The University of Sydney

# CIVL3206 Steel Structures 1

## Department of Civil Engineering

## Semester 2, 2005

## 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).

**Q 1 Tension Members (20 marks)**

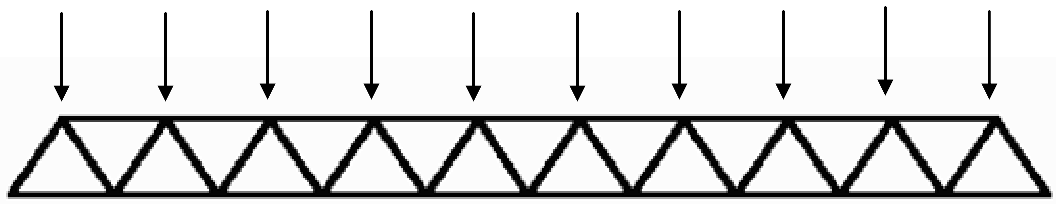
a) Clause 9.1.10.3 of AS 4100 states "When holes are staggered, the area to be deducted shall be the greater of—(a) the deduction for non-staggered holes; or (b) the sum of the areas of all holes in any zig-zag line extending progressively across the member or part of the member, less ($s^2_p t$ / $4s_g$) for each gauge space in the chain of holes", where $s_p$ is the pitch and $s_g$ is the gauge.

**Use a diagram to explain the terms "pitch" and "gauge".**

**Would increasing the pitch in a set of staggered bolt-holes make failure through that staggered pattern more or less likely? Explain the answer (diagrams will help!).**

b) Consider the simply supported Warren truss shown below. There are 10 panels, each 2 m in length, to give a total span of 20 m. The truss uses T-sections for the chords and double angles for the diagonals. The truss is designed to resist a downwards UDL of 22 kN/m, which may be simplified as a set of point loads acting on the panel points of the truss. The engineer has not yet designed the connections but assumes that 15 % of the gross cross sectional area may be lost due to the presence of bolt holes at the connections.

- Since the chords are 20 m long, two separate T-sections spliced together will be needed for each chord. **Sketch a possible splice connection for the T chords and hence determine an appropriate value for $k_t$.**
- **Which chord (top or bottom) is in tension? Determine the design axial tension $N^*$** for this chord using an appropriate method of analysis.
- Use the attached page of section properties for Grade 300 T-sections to **determine the T-section of least mass** that will be suitable for the tension design of the bottom chord. Compression in the bottom chord should not be considered. Please include **the design section capacity in tension ($\varphi N_t$) of the selected section.**



**Q 2 Bending (20 Marks)**

a) Table 5.6.1 of AS 4100 shows that for a uniform BMD the term $\alpha_m = 1.0$, whereas for a triangular BMD, 0 at one end and maximum at the other $\alpha_m = 1.75$. Use these two cases to **explain what $\alpha_m$ accounts for** when determining member moment capacity $\phi M_b$. It is expected that possibly two paragraphs of text, plus diagrams might be suitable to answer this question.

b) A 10 m long 410UB53.7 in Grade 300 steel forms part of a roof system. The connections at the end of the beam to the columns are simple, flexible connections, providing full restraint (F) to both flanges at the end of the beams only but not providing lateral rotation restraint. The beam is oriented so that the web of the UB is vertical and there are purlins on the top flange at a yet undetermined spacing which provide restraint to the top flange but not the bottom flange.

- Assuming downwards gravity loads (live + dead) act as a UDL on the top flange, **what would be the maximum purlin spacing** to ensure that the beam could be considered to have full lateral restraint for gravity loads (*Hint: Cl 5.3.2.4)*? **What is moment capacity in this case ($\phi M_s$), and what is the maximum UDL the beam could support?**

- Consider an upwards UDL due to wind uplift. **How (if at all) is this loading case different to the one above?** Without performing calculation, **outline the different design calculation procedure that may be required, and suggest how the capacity might be able to be increased**. It is expected that possibly three paragraphs of text, plus diagrams might be suitable to answer this question.

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.

**Q3 Compression Members (20 Marks)**

a) **Explain why the typical shape of a UC compared to a UB makes it more suitable for compression applications.** Use of diagrams and reference to different types of buckling would assist the answer. Calculations are not necessary, but identification of key equations or parameters may be useful.

b) Consider the properties of the hot-rolled OneSteel 410UB53.7 section in Grade 300 steel.

$f_y$ = 320 MPa.
$A_g$ = 6890 mm$^2$
$k_f$ = 0.913

Hence section capacity $\varphi N_s = \varphi\, k_f A_g f_y$ = 1810 kN

OneSteel plan to make a new hot-rolled UB, similar to the 410UB53.7, by making the web 50 mm deeper than the original 410UB53.7, but leaving all other dimensions (flange width, flange thickness, web thickness the same). The area of the new cross-section is 7270 mm$^2$.

**Determine the following for the new section:**

- The form factor ($k_f$) (you will need to calculate this)
- The design section capacity ($\phi N_s$) for compression.
- Write a brief report (approximately two paragraphs) for OneSteel commenting on the effectiveness of the new section compared to the original with respect to its compression capacity, giving reasons. Use of diagrams and equations would be useful in addition to the text.

**Q4 Combined actions (25 Marks)**

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

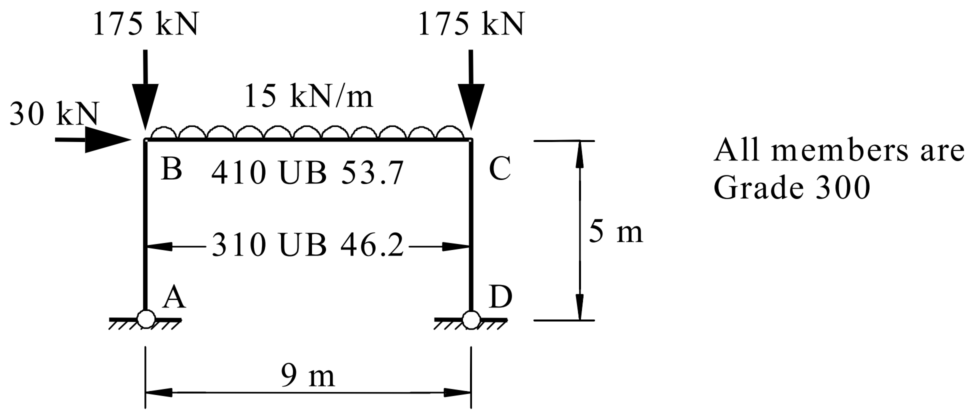
It may be appropriate to write some relevant equations and draw some diagrams in your response, but there is no need to perform any numerical calculations. Directly quoting from AS 4100 is not considered an appropriate answer. At most two paragraphs of text would be required.

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 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. Each member of the frame is sufficiently laterally braced such that buckling out of the plane of the frame is prevented.

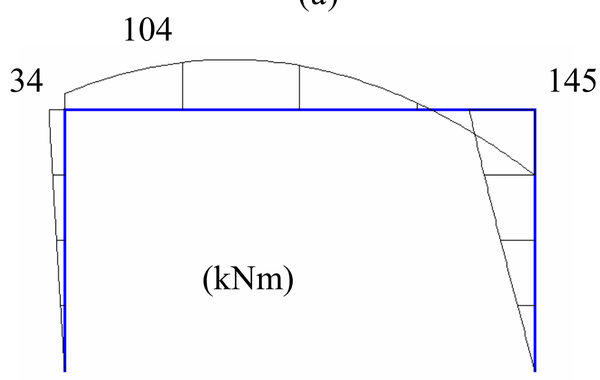
i) **Does the structural analysis program used draw the BMD on the tension or compression side of the structure? Explain briefly.**

ii) **Determine the effective length for in-plane buckling of member CD. Is this *x* or *y* axis buckling? Is this braced or sway? Without calculations would the effective length of AB be greater, smaller, or the same as the effective length of CD? Explain your answer.**

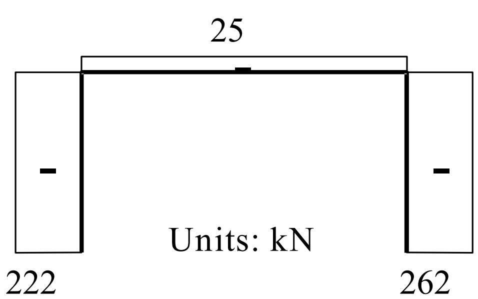
iii) **Determine the in plane member strength ($\phi M_{ix}$) of member CD** and hence establish if Cl 8.4.2.2 of AS 4100 is satisfied. If required, the values of $Z_{ex}$ and $k_f$ may be taken from the OneSteel product literature.




(a)




(b) Bending moment d agram




(c) Axial force diagram

Figure 4

**Q5 Connections (15 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. Use of diagrams would greatly assist the answer.

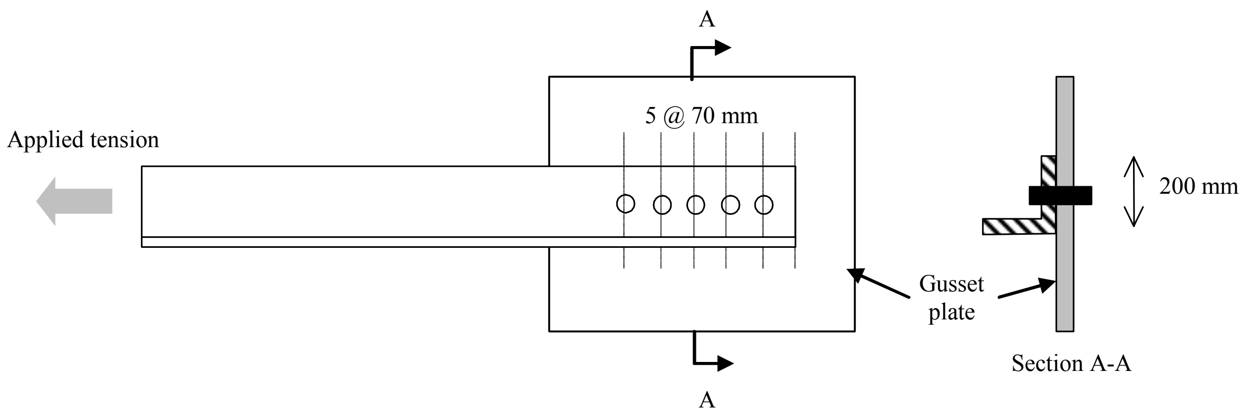
(b) An engineer is assessing the tensile strength of a bracing connection in which a 200×200×18 EA (Grade 300) is bolted to a 25 mm thick gusset plate (Grade 300 to AS/NZS 3678) by 5 bolts as shown in Figure 5. The bolt pitch is 70 mm. Grade 8.8 snug tight M20 bolts are used in this connection, and the 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 $\phi N_t$ = 1750 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

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