FACULTY OF ENGINEERING & INFORMATION SCIENCES | UNIVERSITY OF WOLLONGONG

Team assignment cover sheet

Complete all sections of this coversheet

Student name	Student number	Student submitting work (x)
1. Yash Gokhale	6504383	(x)
2. Soham Thanki	6931510	
3. Joshua Rochford	6783600	

Subject number and name	ENGG102 Fundamentals of Engineering Mechanics
Subject coordinator	Prof Tim McCarthy
Title of Assignment:	ENGG102 Project 1B Report
Date and time due:	4th of May at 11:59 p.m.
Tutorial Number:	15
Team Letter:	B
Total number of pages:	

Student declaration and acknowledgement (must be read by all students)

By submitting this assignment online, the submitting student declares on behalf of the team that:

1. All team members have read the subject outline for this subject, and this assessment item meets the requirements of the subject detailed therein.
2. This assessment is entirely our own work, except where we have included fully documented references to the work of others. The material contained in this assessment item has not previously been submitted for assessment.
3. Acknowledgement of source information is in accordance with the guidelines or referencing style specified in the subject outline.
4. All team members are aware of the late submission policy and penalty.
5. The submitting student undertakes to communicate all feedback with the other team members.

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

Tutorial number: 15 Tutors name: Manish Sreenivasa

Team Number: B Date and time of exercise: 04/05/20 at 11:59 pm

Names and ID Numbers: Soham Thanki (6931510), Joshua Rochford (6783600), Yash Gokhale (6504383)

Aspect	Comment	Mark
ENGG102 Project 1B Beam Design and Reflection Report: Assessment sheet. Use PDF version from Moodle	**Minus 3 marks if this SELF 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	**Minus 5 marks if your Young's Mod exp results are not presented + 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 /6
Overall Presentation Don't forget the PHOTOS!	Neatness Spelling Grammar Diagrams Professionalism	5/5
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.	10/10
Description of PRELIMINARY beam Drawing/sketches with dimensions	Accurate line drawings or neat and clear sketches with all important dimensions (should enable tutor to build the same structure)	8/8
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.	10/10
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)	5/5
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.	10/10
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.	34/34
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.	7/7
Conclusion	1 or 2 paragraphs that draw appropriate conclusions from evidence presented in report. Include the main results, both numerical and qualitative.	5/5
Total		100/100

Balsa Beam Report 1B

Contents

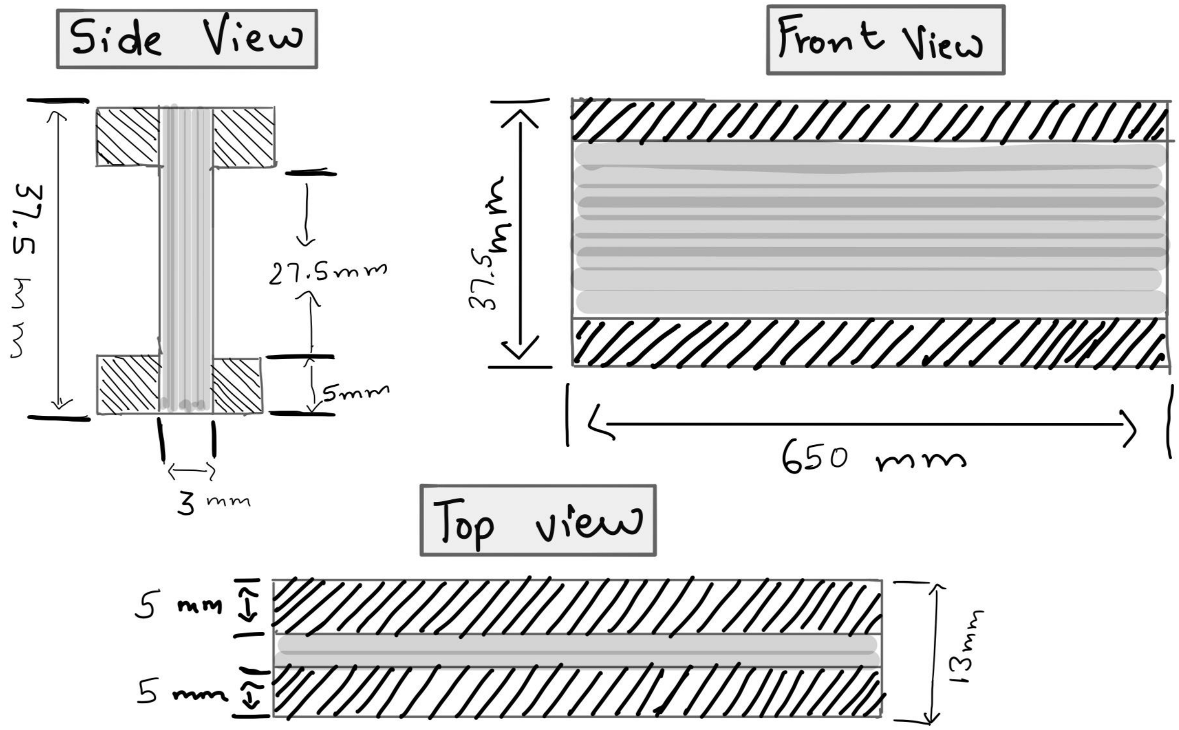
1.Statement of Purpose:

The purpose of this project was to re-design, build and test a beam structure made from balsa wood. The constructed structure is required to be able to carry or support the equivalent of a central mass of 3kg (29.43 N). There were many restrictions to the dimensions of the beam such as the height and the span. The height was restricted to 75mm while the span was restricted to 640mm. The aim of the project was for the beam to be able to carry 3kg (29.43 N) whilst maintaining a central deflection of more than 2mm and less than 5.5mm in order to meet the engineering criteria. The beam was to be designed using up to an additional 8 pieces of balsa that varied in width and height. The 8 pieces to choose from were all 900mm long, a 3x3mm for which the maximum amount was 8 pieces, a 5x5mm for which the maximum amount was 4 pieces and a 6.5 x 6.5mm for which the maximum amount was 4 pieces. The goal of the task was to build a beam using the least amount of material and fabrication effort meanwhile adhering to the beam requirements and also using our calculations to simulate and approximate the maximum deflection to choose the best design.

2.Preliminary Designs:

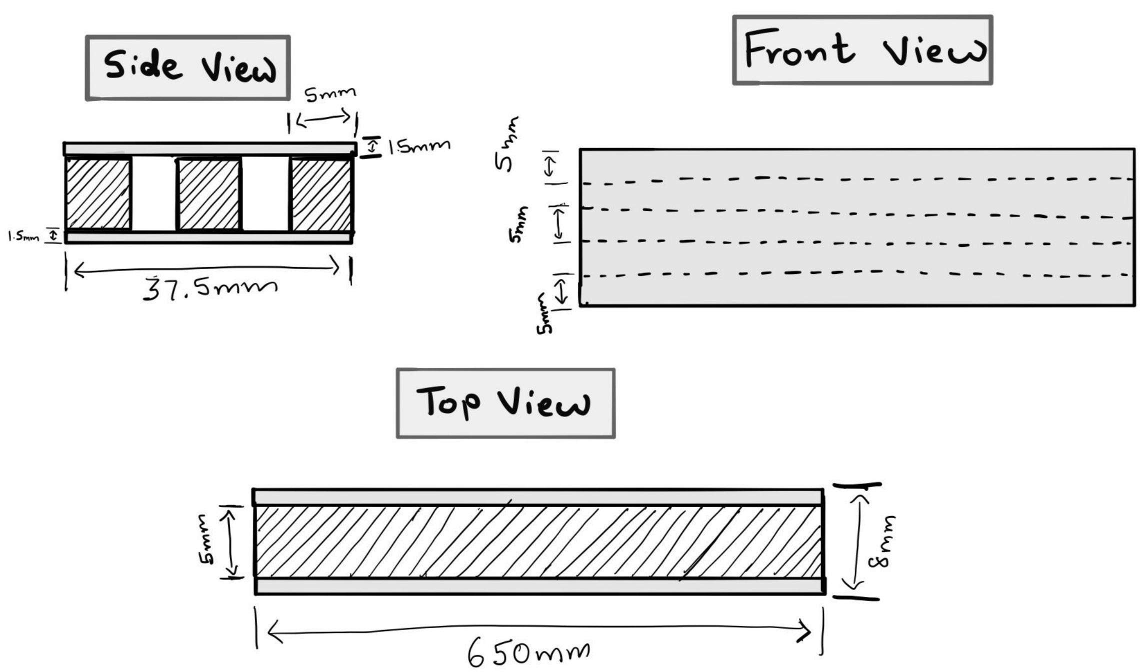
We have decided to design our beam using the I section model because it is widely used in the construction industry due to its strength to amount of material ratio. In making this decision we had to weigh up 3 potential designs to consider which model will meet the criteria with the least amount of fabrication effort and material used. We first looked at the double box cross-section because just by looking it appears to be the strongest design. Although after discussing as a group online, we calculated that it would require the most material therefore we turned to the channel cross-section. This design has the smallest fabrication effort and amount of material needed. Although after comparing the channel to the I cross-section we decided that by adding a little more material and effort the I cross-section would be much stronger than the channel but not as costly as the double box. After some research the I cross-section beam is extremely effective in cases where there is only one direct force which this project requires of the beam.

Idea 1



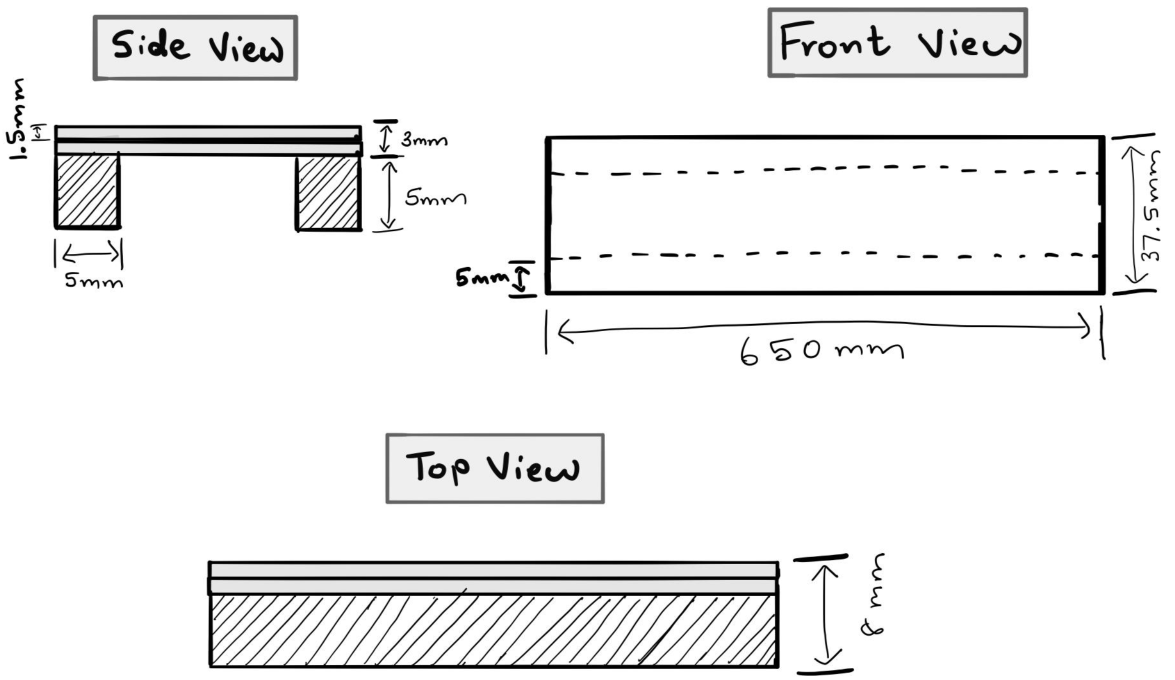
Side View
37.5 mm
27.5mm
5mm
3 mm
Front View
37.5mm
650 mm
Top view
5 mm
5 mm
13mm

Idea 2



Side View
5mm
1.5mm
1.5mm
37.5mm
Front View
5mm
5mm
5mm
Top View
5mm
8mm
650mm

Idea 3



2.1 Design Calculations:

Calculated Deflection of Idea 1

$$I_{I\,beam} = b * h^3/12 - (b - t_w) * D^3/12$$
$$= 39798.17708\ mm^4$$

$$\varphi_{I\,beam} = PL^3/48(EI)$$
$$= 1.36467 mm$$

Calculated Deflection Of Idea 2

$$I_{Box\,beam} = b * h^3/12 - (b - 2t_w) * D^3/12$$
$$= 26490\ mm^4$$

$$\varphi_{Box\,beam} = PL^3/48(EI)$$

$= 2.050mm$

Calculated Deflection of Idea 3

$I_{I\ beam} = b * h^3/12 - (b - t_w) * D^3/12$

$= 26940.8854mm^4$

$\varphi_{I\ beam} = PL^3/48(EI)$

$= 2.016mm$

Based on the calculations we decided to go with the I beam (Idea 1) as it produced the smallest deflection which was within the initial criteria of a deflection of 1mm to 5.5mm. At the same time the I beam either used the same amount of materials or lesser when compared to the other two ideas. This makes it the obvious decision as it is the most efficient and effective when compared to the ideas we came up with

3. Final Design:

After weighing up our options we decided to go with our first idea which was the I beam but made a few changes based on our results for the 1b draft results where our beam was too strong and did not meet the criteria. Although now that the beam is 50mm longer and another 0.5kg has been added we still believe judging by our calculations that we can still reduce the total amount of material used and still meet the beam requirements by changing the 5x5mm pieces into 3x3mm pieces. By adapting our previous design and taking into account what has gone wrong in the past as a group we have decided this is the ideal beam. Our calculations of beam deflection and internet sources suggest the i beam design is perfect for this project.

3.1 Beam calculations

Volume of I beam: not including overhang only including span

$Area = h * b - d * (b - tw)$ $Volume = (Area * distance)$ $V = 96525\, mm^3$

Second moment of area = $b * h^3/12 - (b - tw) * d^3/12$ $I = 23922.84\, mm^4$

Balsas young's modulus = 3.1 (calculated from using internet sources)

Calculated deflection $= \varphi = PL^3/48(EI)$

$$= 29.43 * (680)^3/48(23922.84 * 3.1)$$

$$= 2.59956890435\ mm$$

$$\approx 2.6\ mm$$

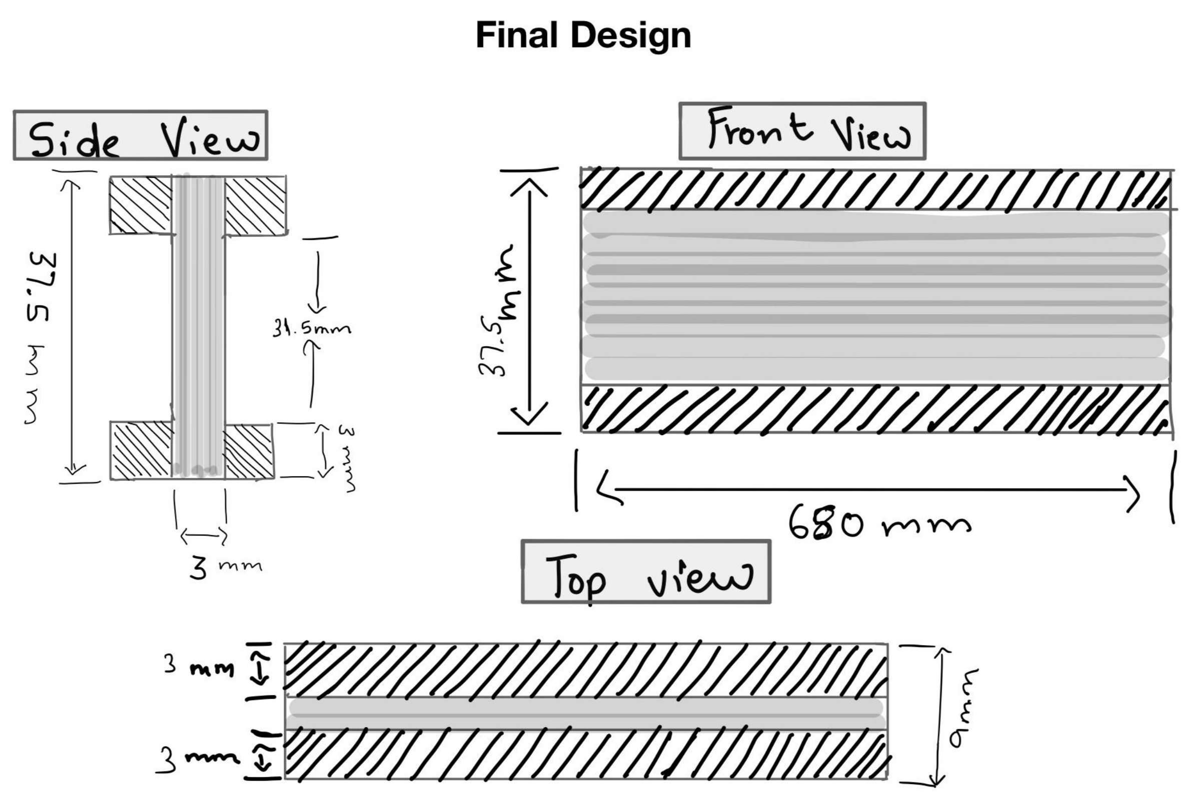


Figure 4: Design chosen for the project

4. Results:

Table 4.1: Results of all the groups

Team	Type of beam	Calculated deflection	Measured Result	Met Criteria	Material used	Volume	Fabrication Level	Comments
A	Channel Cross Beam	3.8mm	1.5315mm	No		86130mm^3		-
B	I Beam	2.65mm	2.6913mm	Yes	One 1.5x75x900 mm sheet Four 3x3 square pieces	100980mm^3	Low	The beam should perform well in the simulation due to big brain strats
C	I Beam	2.636mm	1.5879mm	No		95040mm^3	Medium	-
D	Box Beam	5.22mm	1.2856mm	No		87150mm^3		Maximum deflection within the allowed range using minimal materials
E	-	-		-		-		-
F	-	-		-		-		
G	Box	3.1mm	1.8019mm	No		86130mm^3		
H	Box	4.85mm	1.8855mm	No		96360mm^3		
I	I beam	3.82mm	3.1222mm	Yes		180160mm^3		

J								

Displacement (mm) vs Load (N)

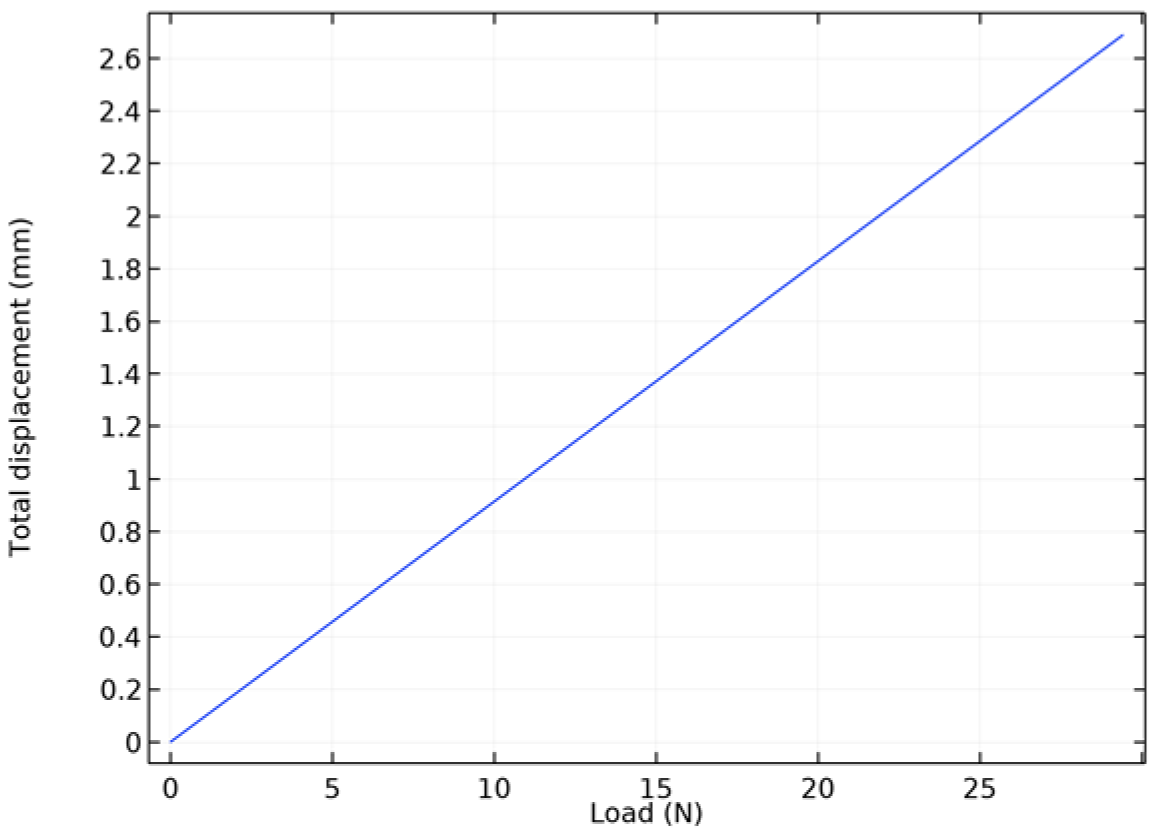


Figure 5: Graph of displacement (mm) vs Load (N) **(4)**

In the table above we can see how our beam performed in comparison to the rest of the beams produced by the other teams. We had calculated a deflection of 2.65mm approximately and ended up with a deflection of 2.6913mm which is off our calculated defection by 0.0313mm. Our Beam met the criteria of a deflection between 2mm and 5.5mm which was the new criteria set in week 5 when we had to remodel the beam. Team I was the only other team that met the criteria, they also used a I beam with a volume of$180160 mm^3$. They used 4 6.5x6.5 beams to make their I beam. Comparatively we were able to achieve a smaller deflection while also using less materials which led to a smaller overall volume.

5. Comparison of Results:

There were many design types used by groups in the tutorial 15 class. The types of beams designed by the groups include channel cross beam, I beam and the box beam. The I beam and box beam were the most popular choices among the groups, due to the fact that the I beam can be created by using the least amount of materials while still being strong enough to support the criteria that was set for it to support 3.5kg (34.3N) while maintaining a deflection between 2mm and 5.5mm.

Group A used the channel cross beam design that did not meet the criteria. The volume of materials used was the lowest at $86130mm^3$. Group B (we) chose the I beam design, our design met the criteria that was given. The only issue with the beam was that our group used slightly more materials than designs by other groups. However, our design measured a deflection of 2.6913mm which was only off by 0.0313mm off what we had calculated before the simulated results. Group C used an I beam design as well, however their beam did not meet the criteria.

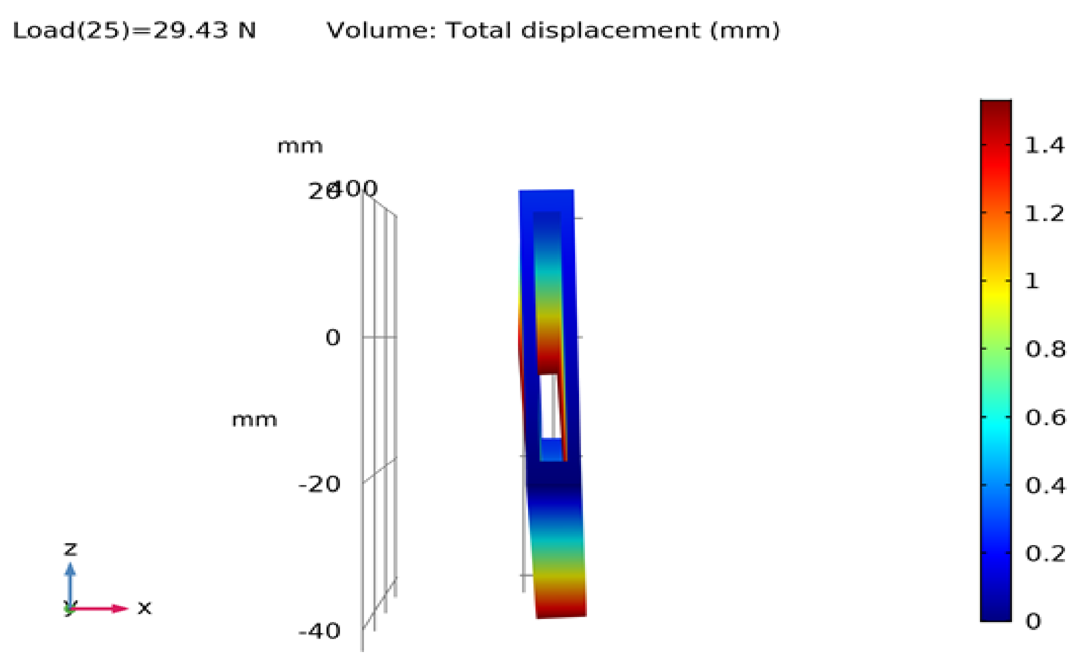


Figure 6: Group A's Beam

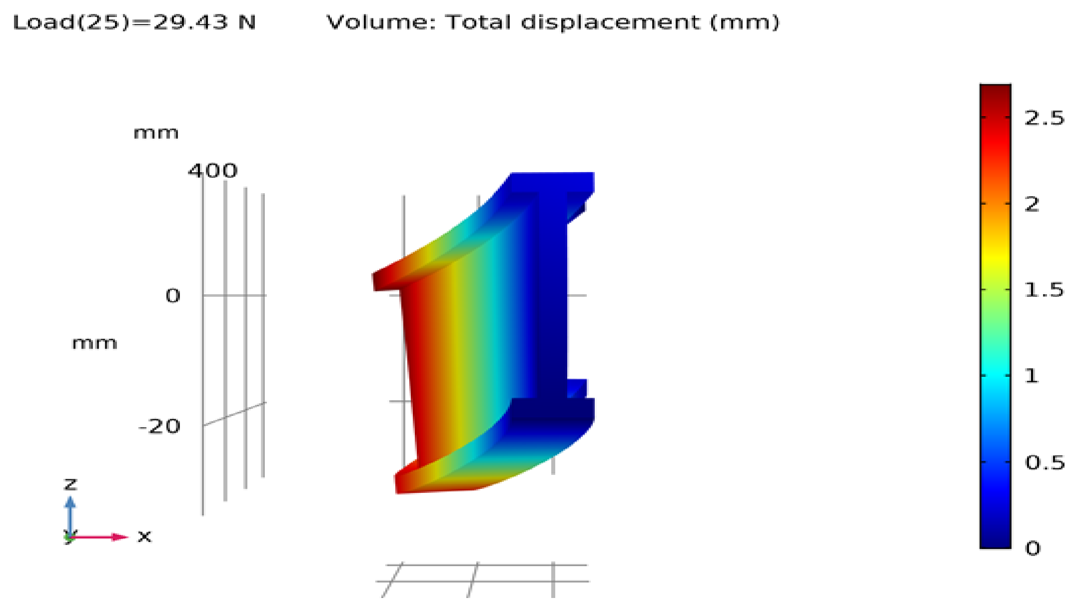


Figure 7: Group B's Beam

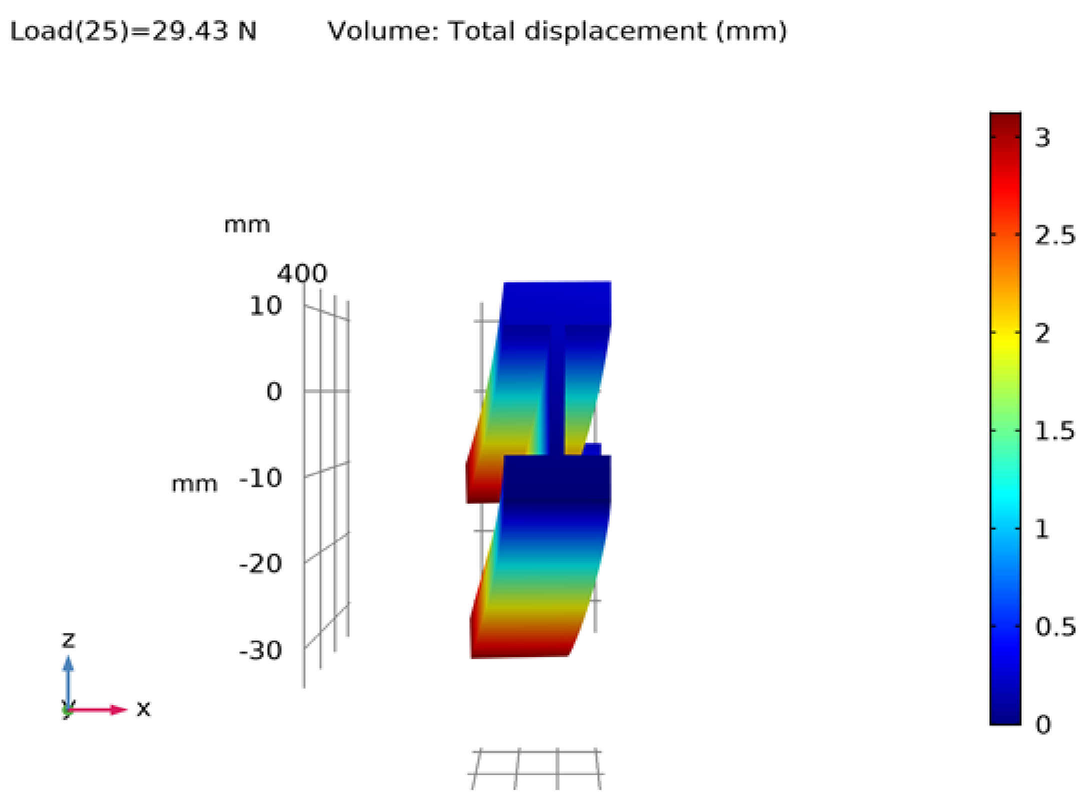


Figure 8: Group I's Beam

As you can see from the simulations above group A like many other groups either made a mistake in their calculations or some other mistake by perhaps misinterpreting how the added 0.5 kg and extra 40mm would affect their previous results. These groups made their beams too strong and not flexible enough to meet the criteria. On the other hand there were 2 groups that were able to meet the criteria being our group B and group i. Both groups made i beams but as you can see in the simulation the material used for group is much greater than Group B.

6. Reflection:

Although every group made changes to their designs, the designs of only two out of 10 groups met the criteria. This meant that the beams designed by 8 groups weren't strong enough or they were way too strong.

Our beam was constructed by cutting the 1.5 x 75 x 900mm balsa sheet into half which reduced the width to 37.5mm and the length to 680mm. Both pieces were then attached to each other using an adhesive in order to increase the thickness of the beam and make it narrower. After the adhesive had set, four 3x3mm rectangular sections were attached to all four corners using the same adhesive in order to provide vertical stability and additional strength horizontally on the beam.

I beams are designed in a way to have a large surface area of material at the top of the beam (where the most stress is experienced) and at the bottom of the beam (where most of the strain is experienced). This is because stress is calculated by force over area (F) therefore to use the material in the most efficient way the beam should look like the image below.

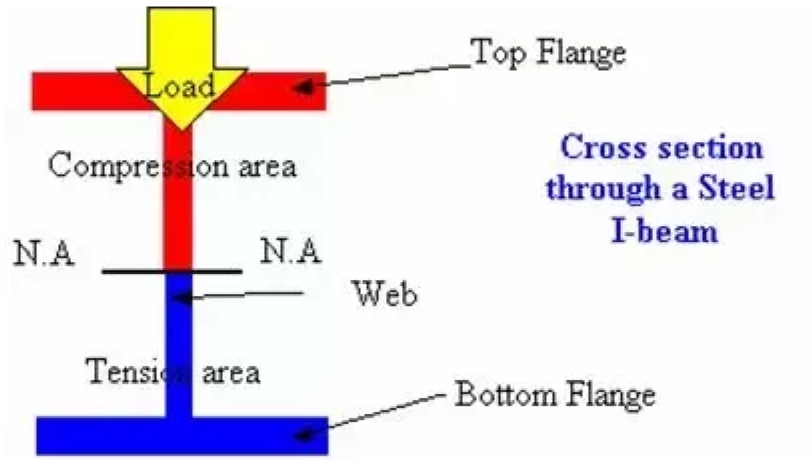


Figure 9: Load on an I-Beam (1)

The design for our beam was similar to groups C and I who also used the I beam as their final designs. However, all these beams were designed in different ways which resulted in the various range of deflections.

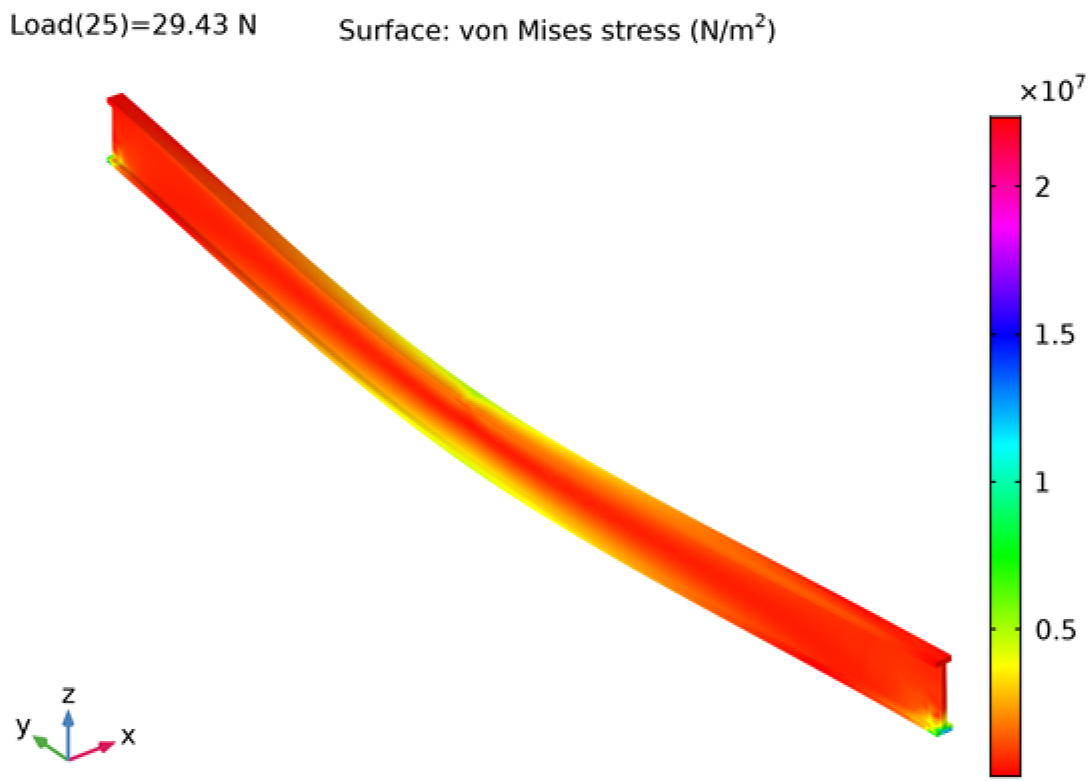


Figure 10: Deflection for Group B's beam

This is a simulation of our beam that shows how the i beam works with the yellow parts having the greatest stress at the top and body face of the beam. This allows for a strong design with a low amount of material by dieverting the stress to the strongest parts of the beam being the top and bottom faces. The shape of the I-Beam makes it excellent for unidirectional bending when a direct force is applied to its face. This design ensures that the beam is more likely to bend instead of buckling.

Although this is where a box beam would have an advantage over a I beam. Box beams can cope with multiple forces from different directions including a twisting force. Where I beams are designed to only cope with one direct force to its top face. Although this was a controlled test with only one direct force therefore in terms of material usage, fabrication effort and strength the I beam is the superior design.

(2) ‘balsa wood has an excellent stiffness-to-weight and strength-to-weight ratio as well as great energy absorption characteristics’. This is because of the material's molecular makeup of hexagonal cross sections that allow it to have a large elastic region before plastic deformation. Which means it can flex in a way that allows us to meet the cretia with the correct design. The amount of flex a material has is based on young modulus, balsa’s stiffness is between 2.55 - 3.17 GPa which as u can see in the figure below is very low compared to other materials such as ceramics that have up to 1000 GPa. Our group simulated our results using a 3.1 young's modulus other groups may have used different values which makes some of the designs more difficult to compare

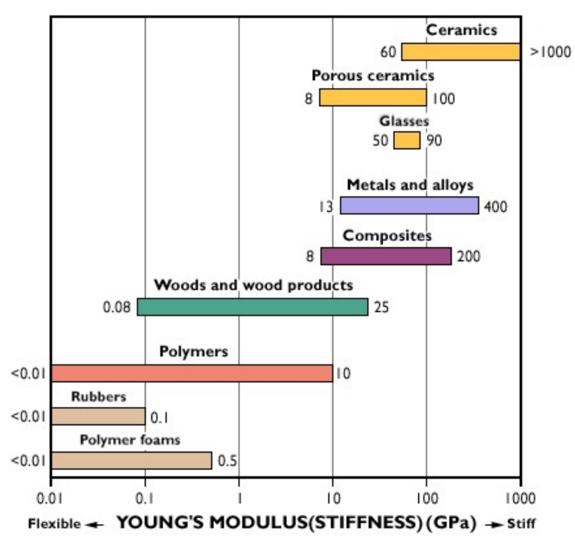


Figure 11: Young’s Modulus in different materials (3)

7. Teamwork Reflection:

Since the start of project 1B our group has progressively worked on the report volunteering to work on different sections in turn motivating each other to match each other's efforts. In terms of the results of our beam we are quite happy to be one of the 2 groups that were actually able to meet the criteria requirements. On top of that our team calculated deflection very close to the results simulation suggesting we had worked effectively. Our team has group chats that we have constantly been communicating in a friendly manner back and forth with. The trust and strong bond we have formed as a group has allowed for us to complete an effective report with a combined effort.

Teamwork skills

Teamwork skills are extremely important if one wants to be successful in a team. These can include making sure that everyone has an equal opportunity to convey their ideas towards the other members of the team and also making sure all the ideas and concepts are understood by every member in the group. Group B worked extremely hard to learn and improve our teamwork skills in order to ensure that the group is successful.

Communication

Our group is constantly communicating with each other through a group chat enabling us to become good friends and work effectively on our ENGG102 projects.

Leadership

Leadership is also extremely important in a team environment. Although our group has many similarities some of us are better suited at different skills therefore we effectively identified each other's strengths and elected ourselves and each other to work on what we're good at.

Decision making

Whenever it came to a hard decision such as selecting a beam design we often all had a different idea in mind so to come to a decision we took time to listen to each other's ideas and often combined each other's thinking to come up with the effective beam we have now.

Conflict management

There was little to no conflict in our team because we had great communication so there was rarely a misunderstanding or aggressive argument.

Individual statements:

Josh Rochford	I personally thought we all worked great as a team and all put in equal amounts of effort. Yash and Soham were easy to work with and any slight disagreements were quickly sorted out.
Yash Gokhale	I think everyone in this group did a great job. Josh and Soham were really easy to work with and our abilities really complemented each other making a strong foundation to work off.
Soham Thanki	Everyone in the group put in a serious effort to complete the report on time considering how busy everyone was with mid session exams, quizzes and assignments from other subjects. Yash and Josh were extremely easy to work with as they both had similar ideas. Their abilities were also extremely integral in order to complete this assignment.

8. Conclusion:

To summarise, in Project 1B we initially had to design a beam that would have a deflection between 1mm and 5.5mm when a 2.5 kilogram load is applied to it. Our group came up with three preliminary designs, a I beam, an Box Beam, and a Channel Cross Beam. After thorough research and calculation we decided to go with the I beam as it produced the smallest deflection with either the least or the same amount of materials used when compared to the other ideas. In the week 5 redesign we decided to use the 3x3 small beams instead of the 5x5 beams as we had to meet the new criteria of a deflection between 2mm and 5.5mm when a load of 3kilograms was applied to the beam. We did this to make the beam weaker so it will be able to meet the 2mm deflection criteria. After redesigning we calculated our deflection and our predicted deflection came out to be approximately 2.6mm. The measured value came out to be 2.6913mm which was off our predicted deflection by 0.09mm. Out of all the Groups only two groups met the new criteria, Our Group and Group I who also used an I beam. Although Group I used more materials than us and ended up with a good beam which met the criteria but at the same time it was not the most efficient Beam. Overall we believe our group had the best beam in comparison to the other designs in meeting the criteria which we believe is a product of our team's hard work and inclusive effort.

9. References:

Reference number	**Source**
1	https://www.quora.com/Why-is-an-I-beam-shaped-the-way-it-is-How-did-an-I-beams-eventual-final-design-come-to-fulfill-its-primary-function Why is an I-beam shaped the way it is?
2	http://www-materials.eng.cam.ac.uk/mpsite/properties/non-IE/stiffness.html Www-materials.eng.cam.ac.uk. 2020. *Property Information*. [online] Available at: <http://www-materials.eng.cam.ac.uk/mpsite/properties/non-IE/stiffness.html> [Accessed 1 May 2020].
3	http://www-materials.eng.cam.ac.uk/mpsite/properties/non-IE/stiffness.html Www-materials.eng.cam.ac.uk. 2020. *Property Information*. [online] Available at: <http://www-materials.eng.cam.ac.uk/mpsite/properties/non-IE/stiffness.html> [Accessed 29 April 2020].
4	Simulations generated from a Comsol application built for ENGG102 at UOW
5	Information and ideas from our team's previous reports 1B draft and 1A
6	https://www.cmrp.com/blog/faq/analysis-design/exploring-stress-strain-curve-mild-steel.html eleastic and plastic deformation The Chicago Curve. 2020. *Exploring The Stress / Strain Curve For Mild Steel - The Chicago Curve*. [online] Available at: <https://www.cmrp.com/blog/faq/analysis-design/exploring-stress-strain-curve-mild-steel.html> [Accessed 30 April 2020].
7	https://www.sciencedirect.com/science/article/pii/S0020768307002727 properties of balsa wood

10. Appendix A: Minutes of team meetings (evidence of teamwork)

Project: Balsa Beam Report 1B	
Purpose: Balsa beam to support 3kg over 650mm	
Place: Zoom meetings and Facebook Group Chat	Meeting date(s): 24/04/20 28/04/20 30/04/20 03/05/20 04/05/20
Attendance: Soham Thanki Yash Gokhale Joshua Rochford	Minutes Issued to: All Attendees Meeting times: 2 hours

Item	Subject	Action	Date

1.	**Planning of Beams** Young's Modulus Experiment Designing Preliminary beam Young's Modulus Averages Designing Final Beam Deflection Calculation	All Attendees	28/04/20
2.	**Making Beam** Cutting up the balsa Gluing the wood together	All Attendees	30/04/20
3.	**Testing Balsa** Simulation	All Attendees	03/05/20
4.	**Writing up report** Statement of purpose Design of Preliminary beam Design of final beam Results table Reflection Mapping of learning outcomes Conclusion Teamwork Reflection	All Attendees	04/05/20

Appendix B: A completed copy of the Team Ground Rules Contract Form

ENGG102 Team Ground Rules and Contract Form

For a team to be effective it is a requirement that all team members understand their responsibilities to one another. It can be useful to discuss and agree on certain project ground rules.

All team members agree to -

1. Come to class and team meetings on time.
2. Come to meetings with assignments and other necessary preparations done.
3. Respect one another.
4. Help each other when the need arises.
5. Show up within 15 minutes after the time set for the meeting (if running late) or else they get a strike.
6. Message in advance (at least 2 hours) if they are unable to make it to the meeting. The meeting will then be rescheduled to another date.

If a team member fails to meet these ground rules, other members are expected to take the following actions -

Step 1: Each member gets 3 strikes, after their third strike they have to bring snacks to the next meeting or buy snacks for the other members of the team at Unibar.

If not resolved – Tell the tutor about it

Step 2: Bring the issue to the attention of tutor

Agree with tutor, actions to be taken -

If still not resolved – Teammate is banned from all group activities and SparkPlus review will show that he has done no work

Step 3: Meet as a group with your Tutor and if necessary, your Subject coordinator.

Tutorial Number: 15

Team: B

Member signatures:

1. Soham Thanki:

2. Yash Gokhale:

3. Joshua Rochford:

Appendix C: Young's Modulus Excel sheet

ENGG102	Week 3		Tutorial Number			Group Number		Date of Experiment	
Members	Name	Yash			Name	Josh		Name	Soham
Tutor's Name	Manish								

Horizontal Beam

L	L^3	b	h	I	M	P = M*9.81m/s^2	Deflection δ	Youngs Modulus
(mm)	(mm^3)	(mm)	(mm)	(mm^4)	(kg)	(N)	(mm)	Pa
240	13824000	13	6.5	1190	0	0	0	0.3022
240	13824000	13	6.5	1190	0.05	0.4905	0.16	
240	13824000	13	6.5	1190	0.1	0.981	0.35	
240	13824000	13	6.5	1190	0.15	1.4715	0.51	
240	13824000	13	6.5	1190	0.2	1.962	0.655	
240	13824000	13	6.5	1190	0.25	2.4525	0.72	
240	13824000	13	6.5	1190	0.3	2.943	0.88	
240	13824000	13	6.5	1190	0.35	3.4335	1.115	
240	13824000	13	6.5	1190	0.4	3.924	1.19	
240	13824000	13	6.5	1190	0.45	4.4145	1.47	
240	13824000	13	6.5	1190	0.5	4.905	1.515	

Vertical Beam

L	L^3	b	h	I	M	P = M*9.81m/s^2	Deflection δ	Youngs Modulus
(mm)	(mm^3)	(mm)	(mm)	(mm^4)	(kg)	(N)	(mm)	Pa
240	13824000	6.5	13	297.51	0	0	0	0.0855
240	13824000	6.5	13	297.51	0.05	0.4905	0.04	
240	13824000	6.5	13	297.51	0.1	0.981	0.08	
240	13824000	6.5	13	297.51	0.15	1.4715	0.125	
240	13824000	6.5	13	297.51	0.2	1.962	0.17	
240	13824000	6.5	13	297.51	0.25	2.4525	0.21	
240	13824000	6.5	13	297.51	0.3	2.943	0.24	
240	13824000	6.5	13	297.51	0.35	3.4335	0.31	
240	13824000	6.5	13	297.51	0.4	3.924	0.33	
240	13824000	6.5	13	297.51	0.45	4.4145	0.37	
240	13824000	6.5	13	297.51	0.5	4.905	0.39