The University of Sydney
Department of Civil Engineering

CIVL3206 Steel Structures 1

Semester 2, 2001

Time Allowed: 3 hours

Instructions to Candidates

1) All questions should be attempted.
2) Suitable working, diagrams and explanations are required for each question.
3) Marks may be deducted for work that is not satisfactorily set out.
4) **Units are important and answers with incorrect units will not be awarded full marks.**
5) Programmable and non-programmable calculators may be used.
6) Read the questions carefully before answering.
7) **Annotated copies of AS 4100 (or the student edition HB2.2) may be taken into the exam, but no other written material is permitted.**
8) Students are reminded that satisfactory exam performance is an essential criterion in this course, and a mark of 40 % in the exam is required.
9) The exam is worth 55 % of the final assessment.
10) **This paper contains 5 questions: Tension (15 %), Bending (20 %), Compression (20 %), Combined Actions (25 %), Connections (20 %).**

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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 single 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.

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.

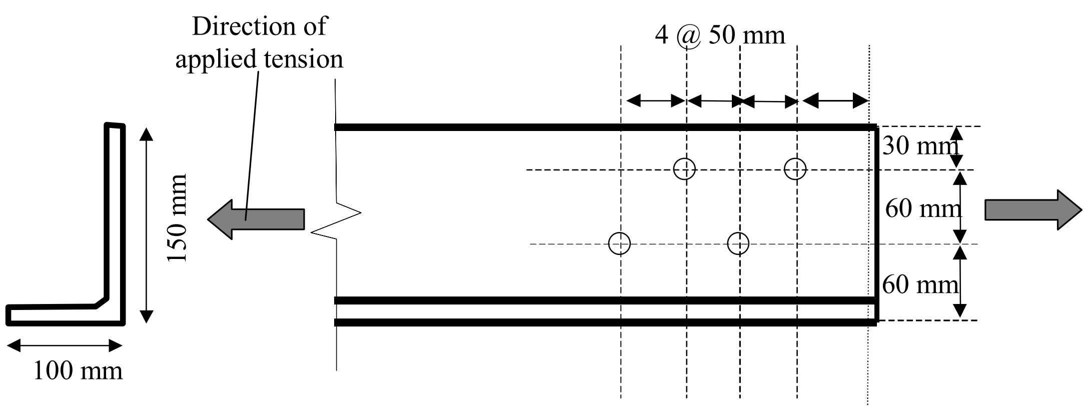


Figure 1: Bolt hole pattern in 150 × 100 × 12 UA Grade 300

Q 2 Bending (20 Marks)

a) **Explain the different types of behaviour of beam sections – compact, non-compact or slender.** Use of a moment vs curvature graph showing the behaviour would greatly assist the answer.

b) A rectangular portal frame, constructed from 250UB37.3 members in Grade 300 steel, has a height of 4 metres and a span of L = 8 metres as shown in Figure 2 below. The webs of the members are oriented so that they lie within the plane of the frame. Figure 2 also xhows the of the frame for a uniformly distributed load w acting downwards on the rafter.

Purlins at regular spacing connect the roof sheeting to the rafter and at each purlin location there is fly bracing to the bottom flange of the rafter. This arrangement can be considered to provide a full restraint to both flanges of the rafter. The rafter also has full restraint at the column-rafter connection.

i) The engineer wishes to place the purlins at close enough intervals to ensure that lateral buckling of the rafter does not occur. **Use Clause 5.3.2.4 of AS 4100 to determine the maximum purlin spacing** required to ensure that the member moment capacity of the rafter may be taken as equal to the section moment capacity.

ii) **Determine the section capacities for x-axis bending (φM_{sx}) and shear (φV_v) of the 250UB37.3.**

iii) **Determine φV_{vm} and hence check the adequacy of the rafter at the connection to the column for shear and bending interaction in accordance with Clause 5.12.3 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.

The diagram is on the next page.

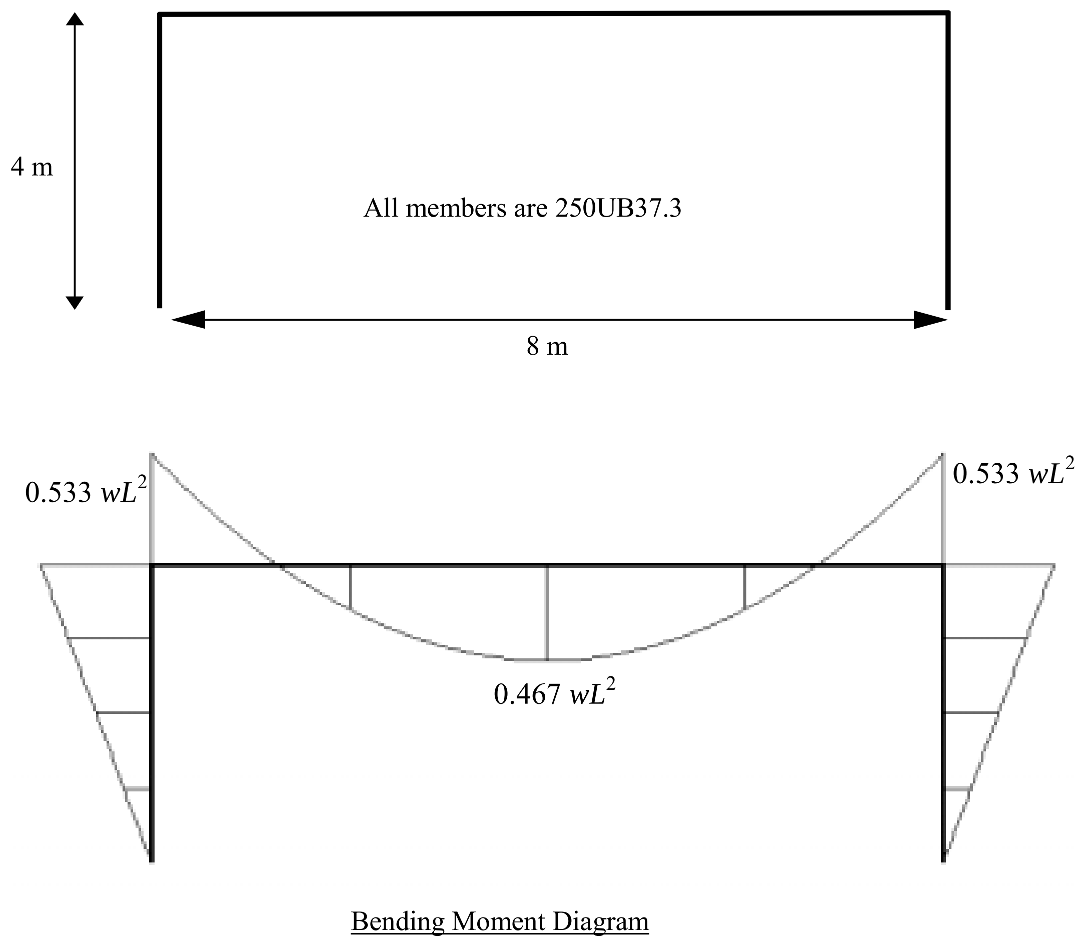


Figure 2: Portal Frame Under UDL *w* on the Rafter

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. Knowledge of the "stub column" practical may be of assistance.

No calculations need to be performed in answering this question.

b) A frame consisting of six 310UC96.8 Grade 300 columns is shown in Figure 3 and is supported by beams as also shown in Figure 3. The beams in the east-west direction are 250UB25.7 in Grade 300 steel and are not rigidly connected to the columns. The beams in the north-south direction are 360UB44.7 in Grade 300 steel and are rigidly connected to the columns. All beams are oriented so that their webs are in the vertical plane. The frame is cross-braced in the east-west direction as shown in Section A-A.

The height of the each storey is 3 metres, and the columns are located on a (pinned) base plate attached to a concrete floor.

i) Consider buckling in the ***east-west*** plane of column C1 in the bottom storey.
- **Is column C1 braced or sway in this plane?**
- **What is the effective length for buckling in compression?**
- **Does this refer to major (x) axis or minor (y) axis buckling?**

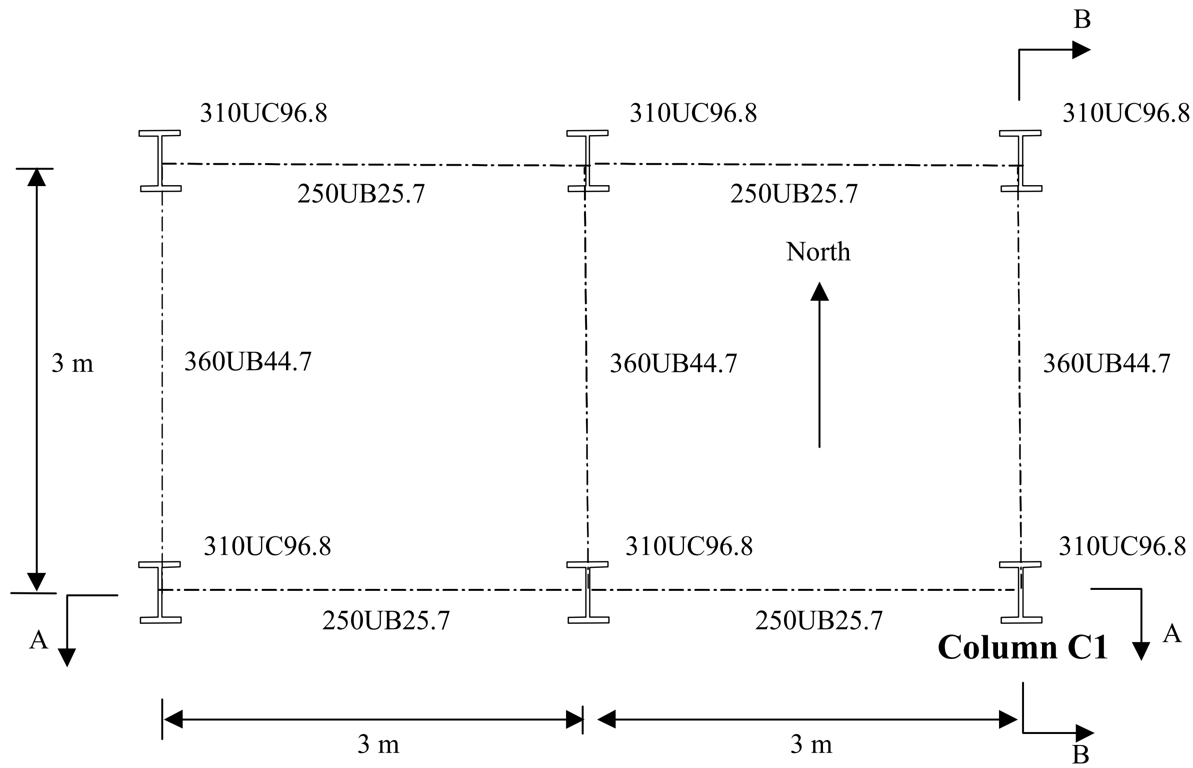
ii) Consider buckling in the ***north-south*** plane of column C1 in the bottom storey.
- **Is column C1 braced or sway in this plane?**
- **What is the effective length for buckling in compression?**
- **Does this refer to major (x) axis or minor (y) axis buckling?**

iii) **Hence determine the design member capacity in compression (φN_c) of column C1.**

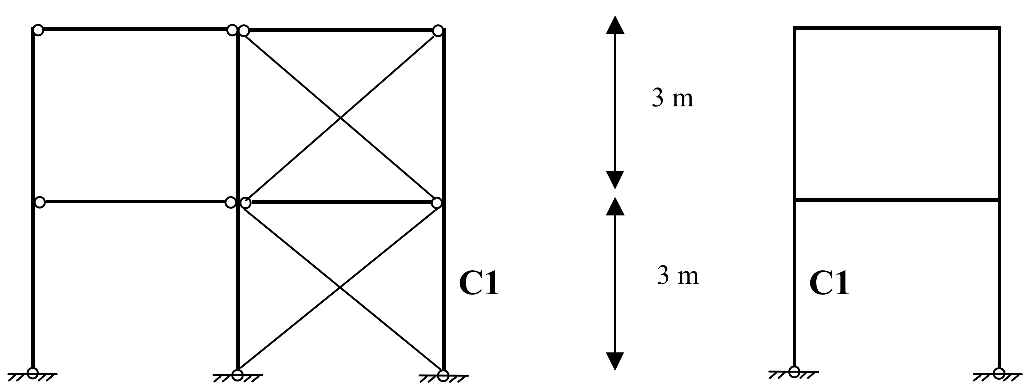
Clearly identify the values of all appropriate variables calculated and include the relevant units.

If required, the values of Z_{ex}, Z_{ey} and k_f may be taken from the OneSteel product literature which is included in this exam paper.

The diagram is on the next page.



Plan of columns and beams



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

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

Elevations

Figure 3: Plan and Elevation of Two-Storey Frame

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) The rigid jointed pitched roof portal frame shown in Figure 4 is subjected to a distributed load along the rafters of w = 10 kN/m as shown. Both flanges of the rafters have full restraint against lateral buckling at the ends and mid-point as shown by the crosses in Figure 4(a). The distributed load can be assumed to act on the top flange. The members are not restrained against lateral rotation.

The rafters of the frame are constructed from 610UB125 sections in Grade 300 steel, and the columns are 200UC52.2 sections in Grade 300 steel.

The **second order** bending moment distribution (M^*) in the rafter is shown in Figure 4(b) and the second order axial force distribution (N^*) in the rafter is shown in Figure 4(c). The bending moment is drawn on the compression flange of the section.

Check the out-of-plane member capacity of the rafter according to Clause 8.4.4.1 of AS 4100.

The in-plane member capacity according to Clause 8.4.2.2, and the section capacity according to Clause 8.3.2 does not need to be checked.

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

If required, the values of Z_{ex}, Z_{ey} and k_f may be taken from the OneSteel product literature which is included in this exam paper.

The diagram is on the next page.

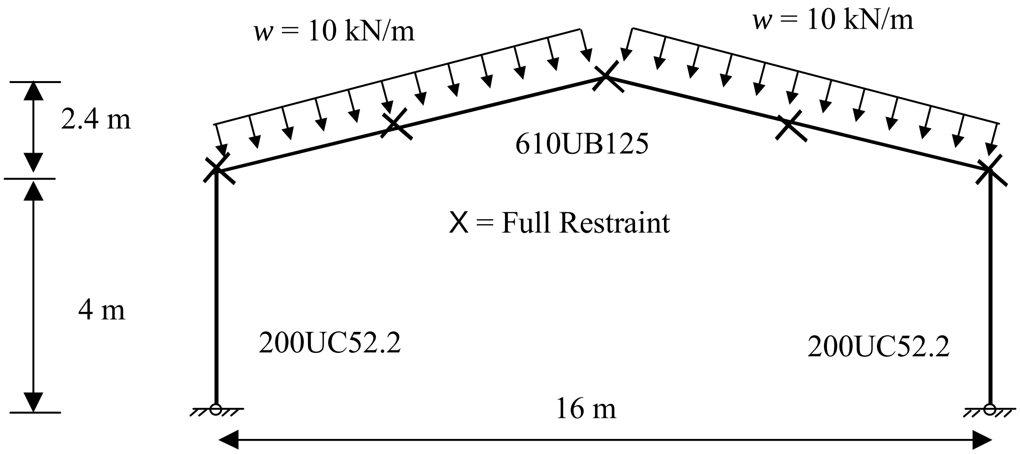


Figure 4(a): Frame Dimensions, Restraints and Loads

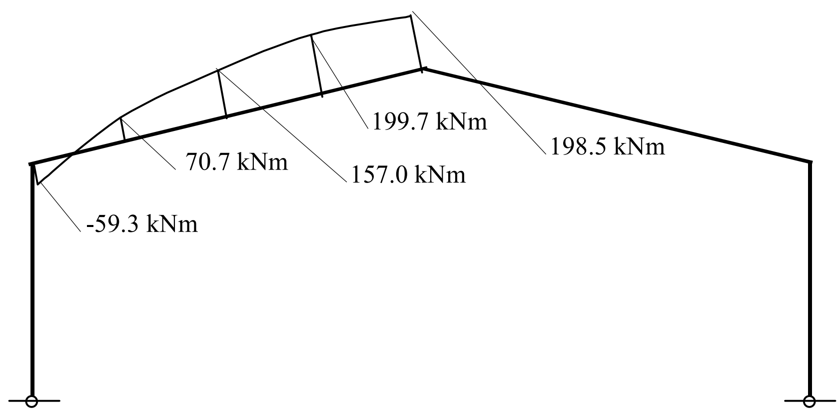


Figure 4(b): Second-order BMD for Rafter

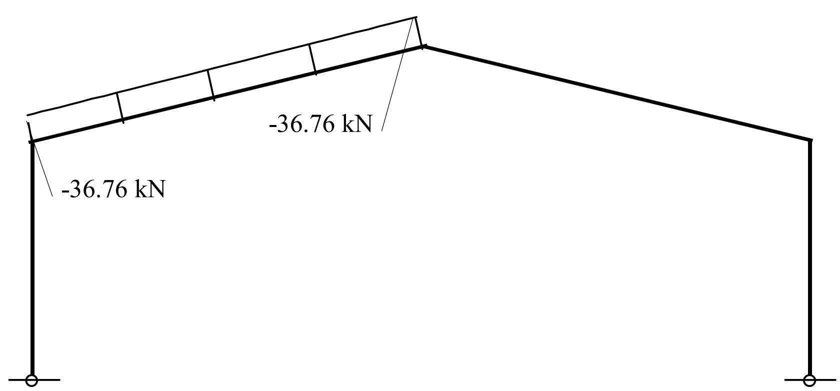


Figure 4(c): Axial Force in Rafter

Q5 Connections (20 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.

(b) Two 150UC30.0 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(a). There are 2 lines and 4 rows of bolts on each flange on each side of the splice. Grade 4.6 snug tight M20 bolts are used in this connection, and the plane between the splice plate and the flange of the UC section coincides with the *threaded* part of the bolt. Each splice plate is Grade 300 to AS 3678, and is 120 mm wide and 16 mm thick

(i) **What is the ultimate strength (f_{uf}) of the Grade 4.6 bolt?**

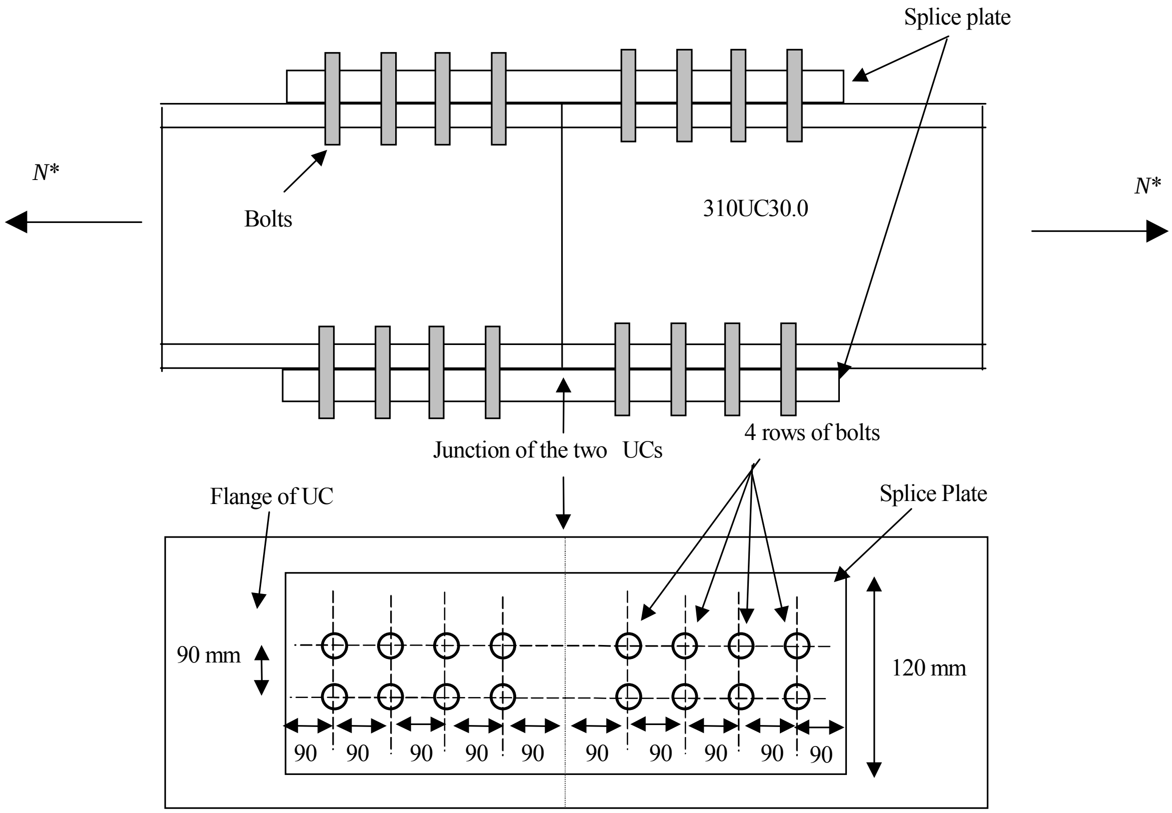
(ii) **List the various failure modes that should be considered when calculating the design capacity of this connection.**

(iii) **What is the design capacity of the connection?** (Students are *not* required to calculate the section capacity in tension of either the UC or the splice plates. For the UC section ϕN_t = 868 kN, and for each of the splice plates ϕN_t = 400 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

The diagram is on the next page.



(a) Plan

Figure 5

(All dimensions in mm)

This is the end of the questions in this examination paper.

THE NEXT 7 PAGES SHOULD CONTAIN ONESTEEL PRODUCT INFORMATION ON UBs, UCs, and UAs.