MECH1280: Semester 2 Composites Material Testing and Selection: Laboratory Assignment

1) Design Brief

What are the considerations for materials selection?

- Strength (to withstand impact loads up to 1 kN without failure)
- Flexibility (should have some degree of flexibility to **absorb impact energy** and reduce the risk of deformation or fracture upon impact)
- Cost (cost of the material, as well as any potential additional costs ie: replacements)
- Potentially weather resistance (as the barrier is for an outdoor track)

[3 marks]

List the company's specifications.

The barrier needs to absorb energy from an impacting kart:

- Must withstand loads up to 1 kN before failure.
- Withstand Impact speeds of up to 10 km/h.
- Each barrier section must be 1m in length and no higher than 0.5m.
- Must be 10 metres from track perimeter.
- Must be able to absorb some impact energy
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[5 marks]

2) Consideration of Methods

In this laboratory you will carry out a three-point bend test, justify why this is an appropriate test to use to gain the data required.

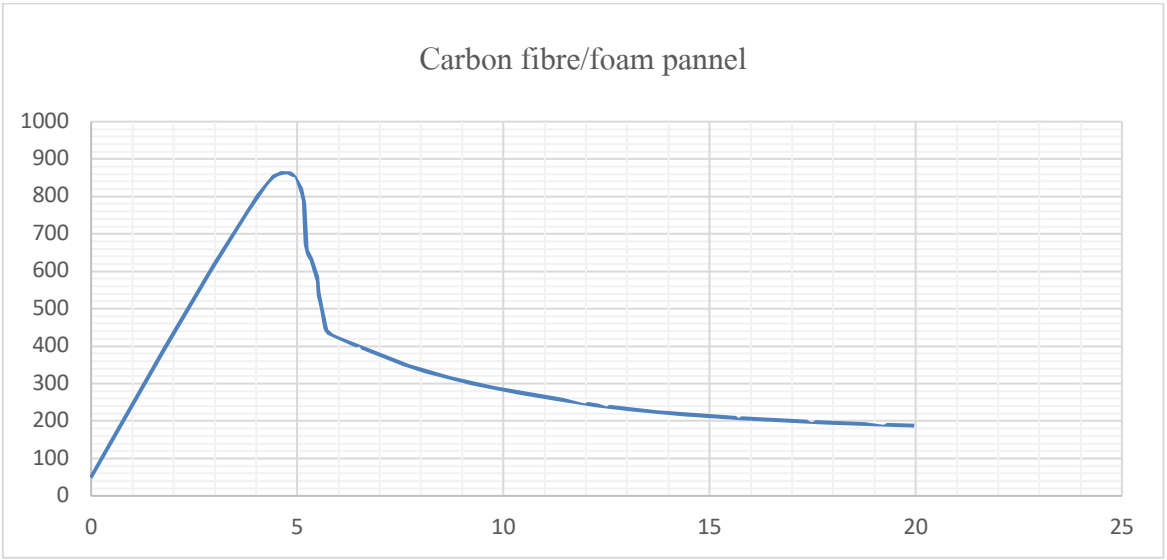
The three-point bend test subjects the material to bending stresses, which simulates the types of loads that the safety barrier will experience in real-world scenarios (head on collisions with go-cart)
It also can provide details of the types of fracture of different matrials which can be useful to find out the material's performance.
The test provides acurate quantitative data (obtained from the Instron machine). This data can be used to measure/calculate the:

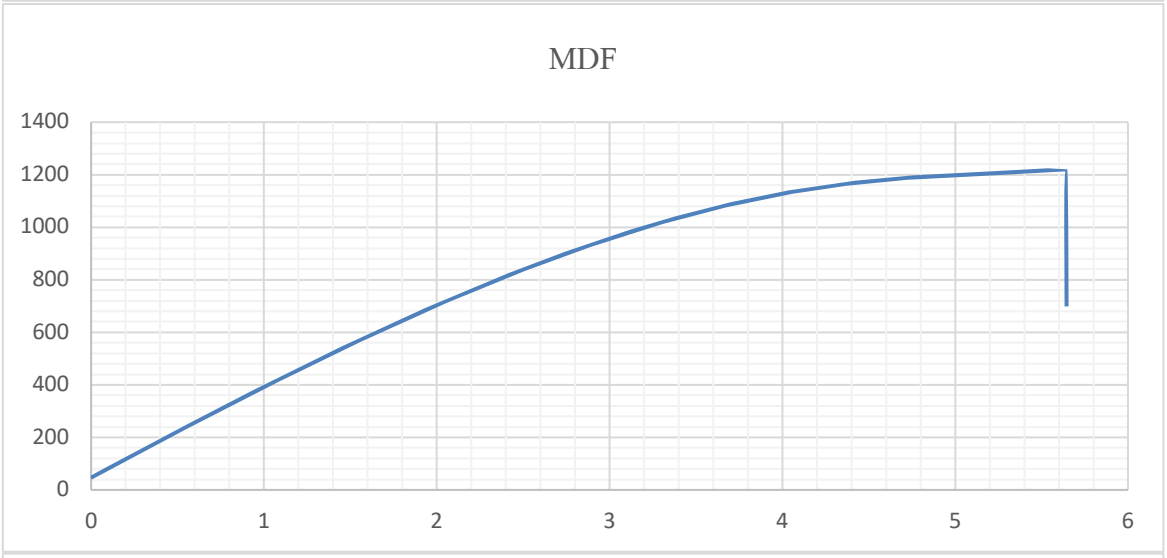
- Maximum failure load
- 2nd moment of area
- flexural strength, strain and modulus.

[3 marks]

3) Experimental Results

NOTE (Applies to all graphs): Y-axis: Load (N); X-axis: Extension (mm)





[3 marks]

Table 1: Data from load/displacement graph

Dimensions/physical description	Carbon fibre/foam pannel	MDF	Plywood
Thickness (d) [mm]	5.80	12.35	12.06
Breadth (b) [mm]	99.92	99.35	99.60
Length between 2 lower supports (L) [mm]	160	160	160
Maximum failure load (F) [N]	864.36	1219.96	3108.73
Displacement at max. failure load (δ) [mm]	4.750	5.638	9.275
Fracture description	No fracture. Carbon fibre coating has bent slightly but no signs of tear	Fracture along the breadth on one side. Other side is only bent but no fracture	Failure on some of the layers but not all

[12 marks]

4) Calculated Material Properties

Complete the table below with the calculated material properties for each material. Show your working solutions in the appendix section.

Table 2: Material properties derived from the test

Material	2nd moment of area (I) or moment of inertia [mm^4]	Material property: Flexural strength (σ_{fs}) [N/m^2]	Material property: Flexural strain at flexural strength (ε_{fs}) [no unit: ratio]	Material property: Flexural modulus (E) [N/m^2]
Carbon fibre/foam panel	1624.633	6.1716 x 10^7	0.006457	9.5580 x 10^9
MDF	15595.077	1.93221 x 10^7	0.016319	1.1840 x 10^9
Plywood	14558.615	5.15039 x 10^7	0.026216	1.9646 x 10^9

[16 marks]

5) Calculate Total Load

Considering the dimensions of the go-kart barrier, what is the failure load for your materials? Show the equations used and working solution below.

Calculations:

$$\text{flexural strength} = \frac{3FL}{2bd^2} \quad \Rightarrow \frac{2\sigma bd^2}{3L} = F \text{ (failure load)}$$

$$\text{Carbon fibre: } \frac{6.1716 \times 10^7 \times 2 \times 0.5 \times 0.0058^2}{3 \times 1} = 692.04\ N$$

$$\text{MDF: } \frac{1.93221 \times 10^7 \times 2 \times 0.5 \times 0.01235^2}{3 \times 1} = 982.35\ N$$

$$\text{Plywood: } \frac{5.15039 \times 10^7 \times 2 \times 0.5 \times 0.01206^2}{3 \times 1} = 2496.97\ N$$

Material: **Carbon Fibre/foam pannel** Failure load: **692 N**
Material: **MDF** Failure load: **982 N**
Material: **Plywood** Failure load: **2 497 N**

[6 marks]

6) Material Selection

Which material that you tested would be most suitable and why?

Plywood: it has the highest failure load (above 1k N) (the other 2 materials had failure loads below 1k N)and has cheapest cost per m^2.

[3 marks]

7) Discussion

Do your own independent research to help answer the questions below.

a) What other materials would you consider for this application and why?

Rubber: highly flexible and impact absorbing, reducing the risk of injury during collision. Rubber is durable and resistant to weathering. It is also very cost effective and easy to install.

Polyethylene foam panel (often used in barriers for F1 circuits with a metal panel in the middle): It absorbs impact energy very well, the material is cheap and can last a very long time. Additionally, it prevents the go kart from bouncing back onto the track.

[5 marks]

b) What other test could have been carried out to help you decide the most suitable material? In your answer specifically state what information could be gained from the test.

Impact tests, which measures the amount of energy absorbed by a material during fracture, would also be an appropriate test (eg Izod impact tests). Energy absorption could be an important safety consideration. Higher energy absorbing materials would prevent harm to the children when colliding with the barrier.

Additionally, since this barrier is for outdoor use, Environmental testing would be a valuable test to make better judgement for the material selection. For example weathering tests and corrosion tests which evaluate durability in conditions such as temperature, moisture and chemical exposure.

[4 marks]

Appendix:

Show your calculations for section 4 below (use additional sheets if necessary).

	2nd Moment of Area	Flexural Strength	Flexural strain	Flexural modulus
Carbon Fibre	$\frac{99.92 \times 5.8^3}{12}$ $\Rightarrow 1624.633$	$\frac{3 \times 864.36 \times 0.16}{2 \times 0.09992 \times 0.0058^2}$ $\Rightarrow 6.1716 \times 10^7$	$\frac{6 \times 4.75 \times 5.8}{160^2}$ $\Rightarrow 0.006457$	$\frac{6.1716 \times 10^7}{0.006457}$ $\Rightarrow 9.5580 \times 10^9$
MDF	$\frac{99.35 \times 12.35^3}{12}$ $\Rightarrow 15595.077$	$\frac{3 \times 1219.96 \times 0.16}{2 \times 0.09935 \times 0.01235^2}$ $\Rightarrow 1.93221 \times 10^7$	$\frac{6 \times 5.638 \times 12.35}{160^2}$ $\Rightarrow 0.016319$	$\frac{1.93221 \times 10^7}{0.016319}$ $\Rightarrow 1.1840 \times 10^9$
Plywood	$\frac{99.6 \times 12.063}{12}$ $\Rightarrow 14558.615$	$\frac{3 \times 3108.73 \times 0.16}{2 \times 0.0996 \times 0.01206^2}$ $\Rightarrow 5.15039 \times 10^7$	$\frac{6 \times 9.275 \times 12.06}{160^2}$ $\Rightarrow 0.026216$	$\frac{5.15039 \times 10^7}{0.026216}$ $\Rightarrow 1.9646 \times 10^9$