UNIVERSITY OF WOLLONGONG IN DUBAI

Laboratory Session 3: (Group 4) Project 1 Attempt B - Determine the Young's Modulus for Balsa

Family Name:				
First Name:				
Student Number:				
Student Submitting				

Subject number and name:	ENGG102 - Fundamentals of Engineering Mechanics
Subject coordinator:	Dr. Umar Asghar
Title of Assignment:	Project 1 Attempt B - Determine the Young's Modulus for Balsa
Date and time due:	15-02-2024
Lab Number:	1.53
Tutor Name:	Mr. Ahmed Mohamed
Total number of pages:	15

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 be posted 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 your 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 its 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 the report. Include the main results, both numerical and qualitative.	/5
Total		/100

Content Table:

Statement of Purpose

The primary goal of this report is to redesign a balsa wood beam design that, using computed values for cross-sectional area, second moment of inertia, and deflection, can support a central weight of 2.5 kg (24.5 N) across a 400mm span. The chosen design will be built in a way to meet the specified deflection, length, and height requirements through this selection process. The beam must deflect within the given range, which is between 1.0 and 6.5 mm. The maximum height and width for the beam are 75 mm and 50 mm, respectively.

Subsequently, the theoretical or computational values will be compared with the experimental outcomes obtained from testing the selected beam design. The purpose of this comparison is to ascertain the extent to which these mathematical projections hold up in real-world applications, providing important insights into the dependability of performance beam operations. The I beam and the Box beam, which both fit the requirements, were the only two suitable options for the beam's structure after extensive study and computations. An I-beam proved to be the superior choice. This lab helped to provide knowledge about the engineering decision-making process, demonstrate problem-solving abilities, and demonstrate collaboration when addressing complex structural issues.

Preliminary Designs

To construct the beam, two designs were chosen; an I beam and a Box beam. The beams were chosen due to their relative ease of construction, less volume requirement and ability to hold the specified load without reaching the fracture point.

The I beam would be designed with a base of 20mm and a height of 15mm. The flanges would have a width of 20mm and a height of 5mm, whereas the web would have a cross-section of 5mm x 5mm. With this design, the second moment of inertia would have been 5468 mm^4 and the deflection would have been 1.21 mm, which would perfectly fit the deflection requirements.
This design would be constructed solely from the large balsa beam sheet with measurements 100mm x 5mm x 910mm. Over a span of 400mm, this beam would have a total volume of 90,000mm^3.

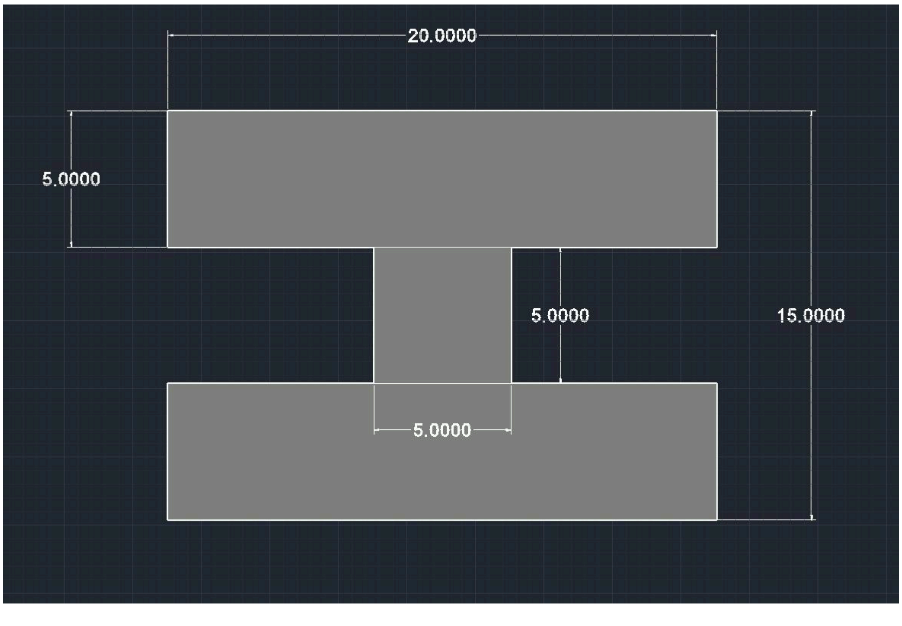


Figure 1: I Beam Preliminary Design

The box beam would have a total width of 20mm and a height of 14mm. It would consist of two pieces with width 20mm and height 5mm, alongside two piece width 4mm and height 8mm. This design would bring down the moment of inertia to 4552 mm^4 and would increase the deflection to 1.46mm, which would still meet the deflection requirements. This design would be constructed from the large balsa beam sheet with measurements 100mm x 5mm x 910mm, and one piece of a balsa beam rod measuring 8mm x 8mm x 1000mm. Over a span of 400mm, this beam would have a total volume of 105,600mm^3.

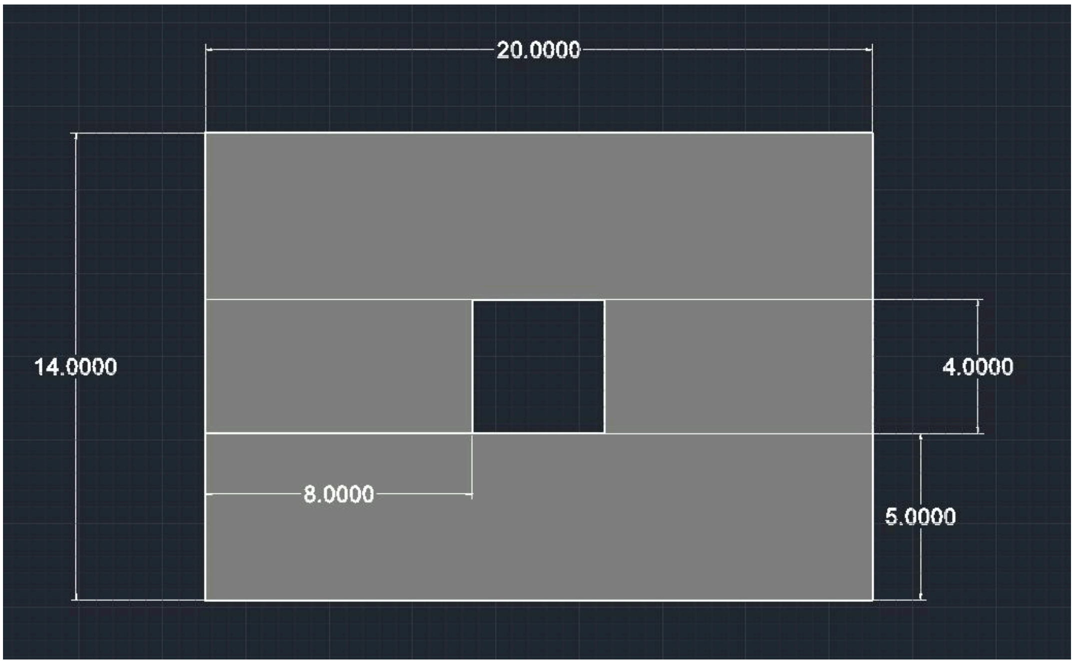


Figure 2: Box Beam Preliminary Design

Calculations for Preliminary Designs

P	**L^3**	**E**		**b**	**h**	**t_w**	**t_f**		**I**	**δ**
N	**mm**	**MPa**		**mm**	**mm**	**mm**	**mm**		**mm^4**	**mm**
24.525	64,000,000	4926.3		20	15	5	5		55468.75	1.21

Table 1: Calculations for preliminary I beam

P	**L^3**	**E**		**b**	**h**	**$2t_w$**	**$2t_f$**		**I**	**δ**
N	**mm**	**MPa**		**mm**	**mm**	**mm**	**mm**		**mm^4**	**mm**
24.525	64,000,000	4926.3		20	14	16	10		4552	1.46

Table 2: Calculations for preliminary Box beam

Chosen Concept

The final concept of choice was the I beam, due its fabrication being a lot simpler than the Box beam whilst using fewer resources. The fabrication was easier for an I beam due to the simplicity of cutting the wood pieces into the required sizes without needing extreme precision as for the Box beam, some parts had to be cut into very small pieces which are unachievable with the box cutter provided. Additionally, the I beam had a lower volume than the box beam, which was recommended.

Additional advantages of the I beam include even weight distribution and high load resistance. On the other hand, the Box beam has the benefits like high durability but that come with cost of using more materials for fabrication and can also prevent the beam from achieving the required deflection.[1, 2]

Optimized Beam

After choosing an I beam, the beam had to be optimized to ensure that it would not fail experimentally. To do this, the flexibility of the wood was tested manually to get a *feel* of how strong the beam would be. During discussions, it was realized that the beam would not hold up to the load and would reach its fracture point prematurely. Thus, it was decided to increase the height of the beam to ensure that the beam would not fail.
However, this increased the second moment of inertia, which in turn decreased the theoretical deflection and caused it to fall below the range of deflection required. Despite this, the team decided to go ahead as the team believed the calculated Young's Modulus was unusually high, since Balsa Wood has a Young's Modulus from 3000 to 3100 MPa. [3, 4] This meant that the experimental deflection would be incredibly higher than the theoretical deflection, and it would be near impossible to set dimensions that met the requirements set forth for the beam.

P	**L^3**	**E**		**b**	**h**	**t_w**	**t_f**		**I**	**δ**
N	**mm**	**MPa**		**mm**	**mm**	**mm**	**mm**		**mm^4**	**mm**
24.525	64,000,000	4926.3		20	25	5	10		25885.4	0.26

Table 3: Calculations for optimized I beam

Description

The optimized beam's dimensions were:

- Flanges: 20mm x 10mm x 400mm
- Web: 5mm x 5mm x 400mm

The web was placed at the center of base, with approximately 7.5mm of distance from either edge of the beam. Great care was taken to ensure that the web was aligned properly in place and was equidistant from the edges of the beam.

The beam was made solely from the large balsa beam sheet with measurements 100mm x 5mm x 910mm, cut into widths of 20mm for the flanges and 5mm for the web. To increase the height, two 20mm pieces were hot glued together. The decision to use only the balsa sheet was due to efforts to reduce the volume while simultaneously reducing wastage of materials. The volume for this design summed up to 176900 mm^3.

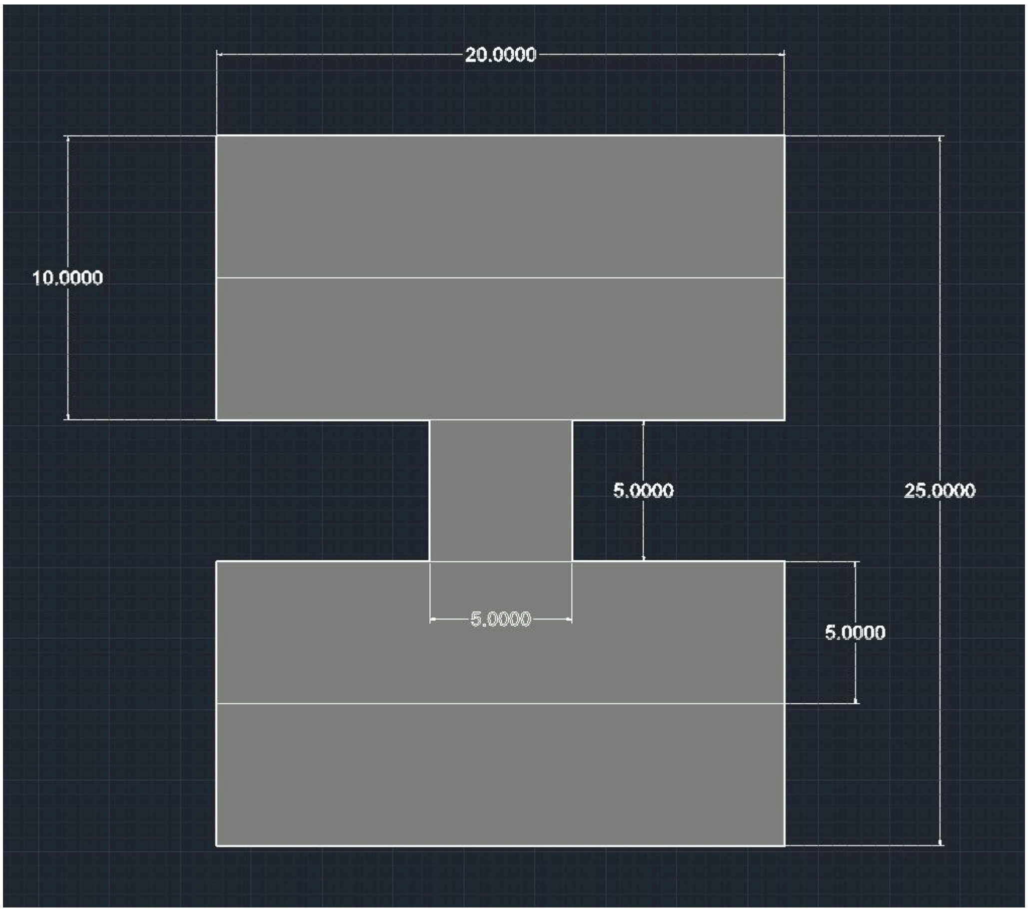


Figure 3: Optimized I beam - Final Design

Figure 4: Optimized I beam - Constructed cross-sectional view

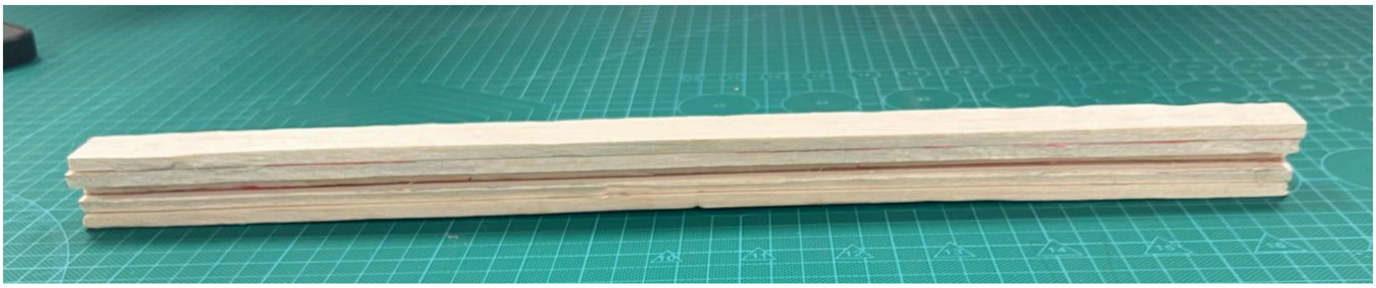


Figure 5: Optimized I beam - Side view

Results

Team	Beam Type	Deflection (mm)	Met Criteria (y/n)	Volume (mm^3)	Fabrication Effort
1	I Beam	8.25	N	72,800	Medium
2	C Beam	4.88	Y	66,000	Medium
3	I Beam	1.99	Y	209,600	High
4	I Beam	4.45	Y	176,900	High
5	I Beam	2.56	Y	106,750	High
6	I Beam	2.03	Y	140,000	Medium

Table 4: Results for Lab session

Comparison with other teams

To begin, the beam types used by the teams differ, with a combination of I and C beams being used. Particularly, Teams 1, 3, 4, 5, and 6 selected an I beam, whereas Team 2 opted for a C beam. This selection may reflect a variety of strategies or preferences among team members concerning beam type appropriateness for their respective projects.

Deflection measurements vary significantly between teams. For example, team 1 had the greatest deflection at 8.25 mm, indicating potential structural problems or inefficiency in their design. Team 3 accomplished a remarkably low deflection of 1.99 mm, indicating a strong and well-engineered solution. Teams 4, 5, and 6 also achieved low deflections, indicating efficient engineering and manufacturing processes.

The criteria for determining whether the deflection measurements met the standards set forth varied. Notably, teams 2, 3, 4, 5, and 6 all achieved the required deflections. Unfortunately team 1 was unsuccessful in meeting the requirements.

A direct link between the volume, deflection and beam type could not be established, since different types of beams with different volumes met the criteria, whereas one failed. Team 1 had an I beam, similar to 4 other teams, and it did not have the lowest volume. However, their beam failed to deflect within the range. This could indicate serious issues with the structure, such as weakened wood or less use of glue.

The beam volumes varied significantly among teams, with values ranging from 66,000 to 209,600 cubic millimeters. This variation is most likely due to variations in design philosophies and optimization techniques used by the teams. Furthermore, the fabrication effort differed, with some teams working at a medium level and others at a high level. The variation could be linked to design complexity and team expertise.

Reflection

Initial Response and Design Calculations

With regards to the beam built in Week 1 - 2, designs and ideas were only based on assumptions due to lack of understanding of how beams react under load, rather than proper methodology that is based on scientific evidence. Through the weeks, and as the team developed more knowledge on concepts like moment of inertia, maximum bending moment, maximum stress and other factors that would contribute to an effective beam, the team succeeded in solving the exact problem with less amount of time and fabricating a design that not only meet the requirements but also deflects precisely, all dependent on calculations and accurate measurements.
Generalizing a scientific approach for dealing with any design problem would save time and effort and reduce any chances of errors. This can be applied by first understanding how the system behaves, analyzing both internal and external variables and applying relevant formulas to calculate for an ideal solution.

Building the Beam

Some difficulties were encountered in the first attempt of building the beam. This included limited precision of measurements while cutting the balsa sheets for flanges and web and rods that would have some imprecise cuts that eventually altered theoretical values and affected the properties of the beam. Moreover, assembling parts required careful attention, as aligning parts perfectly and securing them in place was challenging and time-consuming.
To address these concerns in this attempt, the team made several improvements. The team decided on using better tools and equipment to ensure cutting accuracy. Additionally, the assembly process was broken down into smaller, more manageable steps.

Beam Performance

The beam I, with dimensions 100mm x 5mm x 910mm, cut into widths of 20mm and heights of 10mm for the flanges and 5mmx5mm for the web, met the criteria. This may be due to its low volume as a high deflection was common amongst other beams with low volumes or volumes with the range of I beam of choice. This is possibly due to the beam having less material that could resist bending. Additionally, thickness played an important part when it came to deflection, as when it was increased during calculations, deflection increased as well. This furtherly proves that volume is inversely proportional to deflection.

Understanding of Beam Behavior

Lack of knowledge and understanding the mechanical perspective was the major gap in the team's first attempt, which resulted in massive breaches in solving design problems. However, over the past weeks, lab sessions have enhanced and proven (in real-life applications) topics covered during lecture classes, mainly about internal forces of beams under external loads supported at either or both ends, as well as how dimensions contribute to moment of inertia (the quantity expressed by the body resisting rotation), which indicates the beam's deflection.
Analyzing more complex forms of forces for different types of beams and referring to mechanical books would help to fill any doubts about structural engineering and beam behavior.

Relative Performance of Beams

The beams for this Lab consisted mostly of I beams and a C beam. All the beams shared a similar level of difficulty of fabrication, around medium to hard, which can hint to how difficult it can be to manufacture the parts needed for fabrication from the parts provided as to meet deflection requirements. The I beams share a common factor relating to volume, as they all share a high volume otherwise they may not meet criteria like beam of group 1, while group 2 met criteria with their C beam even though it has a smaller volume. This could hint to the C beam being the ideal choice of beams. Furthermore, the I beams that shared similar volume had similar deflection which may be a key behavior of the beam, meaning that its volume is inversely proportional to its deflection.

Self-Reflection on team's performance

Anon: When I reflect back on the team's performance, I see how well it fits the models of teamwork that were covered in the first-week lecture, the Smith e-reading, and the Engineering Your Future reference book by Dowling et al. Our group showed excellent communication skills, setting clear goals and providing frequent status reports. The team worked well together and respected one another because each member brought their special talents and knowledge to the task. Nonetheless, there were times when it was difficult for us to resolve disputes and coordinate work. Going forward, I think we can get better by putting time management and conflict resolution strategies into practice. Our team's performance as a whole shows an equilibrium between individual effort and group efforts towards reaching our shared objectives, and I am optimistic that it will keep getting better for upcoming projects.

Anon: Reflecting on this lab work, I noticed that the team has split into specific roles that are ideal for each of their interests and skills. This ultimately helped us achieve the required task and construct a beam that is capable of meeting the requirements in a short period of time without any accidents or mistakes happening. This also educated me about the importance of planning beforehand as that can shorten the time taken ultimately providing more time to improve on smaller details.

Anon: As I go back to reflect on our team work during the meetings and lab work, I believe that Although we performed well together as a team, there is always room for development. The main challenge was balancing discussion and practical tasks. Although we completed our tasks within the designated timeframe, discussions often extended due to creativity and plan modifications. However, our team excelled in effective communication, mutual respect, and attentive listening. We also demonstrated adaptability. In the end, the project's overall success was greatly aided by our teamwork, which was directed by the ideas presented in our readings and lectures which greatly increased project efficiency.

Anon: This Lab educated me about effective planning and teamwork. Through the combined efforts of each member; criteria was met, the beam was constructed in a short period, accidents were avoided and knowledge had been gained. This will help us improve our work performance in coming labs and our skills with using the tools.

Commentary on team's performance

The team split was into sections relating to each members' proficiency in the task to be done and their preferred category of work. This resulted in an organized and time effective workflow which ultimately aided in meeting the beam requirements within the labs time limit.

Roles of each member:

- Anon: Outlining dimensions required for the beam by sketching them on the wood parts.

- Anon: Cutting the wooden pieces according to outlined dimensions.
- Anon: Hot Gluing the pieces together and attaching them.
- Anon: Stabilizing beam and assisting teammates

A continuous workflow was maintained during the lab due to our strategic plan making during our meetings which helped in overcoming the high fabrication effort and ensured that the workload was equally distributed among the members.

Conclusion

When deciding on a beam design during the preliminary phase, it was decided that the ideal choice is an I beam due to its ease of fabrication and material sustainability. The experimental results from teams demonstrate variations in beam types, deflections, volumes, and fabrication efforts. There are errors to be considered, which are caused by the previous lab. The cause may arise from the excess use of hot glue, which heavily affected the values received for the theoretical deflection. This however was avoided thanks to the hypothesis of the beam over deflecting. This ultimately resulted in changes in the volume which resulted in below requirement theoretical value of deflection as to meet the experimental deflection values.

References

- [1]I. S. East, "I Beam Strength," *Intsel Steel/Bushwick Metals*, Apr. 10, 2023. https://www.bushwickmetals.com/i-beam-strength/ (accessed Feb. 13, 2024).
- [2]7931-weblinx, "I-Beam Levels vs. Box Beam: What's the Difference?," *Keson*, Oct. 18, 2019. https://www.keson.com/i-beam-levels-vs-box-beam-whats-the-difference/ (accessed Feb. 13, 2024).
- [3] "(PDF) A review of factors that affect the static Load-Bearing Capacity of Urban trees," *ResearchGate*, Jan. 01, 2014. Available: https://www.researchgate.net/publication/317215849_A_review_of_factors_that_affect_the_static_load-_bearing_capacity_of_urban_trees
- [4] "Balsa :: MakeItFrom.com," May 30, 2020. Available: https://www.makeitfrom.com/material-properties/Balsa

Appendix A: Minutes of team meetings

Meeting 1

Date: 06-02-2024
Time: 5:00pm - 6:00pm
Purpose: Discuss the roles of each member and the fabrication dimensions of the beam.
Attendance:

Names:	Present	Late	Absent
	x		
	x		
	x		
	x		

A list of actions:

- Anon
    - Document preparation
    - Sources of error
    - Beam Performance
        - Due by: Friday, 09/02/2024
- Anon
    - Calculations
    - Fabrication
        - Due by: Friday, 09/02/2024
- Anon:
    - Preliminary Designs
    - Preliminary Design Calculations
    - Optimization of Beam
    - Description of Beam
    - Comparison of Results
        - Due by: Friday, 09/02/2024
- Anon:
    - Statement of purpose
    - CAD diagrams and sketches
        - Due by:Friday, 09/02/2024

Follow up: Target met by each member within time limit and discussions have been conducted within meetings with no absence from members.
Next meeting: Week 6, 12-02-2024

Meeting 2

Date: 12-02-2024
Time: 5:00pm - 6:00pm
Purpose: Finishing up report and adding pictures or diagrams.
Additionally, meet assessment sheet requirements.
Attendance:

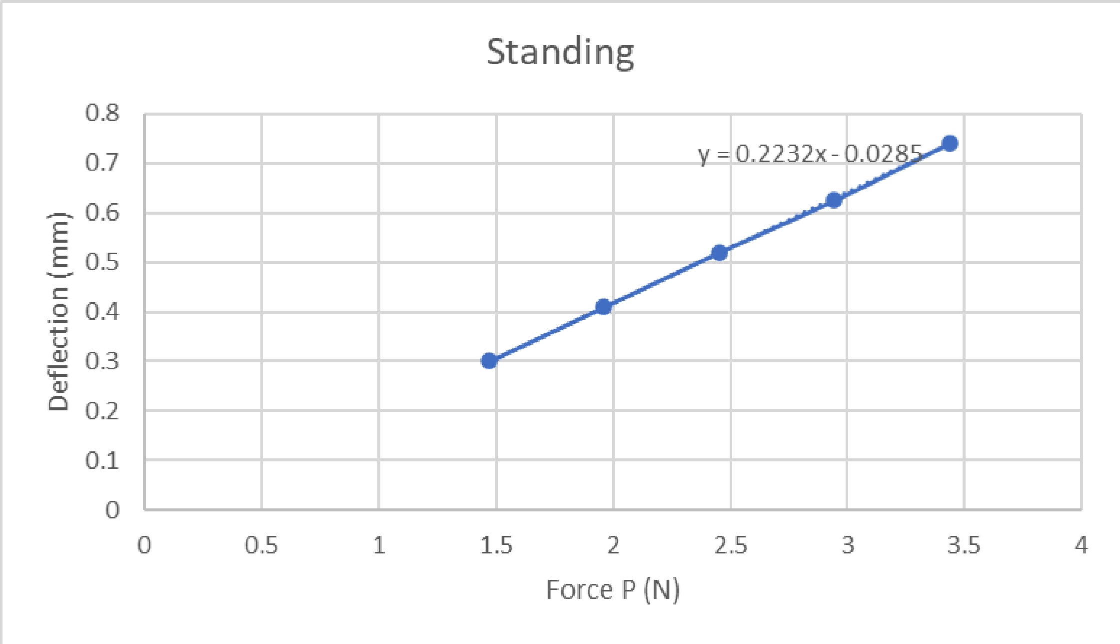
Names:	Present	Late	Absent
	x		
	x		
	x		
	x		

A list of actions:
- Anon:
    - Proofreading
    - Appendix
    - Chosen concept
        - Due by: Tuesday, 13/02/2024
- Anon
    - Reflection
        - Due by: Tuesday, 13/02/2024
- Anon
    - Results
    - Editing
        - Due by: Tuesday, 13/02/2024
- Anon:
    - Conclusion
    - Reflection
        - Due by: Tuesday, 13/02/2024

Follow up: Target met within time limit.
Team Rules:
- Come to class and team meetings on time
- Come to meetings with assignments and other necessary preparations done
- Respect one another
- Help each other when the need arises
- Communication through designated channels
- Maintain a consistent format for fonts and writing style
- Commit to timeline and submit within deadline
- Constructive feedback and assisting fellow members
- Record references used and where they are used
- Follow safety rules and wear gloves whilst when using equipment
- Participate equally on report work

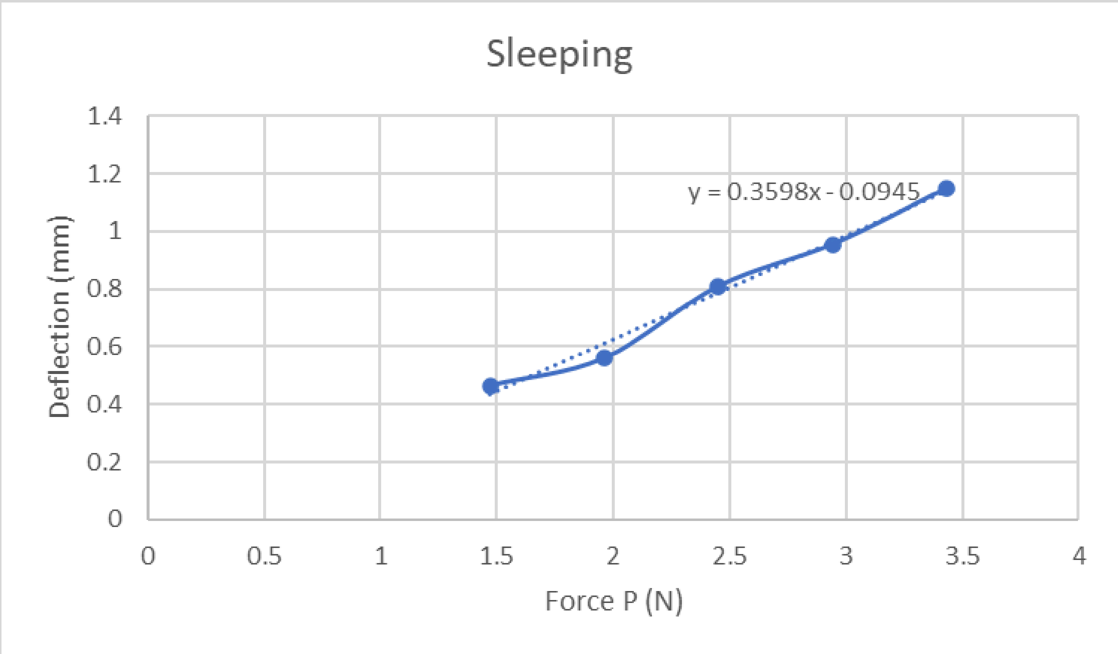
Appendix B: Young's Modulus Experiment

Standing



L	L^3	b	h	I	M	P	Deflection
mm	mm^3	mm	mm	mm^4	kg	N	mm
400	64000000	9	11.9	1263.86925	0.15	1.4715	0.3
400	64000000	9	11.9	1263.86925	0.2	1.962	0.41
400	64000000	9	11.9	1263.86925	0.25	2.4525	0.52
400	64000000	9	11.9	1263.86925	0.3	2.943	0.625
400	64000000	9	11.9	1263.86925	0.35	3.4335	0.74

Sleeping



L	L^3	b	h	I	M	P	Deflection
mm	mm^3	mm	mm	mm^4	kg	N	mm
400	64000000	11.9	9	722.925	0.15	1.4715	0.465
400	64000000	11.9	9	722.925	0.2	1.962	0.56
400	64000000	11.9	9	722.925	0.25	2.4525	0.81
400	64000000	11.9	9	722.925	0.3	2.943	0.955
400	64000000	11.9	9	722.925	0.35	3.4335	1.15

Appendix C: Excel Design

P	L^3	E		b	h	t_w	t_f		I	δ
N	mm	MPa		mm	mm	mm	mm		mm^4	mm
24.525	64,000,000	4926.3		25	20	10	15		16510.4	0.402
24.525	64,000,000	4926.3		25	20	10	10		15416.7	0.431
24.525	64,000,000	4926.3		15	20	10	10		9583.33	0.693
24.525	64,000,000	4926.3		20	15	5	5		55468.75	1.213

Table 1: Calculations for preliminary I beam

P	L^3	E		b	h	$2t_w$	$2t_f$		I	δ
N	mm	MPa		mm	mm	mm	mm		mm^4	mm
24.525	64,000,000	4926.3		30	18	16	10		13982.7	0.475
24.525	64,000,000	4926.3		25	18	16	10		11766	0.564
24.525	64,000,000	4926.3		20	18	16	10		9549.33	0.695
24.525	64,000,000	4926.3		20	14	16	10		4552	1.458

Table 2: Calculations for preliminary Box beam