The University of Sydney

CIVL3206 Steel Structures 1

School of Civil Engineering

Semester 2, 2007

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).

(h) Each question has an "explanation type" section. These should be answered in about ½ page of text plus diagrams. Directly quoting text from AS 4100 or the lecture notes is not considered an appropriate response.

(i) If required, any relevant values should be taken from the OneSteel product tables, which are given as a separate set of data sheets.

Q 1 Tension Members (15 marks)

a) The connection correction factor k_t for tension accounts for non-uniform force distribution, which can be caused by issues such as eccentric connections, and shear lag. For an I-section splice, connected by the flanges only (AS 4100 Clause 7.3.2(b)), k_t = 0.85, yet typically the flanges represent about 60% of the area of an I-section. **Use this information to explain the phenomenon of "shear lag" with respect to tension capacity of a member at a connection.**

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 195 kN. The member will not experience compressive loads. The engineer has not yet designed the connections but assumes that 12.5 % 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 should know they should draw a diagram.

Q2 Compression Members (25 Marks)

a) **Explain what the different terms α_b and α_c account for when determining the compression capacity of a column.**

b) Consider the frame shown in Figure 2. All columns are 200UC46.2 and all beams are 250UB25.7 in Grade 300 steel. The columns are 4 m apart in the north-south and 3.3 m apart in the east-west directions and each storey is 3.5 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 $N^*_{Col\ 1}$ = 500 kN?

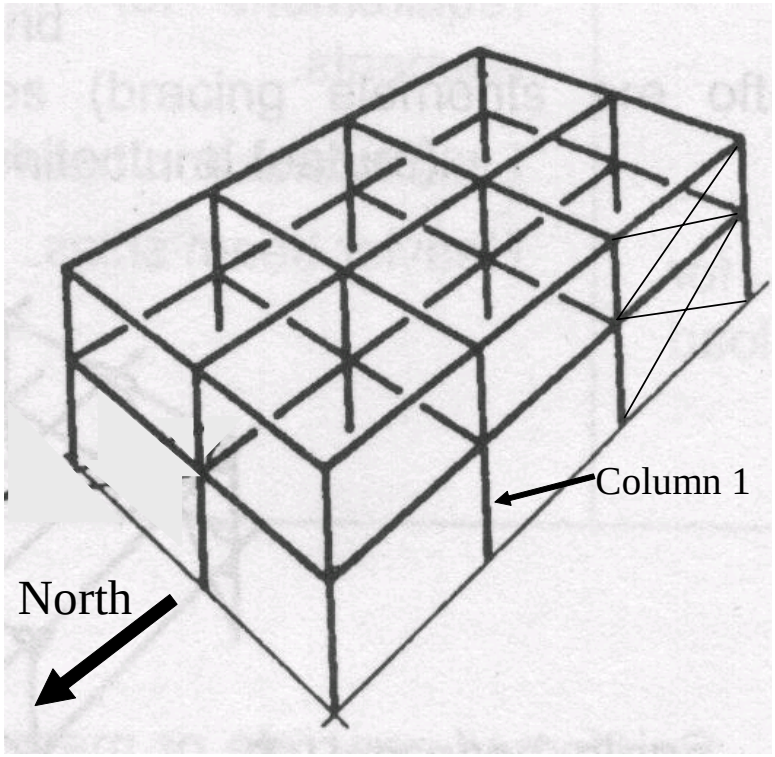
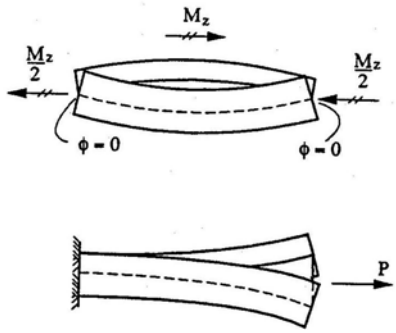


Figure 2

Q 3 Bending (25 Marks)

a) When calculating the member capacity of a beam, it is necessary to calculate the flexural torsional buckling moment, which includes the term I_w, the warping torsion constant. For an I section, $I_w = I_y d^2/4$, whereas for a hollow section $I_w = 0$.



Use the diagram to the right to explain why $I_w = I_y d^2/4$ for an I-section, and why $I_w = 0$ for a hollow section. A strict mathematical derivation is not expected.

b) A rectangular portal frame, constructed from 250UB31.4 members in Grade 300 steel, has a height of 4 metres and a span of L = 8 metres as shown in Figure 3 below. The webs of the members are oriented so that they lie within the plane of the frame. Figure 3 also shows the BMD of the frame for a uniformly distributed load w acting downwards on the rafter.

The rafter has full restraint (F) at the column-rafter connection, but this connection does not provide any rotational restraint. After installation, purlins at regular spacing will 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 (F) to both flanges of the rafter at the points of attachment.

The engineer has been asked to evaluate the strength of the frame before and after installation of the purlins.

i) **Does the structural analysis program used to produce the BMD in Figure 3 draw the bending moments on the tension or compression side of members in bending?**

ii) **Determine the design section capacity for x-axis bending (ϕM_{sx}) of the 250UB31.4.**

iii) 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. **What is the maximum value of the downwards UDL w in this case? Would there be any difference to the answer if the UDL was upwards (eg due to wind uplift)? Briefly explain your answer.**

iv) **Explain briefly what different design aspects should be considered if evaluating the strength of the beam during the construction phase before the purlins and sheeting are installed.**

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

The diagram is on the next page.

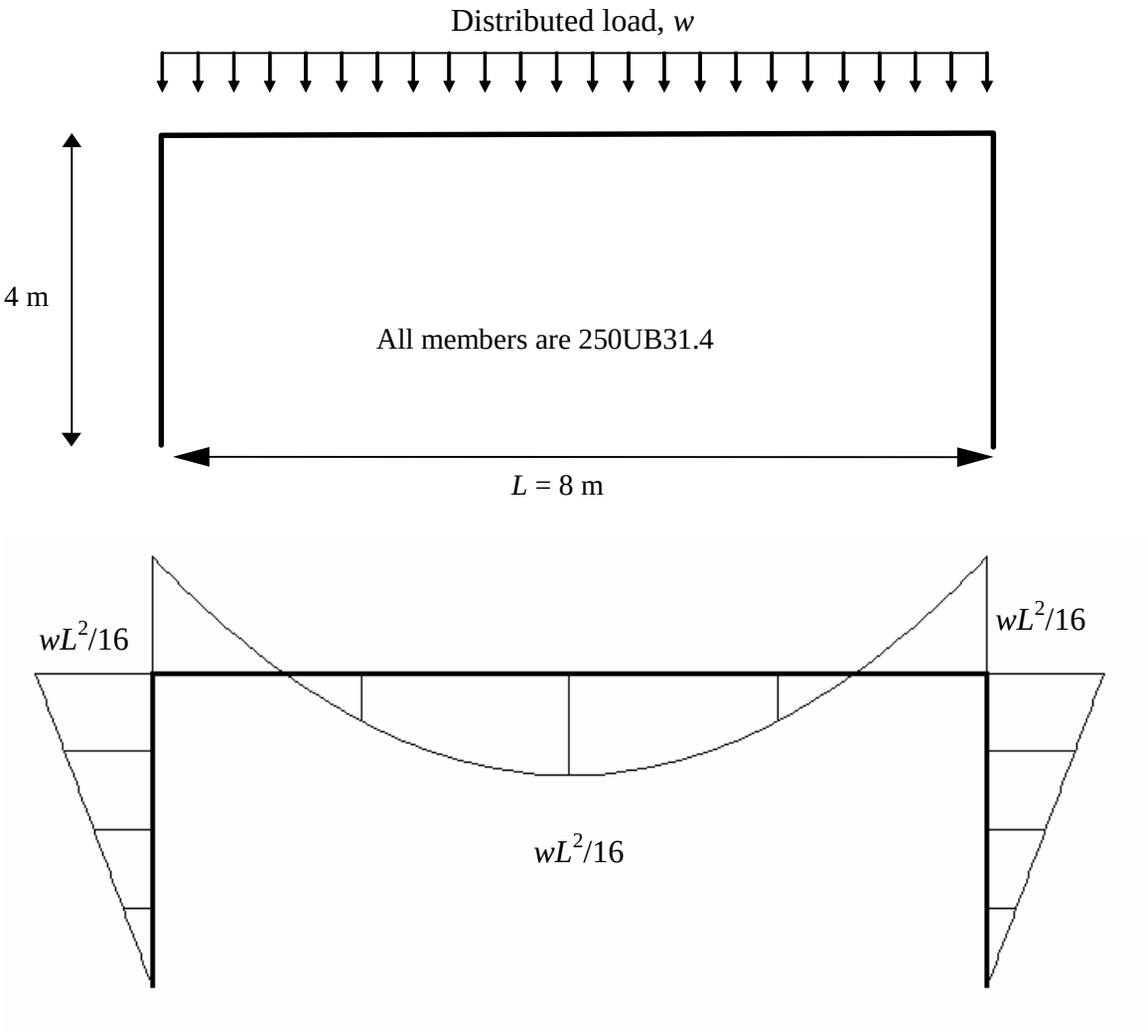


Figure 3: Portal Frame Under UDL *w* on the Rafter

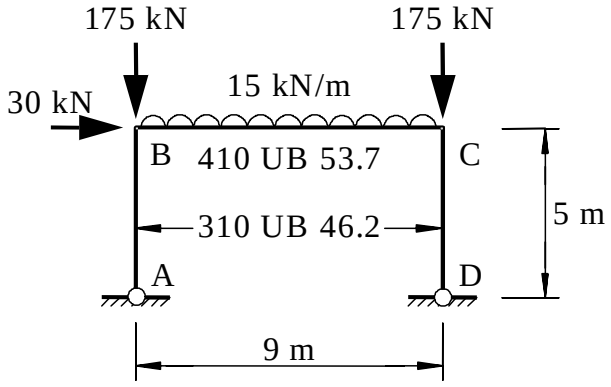
Q4 Combined actions (20 Marks)

a) Explain why it is generally more appropriate to use a UB section as the "column" of a typical low rise portal frame rather than a UC section.

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. An engineer has already assessed the effective lengths of the member CD for different types of buckling:

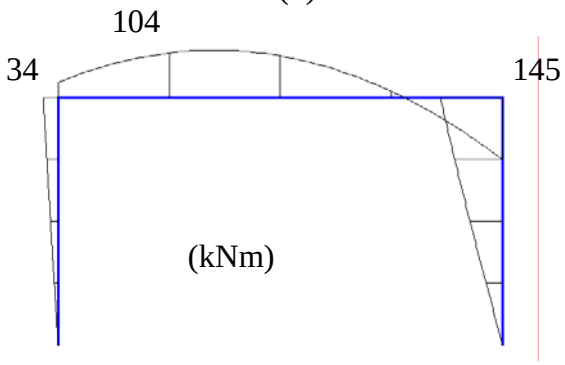
- In plane (flexural) compression buckling: 9.5 m
- Out of plane (flexural) compression buckling: 5.0 m
- Beam (flexural torsional) buckling: 1.25 m (there are 4 equally spaced segments along CD).
- There is no need for you to work out effective lengths.

Determine the combined action member strengths (ϕM_{rx}, ϕM_{ix}, ϕM_{ox}) of member CD and hence establish if the member is satisfactory.

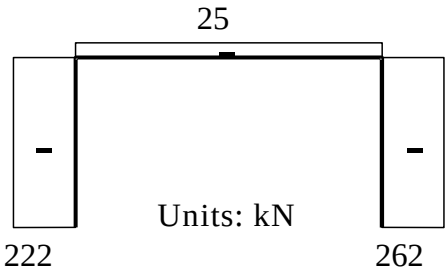


All members are Grade 300

(a)



(b) Bending moment d agram



(c) Axial force diagram

Figure 4

Q5 Connections (15 Marks)

(a) **Sketch a typical beam to column moment connection, and a typical beam to column pin connection** that might be used in a typical portal frame (hint: your design assignment). **What type of loads can these different connections transfer and relate these loads back to the specific components of the connection?**

(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?**

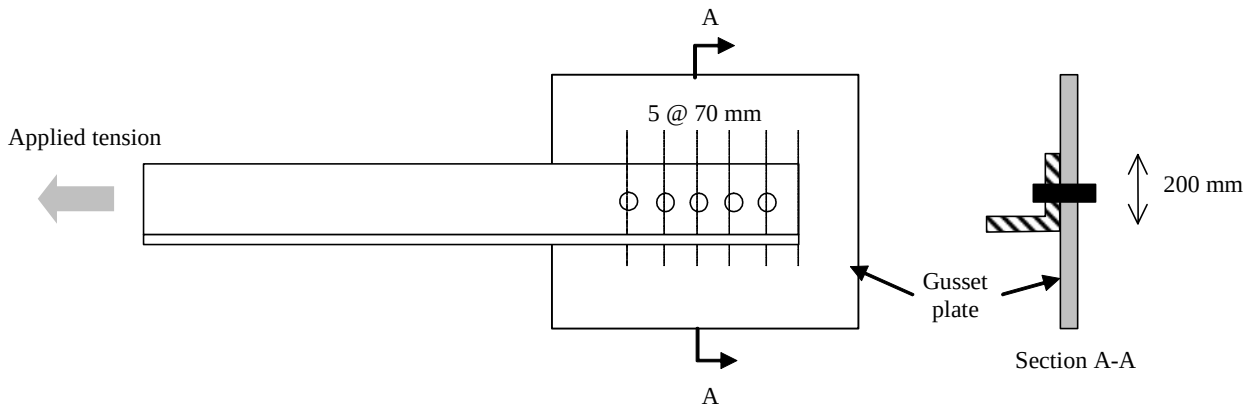
(c) An engineer is assessing the tensile strength of a bracing connection in which a 200×200×20 EA (Grade 300) is bolted to a 25 mm thick gusset plate (Grade 300 to AS/NZS 3678) by 5 bolts as shown in Figure 5. The bolt pitch is 70 mm. Grade 8.8 snug tight M20 bolts are used in this connection, and the 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 = 1930 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. There should be a separate set of data sheets to accompany this exam.

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