ENGN1217 – Introduction to Mechanics

ANU College of Engineering and Computer Science, S2 2014

Group Assignment - Balsa Truss Bridge

1. AIMS

1. To design and construct the strongest possible bridge, given the construction materials and design constraints.
2. To demonstrate proficiency in building and analysing a bridge structure.
3. To experience collaboration, working in groups and producing group report.
4. To relate theory and practice in the subject of Statics.

2. OVERVIEW

In groups of about 6, you will design, analyse, build, and mechanically test a balsa-wood truss bridge. You will be given material for the construction of the bridge, along with a set of design constraints and loading conditions. You must analyse the bridge using theory developed within this course, and document your design and analysis process within a group report to be submitted prior to testing.

KEY DATES

Event	Due date	
Complete Group Sign-Up / Allocation	By Friday 5 pm	Week 5
Collect Equipment (during lecture)	TBA	Week 6
Bridge Competition (during lecture)	Wednesday	Week 10
Submit Group Assignment report (through Wattle)	By Friday 5 pm	Week 11

GROUPS

If you would like to choose your own group members, please do so through Wattle before the end of week 5. Each group should consist of 6 or 7 students. If you want to be assigned to a group by Lecturer, do not sign up through Wattle - you will be allocated to a group at the beginning of week 6. Group leader is requested to collect equipment from the lecturer.

3. BRIDGE CONSTRUCTION

MATERIALS:

Each bridge building group will be given balsa wood from which to construct the bridge:

- 2 lengths (each length approx. 900 mm) of 5 mm square balsa
- 2 lengths (each length approx. 900 mm) of 3 mm square balsa

Each group will be provided with glue and cutting blades for bridge construction, which is to be performed in your own time. **No other materials are allowed to be used**, and note that your raw materials and final bridge will be weighed. Balsa cement should dry 24 hours to reach maximum strength. "Double gluing" may increase the glue strength.

REQUIREMENTS

- The bridge has to support a load applied from the top by a vertically downward moving plate of dimensions 70 mm x 70 mm (see Figure 1). The load will be applied by a universal testing machine fitted with a suitable jig to support the bridge (see Figure 2 in the Appendix).

DESIGN RESTRICTIONS

- The base of the bridge must span the 180 mm gap without touching the internal surfaces of the gap.
- The bridge must be 70 mm wide and no more than 100 mm high.
- No part of the bridge can protrude into the 180 mm space beneath the bridge supports prior to testing.
- The bridge should be "self-standing".
- **The glue may only be used to secure the joints of the bridge**. No glues should be used between the parallel beams to make thicker members. In another word, lamination of the balsa to make thicker members is not allowed. Every structural member should have cross-sectional dimensions less than 5 x 5 mm.
- The four pieces of balsa given weigh about 15.6 g in total. **The weight of the bridge should be less than 18g**.
- The balsa should not be bent or arched. Every part of the structure should be straight.
- Gusset joints are allowed.
- More than two 2D-truss panels can be used.
- The balsa should not be split in the length direction to form thinner members.

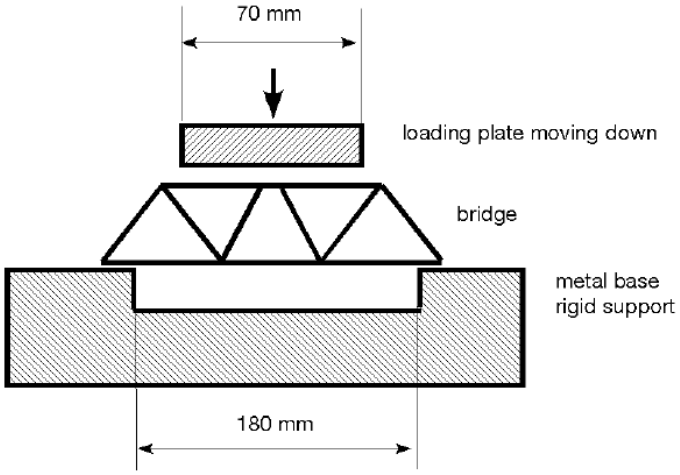

Figure 1: Diagram of the bridge supports and the loading plate.

4. ASSESSMENT

This assignment is worth 20% of your final grade for this course. The marks for the assignment itself will be distributed in the following way: Group Report (10 marks), Bridge Performance (5 marks), Prediction of Maximum Load (5marks).

GROUP REPORT (10 MARKS)

The group report needs to contain the following information:

Cover page:

1. group number;
2. names and student IDs of each group member;
3. a statement of each student's contribution to the assignment (% of overall effort) that will be considered towards the final mark of each student;
4. a photographic image of the bridge;
5. weight of the bridge
6. name of the bridge
7. predicted "maximum load".

Report body:

1. a summary of design assumptions and methods;
2. a drawing of the bridge showing all elements labelled and all dimensions indicated;
3. a table with theoretically predicted tensile and compressive loads in each and every member when the structure is supporting a 100 N load, along with the dimensions of the members. Any assumptions you made should be explicitly stated;
4. a theoretical prediction of which member will fail first. Include the table of max loads for each member;
5. your reasoning in estimating the "maximum load".
6. analysis about the difference between the predicted "maximum load" and real performance.

The report should not exceed 10 pages in length. Appendices can be added outside of 10 page limit but **the appendix should not be longer than 2 pages**. Formatting guidelines are available through the Wattle page.

BRIDGE PERFORMANCE (5 MARKS)

Mechanical testing will be carried out to ascertain the maximum compressive load that the bridge can withstand.

The top 20% of groups will receive 4.5 - 5marks
The next 20% of groups will receive 4 - 4.5 marks
The next 20% of groups will receive 3.5 - 4 marks
The rest of the groups will receive 2.5 - 3.5 marks

If the bridge is in breach of the design-restrictions, the group will receive 0 marks.

PREDICTION OF MAXIMUM LOAD (5 MARKS)

If the mechanical testing load is within 10% of the design load prediction, then these groups will be awarded the full 5 marks. Any variation larger than 10% will result in a

corresponding reduction in marks. For example, a 50% difference between prediction and actual testing will result in an award of 2.5 marks.

HINTS

- In order to theoretically predict tensile and compressive loads in each and every member, the bridge should be designed to be statically determinate.
- You can assume that the external load is going to be concentrated on the joints under the loading block.
- In order to obtain a theoretical prediction of which member will fail first, maximum tolerable (or breaking) loads (tensile, compressive and buckling) should be calculated for each and every member. Then, the theoretically predicted tensile and compressive loads should be compared with the maximum tolerable loads (tensile, compressive and buckling) for each member. The method to estimate the maximum tolerable loads (tensile, compressive and buckling) in each member is given in the Appendix A of this document.
    - If the theoretically predicted tensile load exceeds the max tolerable tensile load, the member will fail by "snapping".
    - If the theoretically predicted compressive load exceeds the max tolerable compressive load, the member will fail by "crushing".
    - If the theoretically predicted compressive load exceeds the max tolerable buckling load, the member will fail by "buckling".
    - If there are many components in your bridge, standard deviation as described in Appendix A should be considered.
- In order to estimate the maximum tolerable load of the whole bridge, the maximum tolerable load of the weakest member should be considered.
- It is recommended that the dimension of the given balsa is measured to confirm that they are in fact 5 mm square or 3 mm square.

5. APPENDIX-A: MECHANICAL PROPERTIES OF BALSA WOOD

The average modulus of elasticity, *E*, is 3GN/m^2, standard deviation +2.4/-2.1MN/m^2
The average tensile strength, σ_t , is 20 MN/m^2, standard deviation +3.6/-3.4MN/m^2
The average compressive strength, σ_c , is 12 MN/m^2, standard deviation +2.1/-2.8MN/m^2

Tensile strength is defined as:

$$\sigma_t = \frac{P_{\max}^{tensile}}{A} \quad (1).$$

Compressive strength is defined as:

$$\sigma_c = \frac{P_{\max}^{compression}}{A} \quad (2).$$

Critical buckling load is defined as:

$$P_{critical} = \frac{\pi^2 EI}{(kL)^2} \quad (3),$$

where: P_{max} is the maximum load at break in tension or compression, as appropriate. A is the cross-sectional area on which the load is *P* is acting, *E* is the modulus of elasticity, *L* is the length of the beam (structural member), *k* is a geometrical factor = 0.5 for the bridge, and *I* is the area moment of inertia

$$I = \frac{a^4}{12} \quad (4),$$

where *a* is the size of the balsa section (either 3 or 5 mm). The equation 4 is correct only when the cross section is a square, not a rectangle.

6. APPENDIX-B: UNIVERSAL TESTING MACHINE

Figure 2 shows the Hounsfield universal testing machine and jig that will be used to mechanically test the maximum load of the bridges during the competition.

The loading plate will be lowered slowly at a speed of 500 mm/min. The maximum load will be displayed on the console of the universal tester in the unit of newton.

Figure 2: Testing area with bridge supports.