semester 2, 2004

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 this unit of study.

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

Q 1 Tension Members (20 marks)

A member is subjected to tensile loads only with a maximum load of 900 kN. It has been proposed that a Grade 350 150 × 150 × 19 EA be used.

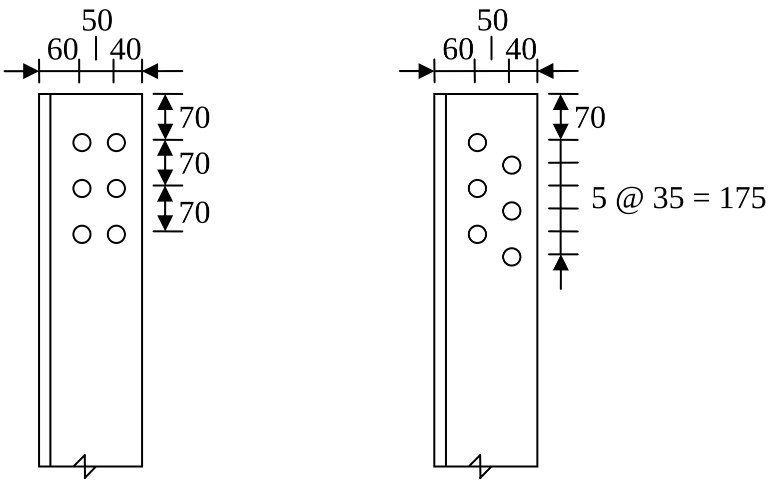
a) Two bolt configurations have been proposed for connection of this member. **Which is the better choice in terms of the member design tensile capacity (ϕN_t)?** Explain your answer. No calculations are required at this stage.

b) **What is the design tensile capacity (ϕN_t)** of the Grade 350 150 × 150 × 19 EA with the connection configuration selected in part (a)? Include diagrams of possible fracture patterns. **Is the member adequate?** Bolt holes are 22 mm in diameter.

c) For the given design load (900 kN) **what size Grade 350 EA would you have chosen** if you were the engineer? (Assume $A_n = 0.85\ A_g$). Justification (including any necessary calculations) of your choice is required.

Clearly identify the values of all appropriate variables calculated and include the relevant units.
Property tables may be used.

- All dimensions are in mm.
- Dimensions to bolt holes are to the centre of the hole.
- All bolt holes are 22 mm in diameter.
- The EA is connected by one leg only in both configurations.



(a) Bolt configuration 1 **(b) Bolt configuration 2**

Figure 1 Proposed bolt configurations

Q 2 Compression (20 Marks)

a) The 200UC59.5 and the 410UB59.7 have nearly the same cross-sectional area. **How do their behaviours under compression loads vary? Which makes a better compression member and why?** (Assume both sections are Grade 300).

b) A frame consists of six Grade 300 200UC59.5 columns, four Grade 300 410UB59.7 and three Grade 300 310UB32.0 as shown in Figure 2. The beams in the east-west direction are connected to the columns by rigid connections. The beams in the north-south direction are connected to the columns by flexible connections. All beams are oriented so that their webs are in the vertical plane. The frame is cross-braced in the north-south direction as shown in Section B-B. The height of each storey is 3 metres and the columns are supported on rigid base plates.

i) Consider buckling in the **east-west** plane of column C1 in the bottom storey.

- **Is column C1 braced or sway in this plane?**
- **Does this refer to major (x) axis or minor (y) axis buckling?**
- **What is the effective length for buckling in compression?**

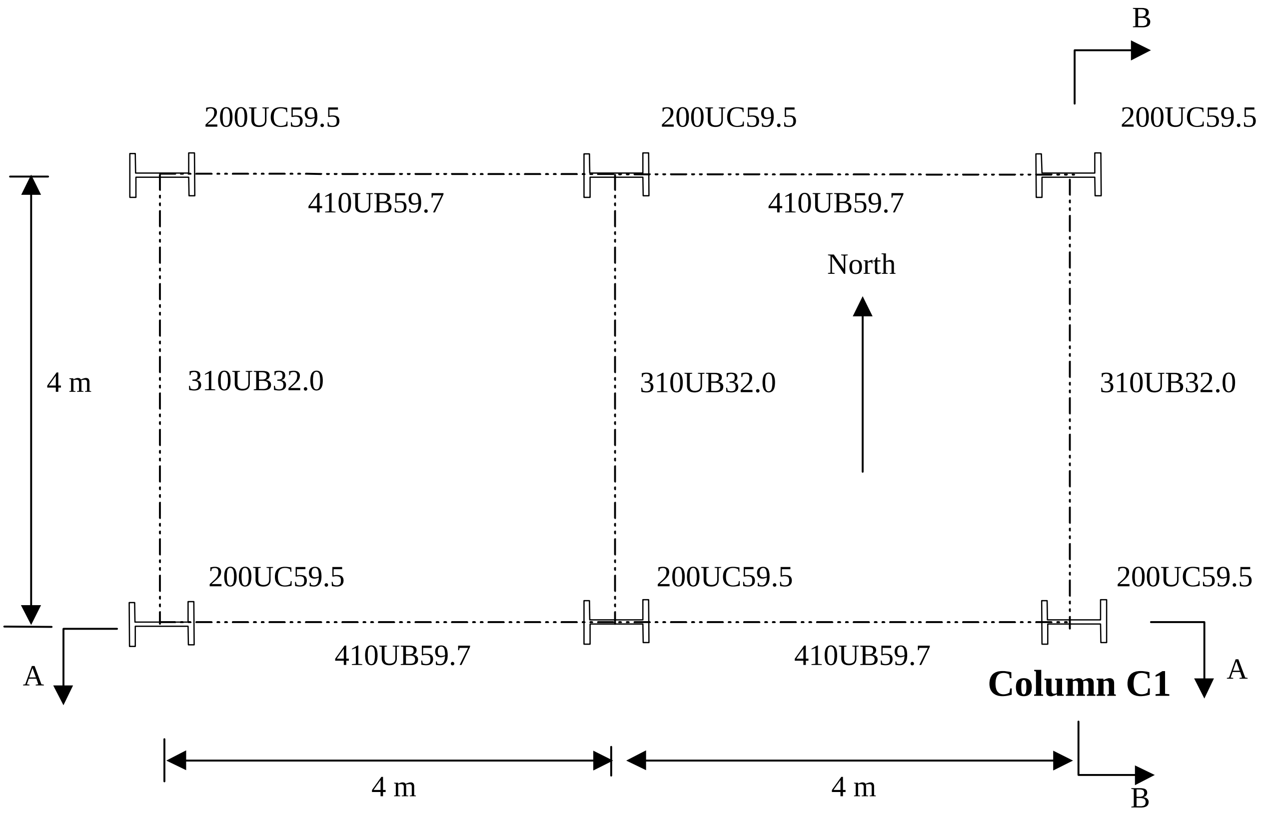
ii) Consider buckling in the **north-south** plane of column C1 in the bottom storey.

- **Is column C1 braced or sway in this plane?**
- **Does this refer to major (x) axis or minor (y) axis buckling?**
- **What is the effective length for buckling in compression?**

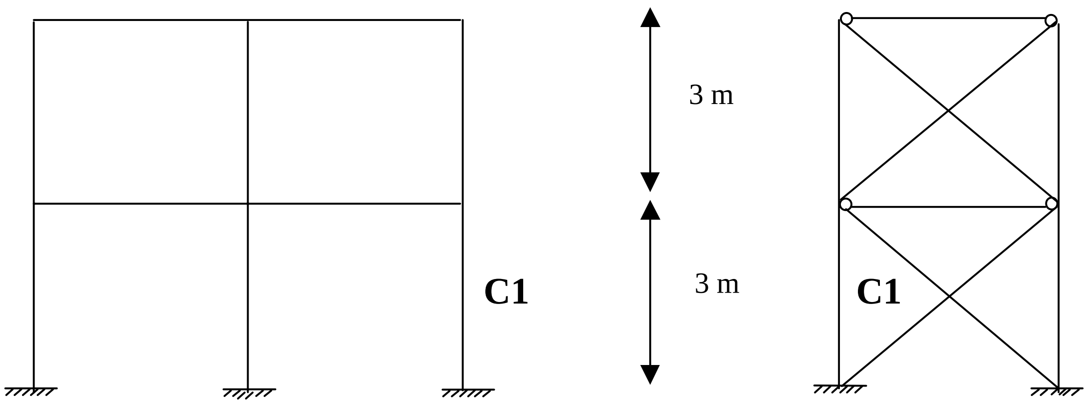
iii) Determine the design member capacity in compression (ϕN_c) of column C1.

Clearly identify the values of all appropriate variables calculated and include the relevant units.
Property tables may be used.

Figure 2 is on the next page.



(a) Plan of columns and beams



Section A-A
East-West Elevation
Beam to column connections are **rigid**

Section B-B
North-South Elevation
Beam to column
connections are **flexible**

(b) Elevations

<u>**Figure 2 Steel frame configuration**</u>

Q3 Bending (20 Marks)

a) The 200UC59.5 and the 410UB59.7 have nearly the same cross-sectional area. **Which makes a better member for major (x) axis bending and why?**

b) As shown in Figure 3, a 10 m long Grade 300 410UB59.7 is simply supported and is subjected to a point load, P^*, at midspan which causes bending about the major (x) axis. The load is applied to the top flange.

i) **Draw the bending moment diagram** including the maximum value of moment in terms of P^* and state whether the diagram is on the tension or compression side.

ii) **Which is the critical flange and why?**

iii) The beam has full restraint at the supports and at midspan (as shown on the diagram by ✕). No lateral rotation restraint is provided. **Calculate the effective length in bending, l_e, and the design section and member moment capacities (ϕM_s and ϕM_b).** (All calculated values should refer to major (x) axis bending).

iv) **What is the maximum P^*** that this beam can support?

Clearly identify the values of all appropriate variables calculated and include the relevant units.
Property tables may be used.

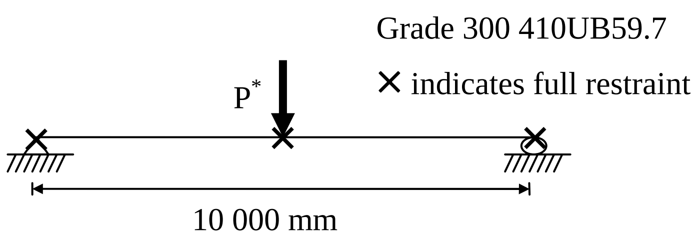


Figure 3 Beam loading diagram

Q4 Combined actions (20 Marks)

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

It may be appropriate to 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-to-column connections are rigid, while the column-to-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.

Both columns are braced by a lateral and torsional restraint at their ends and midpoint so that the beam effective length (l_e) and the out-of-plane column effective length (l_{ey}) are both equal to half the member length ($l_e = l_{ey} = 0.5l$). Also, from analysis of the frame, it has been determined that the in-plane effective length factor (k_{ex}) is equal to 1.9 for both column AB and column CD.

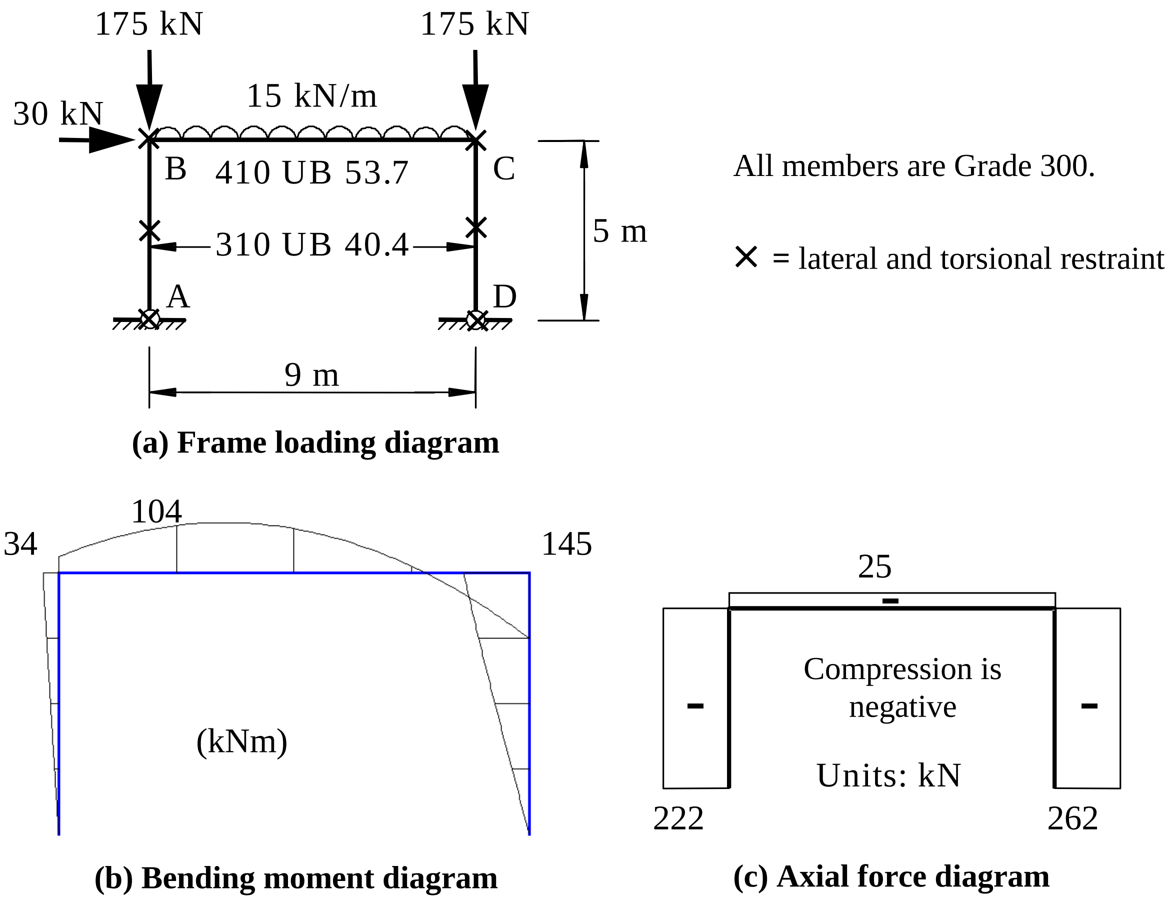
i) Since both columns have full restraint at both ends and at midheight, an engineer should consider two segments in each column – the upper segment and the lower segment. **Which column segment is the most heavily loaded as a beam-column?** (AB upper, AB lower, CD upper or CD lower).

ii) According to AS 4100, what requirements need to be satisfied in designing the critical beam-column segment?

iii) Taking N_s = 1587 kN, N_{cx} = 1066 kN, M_{sx} = 202.6 kN.m and α_s = 0.776, **determine whether the requirements of AS 4100 have been satisfied for the critical beam-column.** (Other capacities may need to be calculated before these requirements can be checked). If the requirements have not been satisfied, **what type of failure is expected?**

Clearly identify the values of all appropriate variables calculated and include the relevant units.
Property tables may be used.

Figure 4 is on the next page.



(a) Frame loading diagram

(b) Bending moment diagram

(c) Axial force diagram

Figure 4 Frame loading and analysis results

Q5 Connections (20 Marks)

a) Briefly describe the two different bearing failures that may occur in bolted connections. Diagrams may be useful.

b) A Grade 8.8 M16 bolt experiences both tension and shear (through the threaded cross-section). The bolt experiences a design tensile force of N^*_{tf} = 100 kN. **What is the maximum design shear force (V^*_f) that 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 60 mm. Grade 8.8 snug tight M16 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 or the gusset plate. For the angle section ϕN_t = 1750 kN). **What is the critical failure mode of the connection?**

d) If a 12 mm structural purpose fillet weld with a throat thickness (t_t) of 8.49 mm was to be used instead of the bolts, **what would be the total weld length required to achieve a design capacity of 1000 kN for this connection?** Assume the weld electrode being used has f_{uw} = 410 MPa.

The following properties of an M16 bolt may be useful.

Core area, A_c = 144 mm^2.
Shank area, A_o = 201 mm^2.
Tensile stress area, A_s = 157 mm^2
Diameter of the hole, d_h = 18 mm

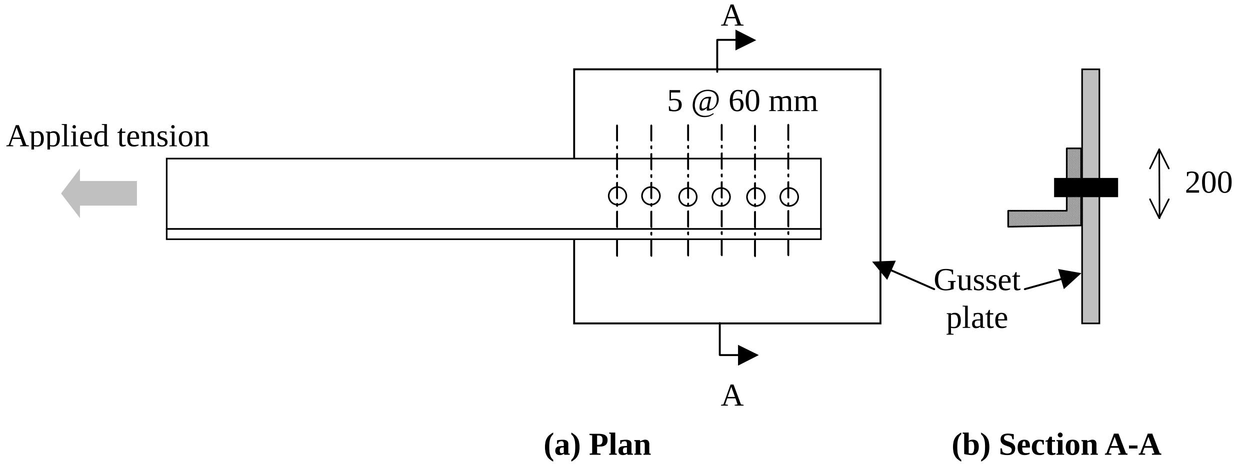


Figure 5 Connection configuration

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