THE UNIVERSITY OF SYDNEY

FACULTY OF ENGINEERING

SENIOR YEAR EXAMINATION

CIVL 3206 STEEL STRUCTURES 1

November 1998 Time Allowed: 3 hours

Programmable and non-programmable calculators may be used.

Annotated copies of the following documents may be taken into the exam:

> "Hot Rolled and Structural Steel Products - 1994 or 1998 Edition - BHP"
>
> "Australian Standards for Civil Engineering Students - Part 2 - Structural Engineering HB2.2 - 1991 or 1995"
>
> "Australian Standard - Steel Structures - AS 4100-1990"

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

Q1 (10 marks)

Q2 (20 marks)

Q3 (20 marks)

Q4 (25 marks)

Q5 (25 marks)

100 marks total

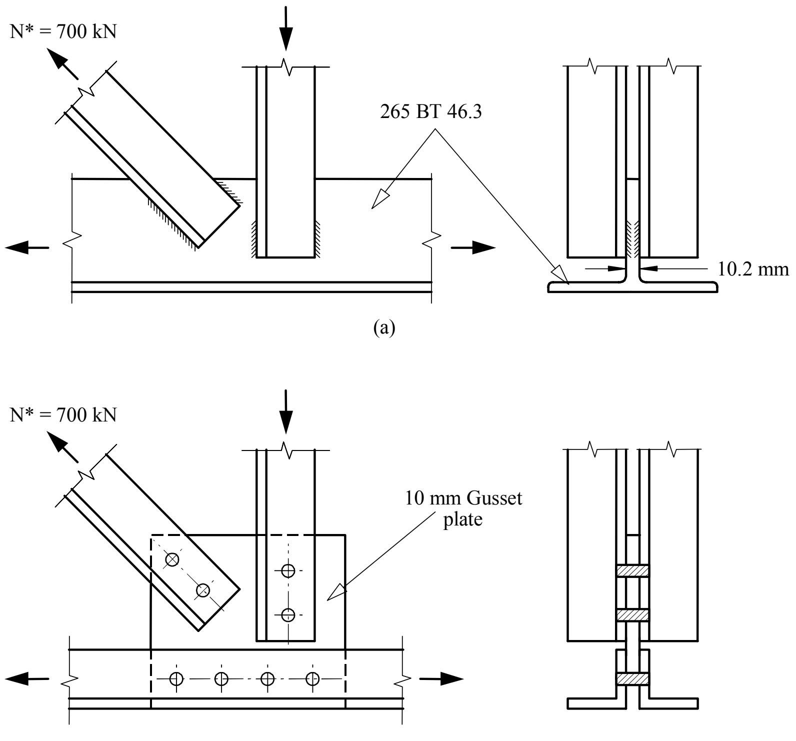
Q 1 Tension Members (10 marks)

The tension diagonal of an all welded Pratt roof truss in which the chords are made from (265BT46.3) cut from a Universal Beam (530UB92.4) is shown in Figure 1. The design load N* in the member under consideration is 700 kN. Assume that a pair of angles on either side of the chord carries the total design load.

(a) Determine a suitable angle size assuming welded connections as shown in Figure 1(a).

(b) Assuming a pair of 20 mm diameter bolt holes in line as shown in Figure 1(b) is used in place of the welds, check whether the angle size determined in part (a) is satisfactory.

You may use Grade 250 or Grade 300 steel depending upon which set of BHP Tables you are using. You are *not* required to design the connectors (welds and bolts) or the connection.



(a)

(b)

Figure 1. Truss connections

Q2 Compression Members (20 marks)

A novel floor system comprising a grillage of simply supported trusses and secondary beams is shown in Figure 2. The floor grillage is prevented from swaying in the horizontal plane.

The secondary beams which span perpendicularly in the horizontal plane between the top chord of the primary load carrying trusses are assumed to be a 75×50×4.0 rectangular hollow section (RHS) of Grade C350 steel, oriented such that the minor (*y*) axis is in the horizontal plane as shown in Section A-A. These secondary beams are connected rigidly to the top chord of the trusses. The top chord of the trusses is a 100×50×3.0 RHS of Grade C350 steel, oriented such that the minor (*y*) axis is in the horizontal plane as shown in Section B-B.

A typical interior truss is subjected to the factored design loads applied at panel points as shown in Figure 2(d).

(a) Using the method of sections or otherwise, calculate the maximum compression force (N^*) for which the top chord of the truss should be designed.

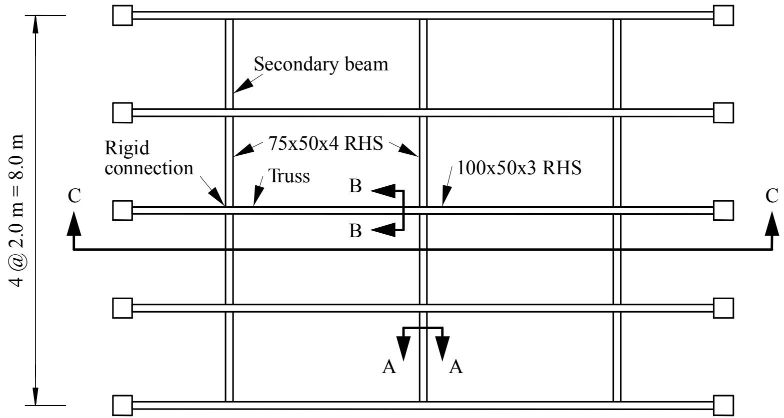
(b) Determine the design compressive strength (ϕN_c) of the top chord member for buckling in the plane of the truss.

(c) Determine the design compressive strength (ϕN_c) of the top chord member for buckling out of the plane of the truss.

(d) Hence deduce if the top chord of the truss is satisfactorily designed as an axially loaded compression member to AS 4100.

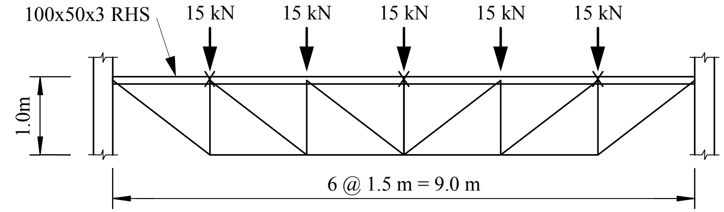
Data:

75×50×4.0 RHS, Grade C350	**100×50×3.0 RHS, Grade C350**
$f_y = 350$ MPa	$f_y = 350$ MPa
$A_g = 881$ mm^2	$A_g = 841$ mm^2
$I_x = 0.630\times10^6$ mm^4	$I_x = 1.06\times10^6$ mm^4
$r_x = 26.7$ mm	$r_x = 35.6$ mm
$I_y = 0.335\times10^6$ mm^4	$I_y = 0.361\times10^6$ mm^4
$r_y = 19.5$ mm	$r_y = 20.7$ mm
$k_f = 1.00$	$k_f = 1.00$



(a) Plan view

(b) Section A-A (c) Section B-B



╳ = Rigidly connected secondary beam

(d) Section C-C

Figure 2

Q3 Beams (20 marks)

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 Bending Moment Diagram (BMD) and Shear Force Diagram (SFD) are as shown in Figure 3.

(a) Assuming that the beam has full lateral restraint on the top flange, determine a suitable size based on bending section capacity.

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

(c) Use Clause 5.3.2.4 of AS 4100 to determine whether the beam is adequately braced in the end regions where hogging occurs and the bottom (unrestrained) flange is in compression.

(d) Determine the size of the beam based on lateral buckling considerations if the only restraint within the span is at the top flange at the centre.

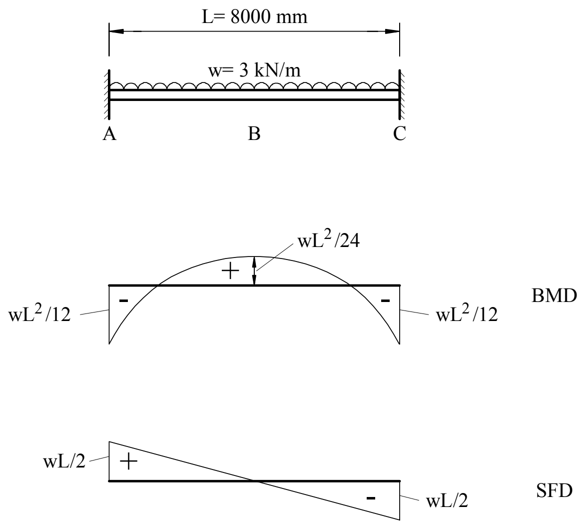


Figure 3

Q4 Beam-Columns (25 marks)

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 connection between the beam and the column at B is a flexible (pinned) connection, while that at C is a rigid connection. The support at A is fixed against translation and rotation and the support at D is pinned. The bending moment and axial force diagrams obtained by conducting a first-order elastic analysis of the frame are shown in Figures 4(b) and 4(c), respectively.

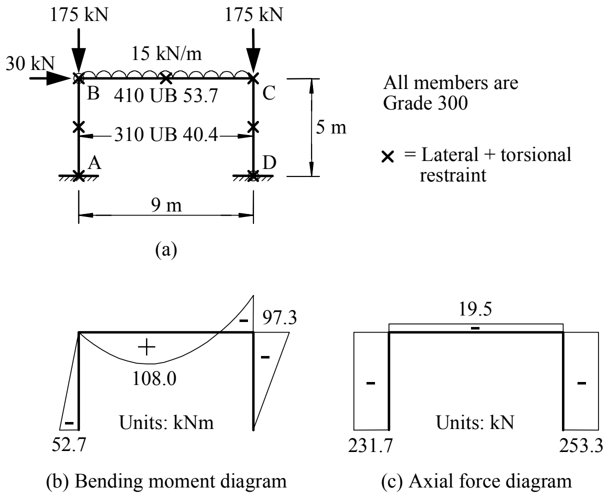
Each member of the frame is braced by a lateral and torsional restraint at its ends and midpoint so that the beam effective length (L_e) and out-of-plane column effective lengths (L_{ey}) of each segment is equal to half the actual member length ($L_e = L_{ey} = 0.5L$). The lateral and torsional restraints are indicated in Figure 4(a).

(a) Identify which of the columns (AB or CD) is more heavily loaded as a beam-column, and explain the reasons for your choice.

(b) For the more heavily loaded of the two columns (AB or CD), determine the in-plane member strength (ϕM_{ix}) as a beam-column to AS 4100.

(c) For the more heavily loaded of the two columns (AB or CD), determine the out-of-plane member strength (ϕM_{ox}) as a beam-column to AS 4100.

(d) Hence deduce if the columns AB and CD are satisfactorily designed to AS4100.



(a)

(b) Bending moment diagram

(c) Axial force diagram

Figure 4

Q5 Connections (25 marks)

(a) **Give two methods** of guaranteeing the specified pre-tension in a fully-tensioned high-strength bolt. **Sketch a connection** in which fully-tensioned bolts should be used, and **briefly explain** why fully-tensioned bolts rather than snug-tight bolts are required for this particular connection.

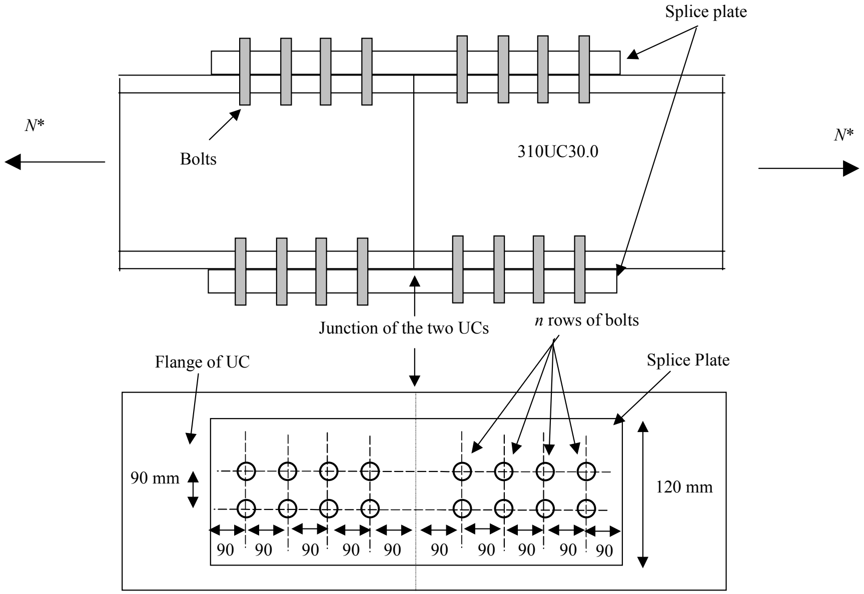
(b) Two 150UC30.0 sections, Grade 300 to AS 3679, are connected with splice plates connected to the top and bottom flanges of each section, as shown in Figure 5(a). There are 2 lines and *n* rows of bolts on each flange. (Note that if there are *n* rows of bolts, then there is a total of 8*n* bolts in the entire connection.) 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 minimum number (*n*) of rows of bolts required to ensure that the connection is adequate for a design axial tension of N^* = 795 kN.** (You 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.). **Also include the design capacity for the connection based on the number of bolts you have chosen.**

(ii) The bolts are replaced by fillet welds, SP Grade, made from E48XX electrode, and equal leg lengths of 6 mm, as shown in Figure 5(b). **What is the minimum value of the length of the weld, L_w, required to ensure that the connection is adequate for a design axial tension of N^* = 795 kN?** Note that there will be eight (8) individual fillet welds, each of length L_w in the entire connection. **Also include the design capacity for the connection based on the length of weld you have chosen.**

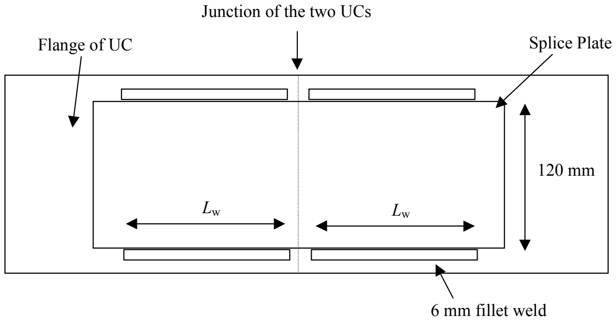
The following properties of an M20 bolt may be useful.

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



Note: This figure shows 4 rows of bolts, as a guide only.
The question is to determine the number, *n*, of rows of bolts required.

(a) Plan



(b) Plan

Figure 5

(All dimensions in mm)