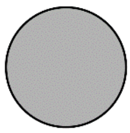
Comparing Beams

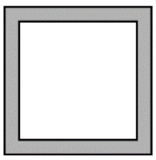
Just as important materials selection is for applications, the shape or geometry of the component and how it responds to external stresses also needs to be considered. In the field of Materials Science and Engineering, we do more than just creating and modifying materials, we also study how different material shapes and application needs impact the material properties. We can study this through physical experimentation or computational simulations using Finite Element Analysis. This experiment will focus on understanding how different beam shapes impacts the strength of materials through physical experimentation using the bending test jig.

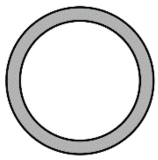
For Stage 6 Engineering Studies, this experiment covers the following syllabus points: P/H1.2, P/H2.1 and P/H3.1

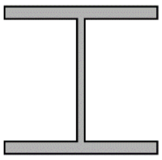
If you look at the any infrastructure around you, buildings, bridges and etc, there will usually be a few different types/shapes of beams used in one large structure. Some of these shapes may include hollow rectangular or cylindrical beams, I-beams or L-beam. Selection of beam shapes depends on their shape and the stress environment.

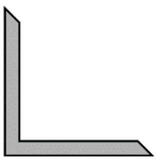

Rectangular bar / plate

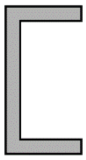

Circular bar / rod

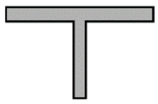

Hollow bar - square


Hollow bar - circle


I beam


L beam


C beam


T beam

The 3-point and 4-point bending tests are useful in studying the changes in bending moment and second moment of area in materials. While tensile, compressive and other forms of mechanical testing can be used to study the mechanical properties of these materials and geometries, the bending test provides more valuable information about the beams and the stresses they will experience during application.

The 3D printed bending test rig design follows the criteria outlined in ISO 178. The material property that can be collected from this set up are the elastic modulus, flexural stress, strain and the bending moment.

1. *Safety:*

Safety in science and engineering is important for everyone, whether you are the one running the experiment or an observer. Understanding methods of fracture and failure is a major component of Materials Science and Engineering. Therefore, with the Bending Test, it is expected some samples will break. To ensure the safety of everyone involved with the experiment, everyone in the room where the Bending Test is being conducted should wear safety glasses and enclosed shoes. Other than the 1-2 persons setting up the experiment – loading the sample, adding weights – other persons should be at least one metre away from the Bending Test jig. If available, a clear acrylic shield should be placed in front of Bending Test jig, with observers standing behind this shield and not to the side.

2. *Method:*

This experiment is about investigating how different beam cross-sections have an effect on the resulting strength of the material and component. This experimental setup is designed to simulate tests that are conducted on materials that will be used as a beam, subjecting the material to typical forces and stresses beams experience during application. The results will provide information about the mechanical properties of the material of that specific cross-section. Comparisons can then be drawn between the same material with different cross-section geometries.

What you need:

- 3D printed Bending Test jig – available at: https://www.thingiverse.com/thing:4609818
- A sample 110 - 130 mm long and no wider than 25cm or thicker than 10mm and you should also be able to bend it fairly easy with your hands. You can use a variety of materials, from plastic, thin sheets of metal, wood and even confectionary, just make sure you avoid brittle materials like glass that are likely to shatter.
- Hanging weights, such as water bottles or metal graded weights.

Testing Procedure:

Ensure safety goggles are worn at all times during the experiment. Be careful of sample fragments flying when the sample fractures.

Jig and Sample Set up

1. Place the Bending Test jig in between 2 tables (to allow space for the ruler and weights to hang), ensuring the jig is stable (using blu-tac to stick the jig down).
2. Place a sample on the jig, centring the sample between the bottom support pins.
3. Insert the ruler and align the 0 marking to the bottom of the sample and stick the ruler to the jig (using blu-tac).
4. Slide the top loading pin onto the sample, centring it between the bottom supports. Thread the string through the bottom of the jig.

Mechanical Property Tests

1. Attach weights to the string connected to the top loading pin until a substantial deflection is observed (approximately 5 mm).
2. Record the weight and resulting deflection by the sample.
3. Repeat for different materials, keeping the weight constant. Observe how the amount of deflection varies between different sample cross-sections for the same weight.
4. Convert weight to force for mechanical property calculations.

Maximum Weight Test – fracture behaviour of materials

1. Use the same sample set up as the previous.
2. Continue adding weights until sample fractures.
3. Observe and describe the appearance of the fracture surface.
4. Repeat for different sample cross-sections.

3. *Results:*

Material	*Elastic Modulus*	*Flexural Stress and Strain*	*Bending Moment*	*Second Moment of Area*
Example: *PLA* *Cross-section area: XXX*				

4. *Discussion:*

Question time!
Question 1: What was interesting about each sample? How do they compare to each other? (Hints: deflection length, elastic modulus, brittle / ductile behaviour)
Question 2: How does the different cross-section profiles effect the stiffness? (Hints: more support, different stress distribution profile)
Question 3: What types of benefits do different cross-section profiles have on their applications? Give examples. (Hint: support beam, vertical pole)
Question 4: What are the sources of errors in this experiment? What are the limitations of this testing method? (Hint: sensitivity of measurements, stiff materials, small scale)

5. *Acknowledgements*

This project builds on the open source 3 point bending test platform created by Stefan Hermann of CNC kitchen. You can download the original files at the link below and check out his YouTube channel for some awesome material science videos relating to 3d printing!

Original files at: https://www.thingiverse.com/thing:3142077

Stefan's YouTube channel: https://www.youtube.com/watch?v=te0Wwf7Dxj4&feature=youtu.be

UNSW
SYDNEY

Example for teachers:

I-beams – great for unidirectional loading parallel along the I direction. the flanges (horizontal section) resist bending moment while the web (vertical section) resist shear forces. The combination of both, overall, increases the stiffness of the beam. However, I-beams are weak against torsional forces (twisting). This makes I-beams great for horizontal loading

Hollow beams (hollow rectangular / circular sections) – the uniform geometry along 2 axis of the cross-section allows for these beams to have high resistance to torsion. This makes hollow beams great as columns.

Other shapes, l, C and T – are also used as supports in structures. With different geometries, the stress profile changes in these beams and they provide strengths in various applications. These shapes are more commonly observed in non-metal beam, i.e. composite and concrete.