ENGG102: Project 1 Attempt B - Balsa Beam Redesign and Test

A: Preliminary Redesign of 600mm beam structure

A draft report including all design calculations and drawings required for discussion and manufacture is due at the beginning of lab in **week 4.** This preliminary design will be then used to design and test a similar beam during the week 4 lab. The final report incorporating these results to be submitted in **Week 6 via Moodle**.

This is a team task following on from week 2. During the Week 5 lab you will have your final redesign and build a **similar** beam based on your draft report for your preliminary redesign as above.

A straight beam structure is required to carry a central mass of 2.5kg (24.5N) over a clear span of 400mm. The central deflection under this load must be more than 1mm but less than 6.5mm. The weight will be suspended over a 10mm x 25mm area in the middle of the beam with a notch to hold it as shown below-

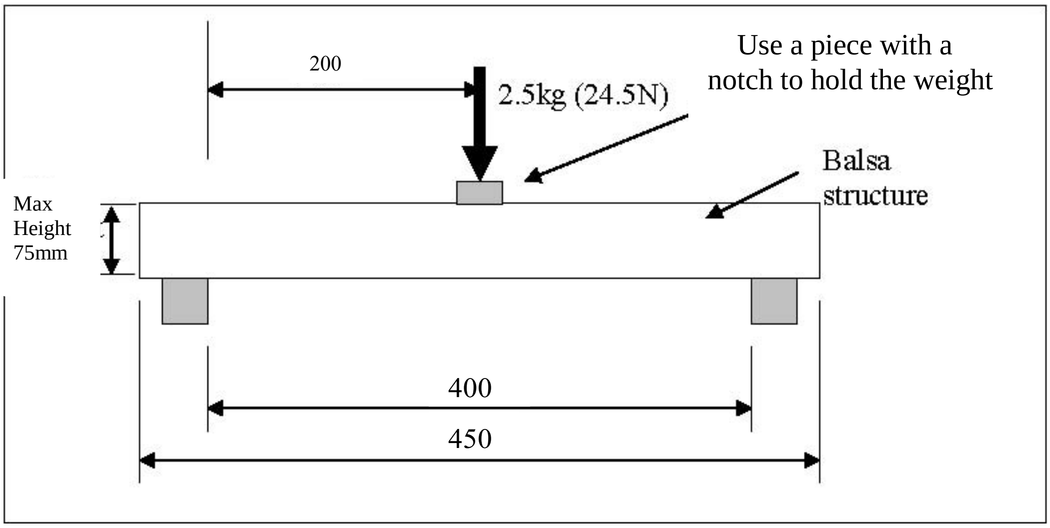


Figure 1: Side View of Beam

Procedure - Part A: Preliminary redesign

1. Consider two of the cross section shapes given in Figure 2. Begin by guessing the dimensions (based on the available material sizes - see below). Keep notes for your Report.
2. Calculate the cross sectional areas and the second moment of areas for each full cross section. Use the formulae in Figure 2. Note that you can only use a shape if you know how to calculate its 2nd moment of area. Suggest use the first section of your Excel Design Worksheet to calculate this.
3. Using the results from your experiments in week 3, estimate the Young's modulus of the balsa. Check this value against published data (e.g. Encyclopaedia Britannica Online).
4. Calculate the deflection at the midpoint using the formula, $\delta = PL^3/(48EI)$, where L is the clear span, P is the load in newtons, E is Young's modulus for balsa and I is the second moment of area. Do this for each beam design based on the cross section shapes selected in Step 1. Suggest use the second section of your Excel Design Worksheet to calculate this.
5. Check for the maximum stress at the middle of the beam. This occurs on the top and bottom surfaces of the beam directly under the load. Find the maximum bending moment ($M_{max} = PL/4$) and the stress, $\sigma_{max}=M_{max}h/(2I)$, where h is the overall height of the cross section. Again, do this for each beam design based on the cross section shapes selected in Step 1. Suggest use the third section of your Excel Design Worksheet to calculate this.

6. By considering the results of Steps 4 and 5 above, choose only ONE of the above preliminary designs. Justify your choice by identifying what is better about the design shape you chose and why you rejected the other alternative design shape.
7. Sketch this preliminary design showing all details so it can be built.
8. Check your Excel Design Worksheet by doing test runs with similar but different loads, spans and deflection requirements. Do this by doing some calculations on paper using a calculator and correct the Worksheet as necessary. It will be too late in week 5 to find out your Worksheet has errors. This will prepare your Team for this week's homework when you will finalise your design for a set of similar but different span, loading and deflection requirements.
9. Document all of the above in your Draft Project 1B Design Report. You should also add your title page, Contents, and Purpose statement at this point ready for showing your Tutor in Week 5.

NOTE:

- The above formulae work only for beams of **constant cross section** (i.e. beams that have the same cross section along their entire length). The maximum bending moment and deflection equations are true for a central point load on a simply supported beam as shown in Figure 1. The maximum stress equation is true for symmetrical (e.g. I, H, Box, Channel) and anti-symmetrical (e.g. Zed) structures.
- We are restricted to using mathematical models that we understand and formulae that have been justified by experiment or research in literature. If your team wants to make something more elaborate, then the mathematical model must be derived for that.
- Suggest strongly that you choose from the available cross sections given in Figure 2 as any variations will result in significant additional work to justify your selection and your design.

B: Final Redesign of nominal 400mm beam - to be done as homework

Your team is provided with new (but similar) design requirements to complete your final centrally loaded balsa beam design.

You will need to use your Excel or Matlab Design Worksheet to check that your preliminary design will still meet the criteria. If it does not meet the criteria according to your Design Worksheet, you will need to change the design. You could consider -

- Changing the height
- Changing the width
- Using different sized balsa sections
- Using the discarded design shape you considered earlier in Step 6 above or maybe a different one

Whatever you choose to do on the day, you cannot afford to waste time with a Design Worksheet that doesn't work or has confusing errors. So get it right BEFORE you come to week 5 t\lab by testing it as outlined in Step 8 above. When ready, give your Tutor your written Material Request (a shopping list!) covering the Balsa sheet and square sections quantities they require. Use the standard form in the Student's Handout (See ATTACHMENT 2: from the Week 1 Students Notes). You can email this list to your tutor but make sure you send before end of week 4 so that material can be arranged for your week 5 fabrication lab.

C: Building Your Beam -- to be done in class in Week 5

Each team is allowed -

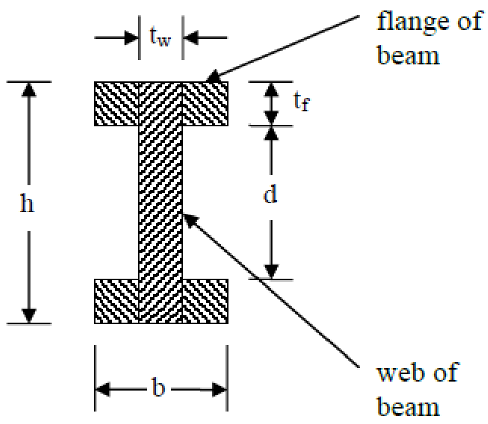
- 1 balsa sheet 5x100x900
- up to a maximum 1 of the 900mm long balsa square sections subject to the following restriction: square of 8*8 or 10*10 mm max 3.

I section

Area = h.b – d.(b-t_w)

$$I = \frac{b.h^3}{12} - \frac{(b - t_w).d^3}{12}$$

This can be formed by gluing 4 square sections to the sides of a thin sheet at the top and bottom.

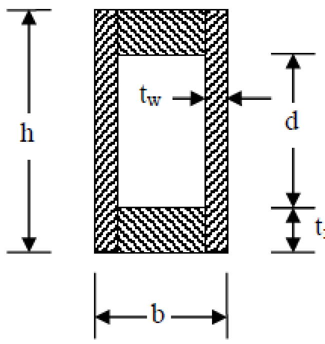


Box cross section

Formed by using two thin sheets for the side walls and one or two square sections at the top and bottom.

Area = h.b – d.(b-2t_w)

$$I = \frac{b.h^3}{12} - \frac{(b - 2t_w).d^3}{12}$$

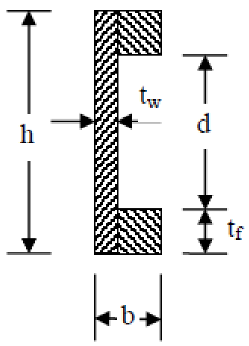


Channel cross section

Formed by gluing one square section top and bottom on a thin sheet.

Area = h.b – d.(b-t_w)

$$I = \frac{b.h^3}{12} - \frac{(b - t_w).d^3}{12}$$



Double box cross section

Like the box section but with a stiffening diaphragm at mid height. (Why might this improve the box section performance?)

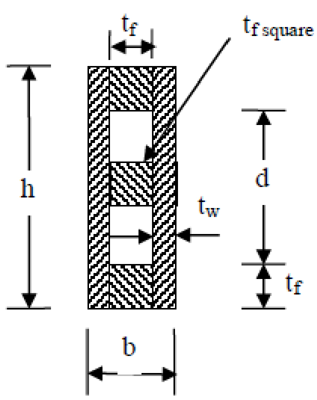


Figure 2: Available Cross section shapes

Also, you should -

1. Get a feel for how strong the material is - without breaking it!
2. In the interests of Sustainability, try to design the lowest mass structure that meets the engineering criteria.
3. Remember that fabrication should begin as early as possible to allow glue to dry.

Procedure - Part C:

Build your structure taking care when cutting.

1. Use the glue sparingly. ***Use up the already open glue bottles first.***
2. ***Wear safety glasses when using the glue and cutting balsa pieces.***
3. ***Wear plastic gloves when using the glue***
4. ***All cutting is done on the cutting boards provided***
5. You will need to share cutting resources with other teams.
6. Remember that you need some extra length at either end to go over the supports to provide adequate bearing strength to support your beam.
7. Take photos of the building process as you go - but do not waste time!

Classroom Health and Safety

Three safety risks are identified for this project -

1. *Handling of glue*

   Putting too much pressure on the glue tube results in the tube bursting, potentially ending up in the eyes of the handler or his/her team-mates. This can result in a serious eye injury. Such incidents typically happen when opening the new glue tube or when the nozzle gets blocked by the set glue (tube not closed properly). To avoid this happening -

   - <u>NEVER apply excessive pressure to the glue tube.</u> If the glue does not come out easily, consult the tutor.
   - The Glue nozzle will be cut open for you. Inspect it before each use. If it is not open, ask your tutor.
   - ALWAYS wear safety glasses and gloves when handling the glue.
   - Be mindful of your team-mates. They may get injured by you handling the glue. Always point the nozzle away from people around you.

2. *Cutting balsa pieces*

   Use the small saws where possible. A sharp blade can also be used for cutting balsa pieces. Fingers can get cut and blade may snap, potentially resulting in eye injury. To avoid this -

   - Always use the safety rule when cutting the balsa sheet, keeping your fingers in the groove to protect them from the blade.
   - Keep your fingers well away from the blade at all times.
   - ALWAYS wear safety glasses when cutting.
   - Make sure your team-mates are at safe distance (at least a metre) to prevent injuring them.
   - <u>Always cut in a direction away from your fingers.</u>

3. *Use of testing rig*

   A weight of 500 g will be used to apply a force on the beam. It may fall from the rig lever, potentially hurting your feet. To avoid this -

   - Wear sturdy closed-type shoes. You are not allowed to be in the class in thongs or similar shoes.
   - Keep your feet away from the lever at all times.
   - Place the weights onto the rig lever with care and check regularly that the weight has not moved.
   -

D: Testing Your Beam - to be done in class in Week 5

Your Team is allowed an <u>absolute maximum of 10 minutes</u> to set up and test your beam. The Tutor will briefly demonstrate this to the first team - suggest you watch!

While you are waiting for your turn, make a start on the next Task.

Procedure - Part D:

1. Take photos during the Testing phase. Suggest -
   - take one wide angle photo showing their beam set up ready to test - make sure their team label is clearly visible,
   - take one close up shot of the beam under load showing the reading on the dial gauge, and,
   - if the beam fails, take one shot of the failed/collapsed/twisted/whatever beam.
   - include these photos in your Report in the Comparison of Results and Reflections sections.
2. Throughout the exercise, document your discoveries and how you overcame unexpected problems.
3. Complete your Team's part of the Results Table on the whiteboard. You are expected to reproduce this table using the Table Template provided in Moodle for your Report.
4. Make sure a member from your team posts your Team's photos onto the Moodle lab Class Forum with their Team label (ie Team 1, Team B etc) clearly showing - by 5pm the day after your lab class.

Guidelines for preparing your Project 1B Design and Reflection Report

You will submit this report through Moodle by 11:59pm on the day of your lab in Week 6. **Make sure you select correct submission link and complete the team assignment cover sheet.** The cover sheet can be downloaded from Moodle.

One report per team must be submitted via Moodle. The submitting student can review this report within a few hours of uploading – the turnaround time depends on traffic in the system. Submit early to be sure to get the report in time to allow you to make any necessary edits. You can re-submit your report up to the deadline time. However, any resubmitted reports must be submitted by the same student and with exactly the same file name.

All assignments that are required, are to be uploaded by 11:59pm on the day of your lab.

DO NOT LEAVE IT TO THE LAST MINUTE.

Since you are submitting the report as a team, your team leader will take the responsibility of generating the cover sheet, uploading in the assignment and collecting it back from Moodle. The team leader must arrange for a meeting with the team to review the feedback together.

Reports are due to be returned within 1 week of submission.

The Project 1B Design and Reflection Report you submit in Week 6 accounts for 10% of the overall marks for this subject. It is a team report and normally each member in the team will be awarded the same mark. The Design and Reflection report **must show clear evidence of team work** and the contributions from each member.

Use the Report Structure list provided below. Teams should use these headings for their reports. Teams should assess their own work by using the Project 1B Assessment Marking Sheet before submitting their report.

Anything missed <u>will result in lost marks</u>. *Please properly proofread your report before submitting!*

Submission requirements:

- In week 4 - MUST bring your draft preliminary design report to the tutorial (HARD COPY/PDF) You will use this to design and predict the performance of a similar beam to carry a similar load.
- <u>Your design should be generic to allow for different lengths of beam and magnitudes of central point load and limiting deflection. An Excel/Matlab Design Worksheet should be set-up to make the re-design during the week 4-5 faster**.** The printed worksheet should be self explanatory.</u>
- **<u>The Week 4 draft preliminary report should contain items 1-7 in the list below.</u>**

The Project 1B Design and Reflection Report due in Week 6 should contain the following -

1. Assignment cover sheet with name and student number for each team member.
2. Assessment sheet with Team information (Team number and names). Place, time and date of design exercise. If you were in a different team for the first attempt give that information too. Use the version provided in Moodle for this.
3. Title page and Contents page.
4. Statement of purpose of the report.
5. Description of the preliminary design completed as homework, for week 6. This should include the alternative schemes considered and the reasons for selecting the final shape.
6. Results of your preliminary design calculations to predict the midpoint deflection and maximum stress of the beam shown in Figure 1.
7. Briefly describe your 600mm span beam with drawing, dimensions & volume of wood req'd.
8. Description and re-design done during the week 6 tutorial to meet the new requirements.
9. Revised updated beam drawing, dimensions and volume of wood required.
10. Results for your final beam and results for the rest of the teams.
11. A comparison of the results of your beam to the others (WHAT happened)
12. Reflection on the process and outcomes (WHY it happened).
13. Include a section on the teamwork performance of your Team.
14. Conclusions
15. References
16. Appendix A: Minutes of team meetings (evidence of teamwork)
    Appendix B: Young's Modulus experiment including all results and conclusions. Appendix C: A print of your Excel Design Worksheet (Preliminary OR Final values)

Your reflections might contain the following - (Suggest you use these Headings!)

1. Consider your initial response to the 400mm bridge problem in Week 1-2 and how your design calculations have helped you or hindered you in producing a new solution. You should consider how you have generalised your method to allow you to rapidly produce a new design to meet new performance criteria. How can we generalise these approaches to allow us to tackle any new engineering design problem?
2. In your first attempt you may have had difficulties building of the beam. What were the most difficult or fiddly bits that took most time? How did you avoid this in the final attempt?
3. Reflection on the performance of your beam relative to the others. What things made some beams perform better with respect to the predictions? What improvements would you make if you were to repeat the design one more time? Did you adopt a conservative approach or try to push the envelope? Both are valid!
4. Compare how your team's understanding of beam behaviour has changed since the first attempt. Try to identify the relevant knowledge you gained during the last 5-6 weeks. Are there still gaps in your understanding? What can you do about filling those gaps during your degree studies?
5. What did you learn from the relative performance of the beams in the second attempt?
6. Reflection on your team's performance in relation to the models of teamwork discussed in the e-reading by Smith or the reference text Engineering Your Future by Dowling et al. and the lecture in week 1. <u>Each team member should write an individual paragraph for this part of the reflection.</u>

Keeping your reports: The person submitting the report on behalf of the team is required to forward all feedback from the marker to the other team members. It is a good idea to keep a portfolio of all your work. This can be used later in job interviews.

UNIVERSITY OF WOLLONGONG IN DUBAI
Faculty of Engineering and Information Sciences

ENGG102 Project 1B Beam Design and Reflection Report: Assessment sheet

Tutorial number:______________________Tutors name:_________________________

Team Number:____________ Date and time of exercise:_____________________

Names and ID Numbers: ____

Aspect	Comment	Mark
ENGG102 Project 1B Beam Design and Reflection Report: Assessment sheet.	**Minus 3 marks if this Assessment Sheet is not included with the Project 1B Design and Reflection Report**	
Appendix A: Minutes of Team Meetings (evidence of teamwork)	**Minus 2 marks if Minutes of Team Meetings (more than one!) are not included with this Report**	
Appendix B: Young's Modulus Experiment MUST also post by Deadline!	**Minus 5 marks if your Young's Mod exp results are not posted by deadline + all results & conclusions are not included with this Report.**	
Appendix C: Excel Design Worksheet	**Minus 2 marks if a print of your Excel Design Worksheet (Preliminary OR Final) is not attached.**	
Structure of report, team information etc (as per "what report should contain")	0.5 mark for each item 3-14 (see Report structure provided above)	/6
Overall Presentation Don't forget the PHOTOS!	Neatness Spelling Grammar Diagrams Professionalism	/5
Relevant theory and model development (equations to predict deflection etc) Reasons for selection of prototype for PRELIMINARY design.	Must show evidence of at least two distinct design ideas and optimisation of chosen one. Describe the principle behind the design. Include all FBDs & calculations leading to predicted deflection and maximum stress values.	/10
Description of PRELIMINARY beam Drawing/sketches with dimensions	Accurate line drawings or neat and clear sketches with all important dimensions (should enable to build structure)	/8
REDESIGN calculations and justifications to meet new criteria for FINAL beam design.	Include all FBDs & calculations leading to predicted deflection and maximum stress values. Include any additional information eg if beam design shape is changed.	/10
Description of FINAL beam Drawing/sketches with dimensions	Revised accurate line drawings or neat and clear sketches with all important dimensions (should enable tutor to build the same structure)	/5
Results including comparison with other team(s). WHAT happened!	Comparison table of all results. Discussion of results with commentary on table and main factual findings. Describe the main failure mechanisms.	/10
Reflections – identify some reasons for the performance of your beam and other teams. WHY it happened! Consider the various aspects of the task (design, fabrication, material use). Discuss how it might be improved, what knowledge might be needed, & design criteria considered.	To achieve top marks (26-34/34) in this section your report must demonstrate clear and insightful reflection considering own solution and others in the class. Demonstrates further reading and critical analysis. To achieve 19-25/34 your report must describe the performances of your solution and some others. Itemisation of knowledge gaps and some critique of designs. To achieve 0-18/34: Simply describes own solution with limited reference to other beams.	/34
Teamwork reflection in report	Identifies models of teams e.g. from Smith (see e-reading) Compares own team with recognised models. Demonstrates awareness of how to perform better as a team.	/7
Conclusion	1 or 2 paragraphs that draw appropriate conclusions from evidence presented in report. Include the main results, both numerical and qualitative.	/5
Total		/100

