



University of Wales Trinity Saint David

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Materials Testing and Sustainability of Composites for
Motorsport & Automotive Industries

Automotive Materials & Sustainability

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1 Introduction

Composite materials are estimated to account for up to 85% of modern Formula 1 (F1) cars, highlighting their critical role in high-performance motorsport where optimising strength-to-weight ratio is essential (Hatton, 2019). They are widely used in structural and aerodynamic components, where minimising mass while maintaining rigidity is essential. Despite their superior specific properties, composites exhibit limitations such as poor impact resistance and complex end-of-life recycling challenges, which raises questions about their long-term sustainability in motorsport. This study aims to evaluate the mechanical performance of selected composite systems through tensile testing, while assessing their sustainability across the full lifecycle from material extraction to disposal.

2 Composite Materials in Motorsport

2.1 Material Application Requirements

Materials in motorsport face different load mechanisms and environments depending on the application. An example of a composite chosen to suit a specific application was during the development of the front splitter and crash structure of the 2007 NASCAR (Wilkie, 2007). A self-reinforced polypropylene called Tegrise was selected after extensive material testing. The benefits to using this type of composite to meet this application include high impact resistance to protect occupants and non-brittle failure, which stops the splitter shattering or breaking into pieces, protecting spectators and drivers (Hayes, 2008).



Figure 2.1: Tegrise composite shown in the crash structure of a NASCAR (Hayes, 2008)

Composite material design is important when tailoring to motorsport applications and the versatility can be improved through overall design choices. Adjustments can be made to fundamental structure, like fibre orientation, or aftertreatment like coatings, for specified conditions. A paper exploring the use of composite coatings explains this through the ability to protect the component against heat and electricity interference (Bailey, 2015). This enabled F1 cars to use composite rear diffusers with hot exhaust gases flowing over the surfaces at 850°C.

2.2 Composite Structure and Mechanics

Composite materials consist of reinforcing fibres within a polymer matrix, where fibres provide strength and stiffness. Mechanical behaviour is direction dependent, with fibres typically oriented at 0° , $\pm 45^\circ$ and 90° to optimise load-bearing performance (Multi-Sport Composites, 1995).

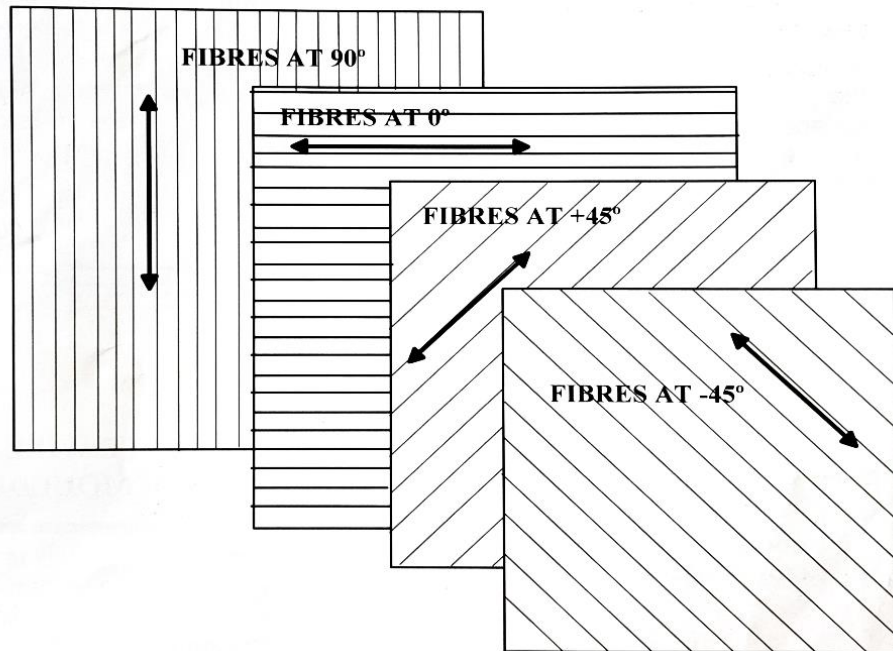


Figure 2.2: Fibre orientation showing different angles influencing direction pattern (Multi-Sport Composites, 1995)

Weave patterns such as plain and twill further influence stiffness, damage tolerance and manufacturability, with twill weaves often preferred in motorsport for improved drapability over complex geometries (Multi-Sport Composites, 1995; Van Gorder, 2025).

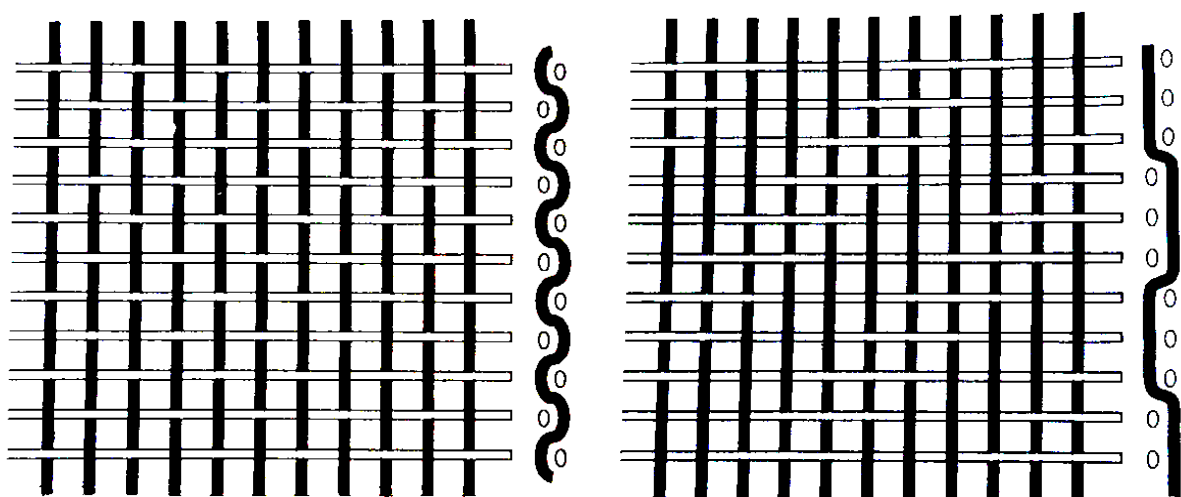


Figure 2.3: Plain weave (left) vs twill weave (right) (Multi-Sport Composites, 1995)

These materials are formed as multi-ply laminates or sandwich structures, with laminates tailoring properties through fibre orientation, while sandwich structures achieve high bending stiffness by separating face sheets with a lightweight core (Linganiso and Anandjiwala, 2016; Singh, Sheikh and Behera, 2024).

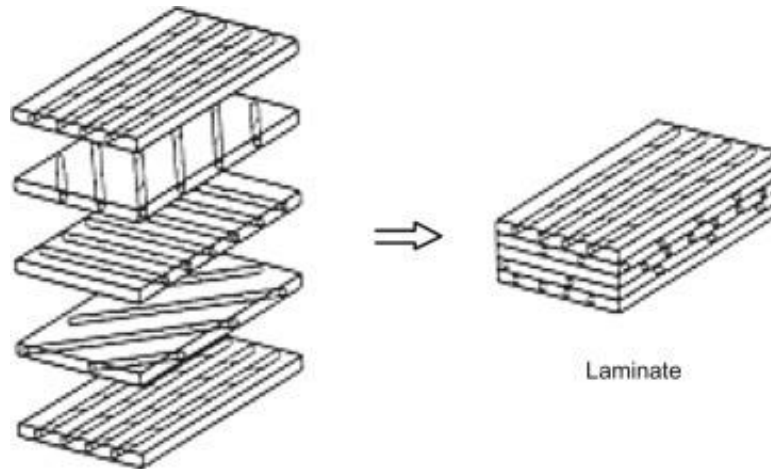


Figure 2.4: Multi-layer laminate structure example (Linganiso and Anandjiwala, 2016)

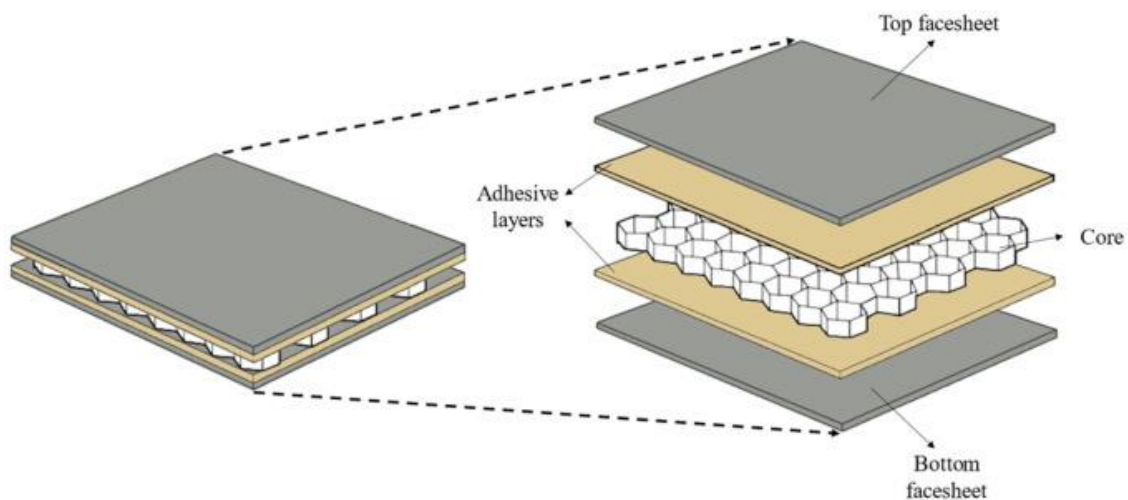


Figure 2.5: Face sheet and core sandwich structure example (Singh, Sheikh and Behera, 2024)

2.3 Resin Matrix Systems

The resin matrix is essential for binding fibres together, transferring load between them and maintaining the overall structural integrity of the composite. There are two generic forms of resin used in composite manufacture: thermoplastics and thermosets. Thermoplastics can be heated until in liquid form and cooled until solid, with a short cure time. Thermosets are in liquid form until heat is applied, turning irreversibly solid with a longer cure time, although not requiring specialist equipment (McBeath and O'Rourke, 2000).

Thermosetting resins, particularly epoxies, are widely used in high-performance composites due to their superior mechanical strength and thermal stability, making them suitable for motorsport structural applications. In contrast, thermoplastics offer improved toughness and recyclability, leading to increased interest as a more sustainable alternative (Nishida *et al.*, 2018).

2.4 Carbon Fibre

Carbon fibre is a dominant material in F1 with a range of uses from the chassis to smaller components, such as body panels, wings, steering wheels, and suspension elements (Piran Composites, 2024). The reason this material is well suited to this environment is due to the range of parts that can be made from it and the resistance to high temperatures without degradation (Alpine F1, 2026).

Additionally, carbon fibre presents sustainability challenges due to energy-intensive production and limited recyclability, driving interest in recycled carbon fibre and alternative composite systems (McLaren Racing, 2023).

2.5 Natural Fibre

Natural fibres are more sustainable due to being renewably sourced and are growing in popularity for use within motorsport. Flax is an example of a popular natural composite extracted from the *Linum usitatissimum* plant (Hatton, 2019).

BMW mark them as particularly suitable for visible exterior and interior components taking advantage of lightweight fibres (BMW M, 2022, 2025). Synthetic composites like carbon fibre offer better strength and degradation resistance however, natural based composites often have a lower weight and cost (Elfaleh *et al.*, 2023). This explains the current primary application being non-structural components.



Figure 2.6: The interior of the BMW M4 GT4 racing car with Bcomp natural fibres visible on the centre console (BMW M, 2022)

3 Methodology of Experimental Testing

3.1 Materials Tested

The materials tested included both carbon fibre and flax fibre reinforcements, combined with either traditional epoxy or bio-based thermoset resin systems. This enables direct comparison between synthetic and natural fibres, as well as conventional and more sustainable resin matrix systems. Aluminium was included to provide a baseline lightweight metallic material for comparison.

Table 3.1: Tensile test samples named and pictured

Aluminium	Carbon Non-woven Bio-resin	Carbon Woven Bio-resin	Flax Woven Bio-resin	Carbon Fibre Epoxy Resin
				

The composite test samples were manufactured using a resin infusion process, in which dry fibre reinforcements were placed within a mould and impregnated with resin under vacuum pressure.

Two different reinforcement architectures were investigated: woven (twill) and non-woven composites. The twill composites consisted of three layers of 200 grams fibre, giving a total reinforcement mass of 600 g, while the non-woven composites consisted of a single 300 g layer.

For the multi-layer twill samples, each ply was oriented at 45° relative to adjacent layers. The non-woven samples exhibited a random fibre orientation to evaluate the effect of different composite reinforcement techniques.

Each sample was made to a template size however, there was a variation in width and thickness between materials, important for the cross-sectional area calculation of the gauge section (where the material is likely to fail). Therefore, these dimensions were measured each test to ensure the correct area was input to output valid results.

Table 3.2: Test materials critical section dimensions

	Aluminium	Carbon Non-woven Bio-resin	Carbon Woven Bio-resin	Flax Woven Bio-resin	Carbon Fibre Epoxy Resin
Width (mm)	15	14.7	19.4	14.75	14.5
Thickness (mm)	1.5	1.3	0.7	1.9	0.75
Cross-sectional area (mm ²)	22.5	19.11	13.58	28.02	10.88

3.2 Test Equipment

After recording and inputting measurements into the machine software, the samples could be placed in the mechanical jaws of the Denison test rig (Figure 3.1).

**Figure 3.1:** Denison tensile test rig post sample test

The rig inflicts a tensile load by moving the jaws in opposing directions, with extension measured using an extensometer (Figure 3.2), until the point of near failure. This is removed before the machine allows failure, to break the sample without damaging equipment.

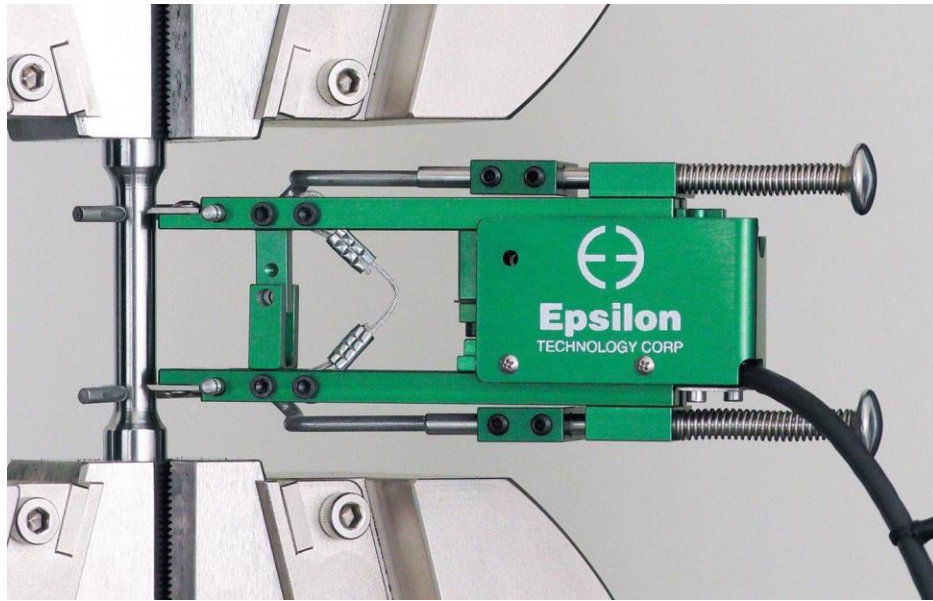


Figure 3.2: Epsilon extensometer setup on a sample within a tensile test rig (AZO Materials, 2021)

The extensometer is a key part of the test equipment to measure extension at microns in accuracy. This means elastic modulus and specifically the strain portion of the test are measurable for inclusion in the results (AZO Materials, 2021).

3.3 Calculating Outputs

The Denison software records the test data against time, with variables such as inflicted load and elongation. The software calculates stress, strain and elastic modulus automatically using the equations below:

$$(3.1) \quad \text{Stress (Nm}^2\text{)} = \frac{\text{Force (N)}}{\text{Area (m}^2\text{)}}$$

Equation (3.1) Stress calculation (The Science and Maths Zone, 2020)

$$(3.2) \quad \text{Strain } (\epsilon) = \frac{\text{Change in length } (\Delta m)}{\text{Original length (m)}}$$

Equation (3.2) Strain calculation (The Science and Maths Zone, 2020)

$$(3.3) \quad \text{Elastic Modulus (Pa)} = \frac{\text{Stress (Nm}^2\text{)}}{\text{Strain } (\epsilon)}$$

Equation (3.3) Elastic (Young's) Modulus calculations (The Science and Maths Zone, 2020)

These equations highlight the importance of cross-sectional area being input correctly, as this effects the calculations made by the software.

4 Results & Analysis

4.1 Output Overview & Standard Deviation

Within the results groups made errors with area input or other aspects of the test therefore, only valid test data will be used for analysis, with invalid data removed. To broaden the dataset analysed for the validation and material comparison, results will be taken from three test groups, equalling six tests maximum for each material (raw data graphs Appendix A). Standard deviation will be used as a measure of strength and modulus consistency.

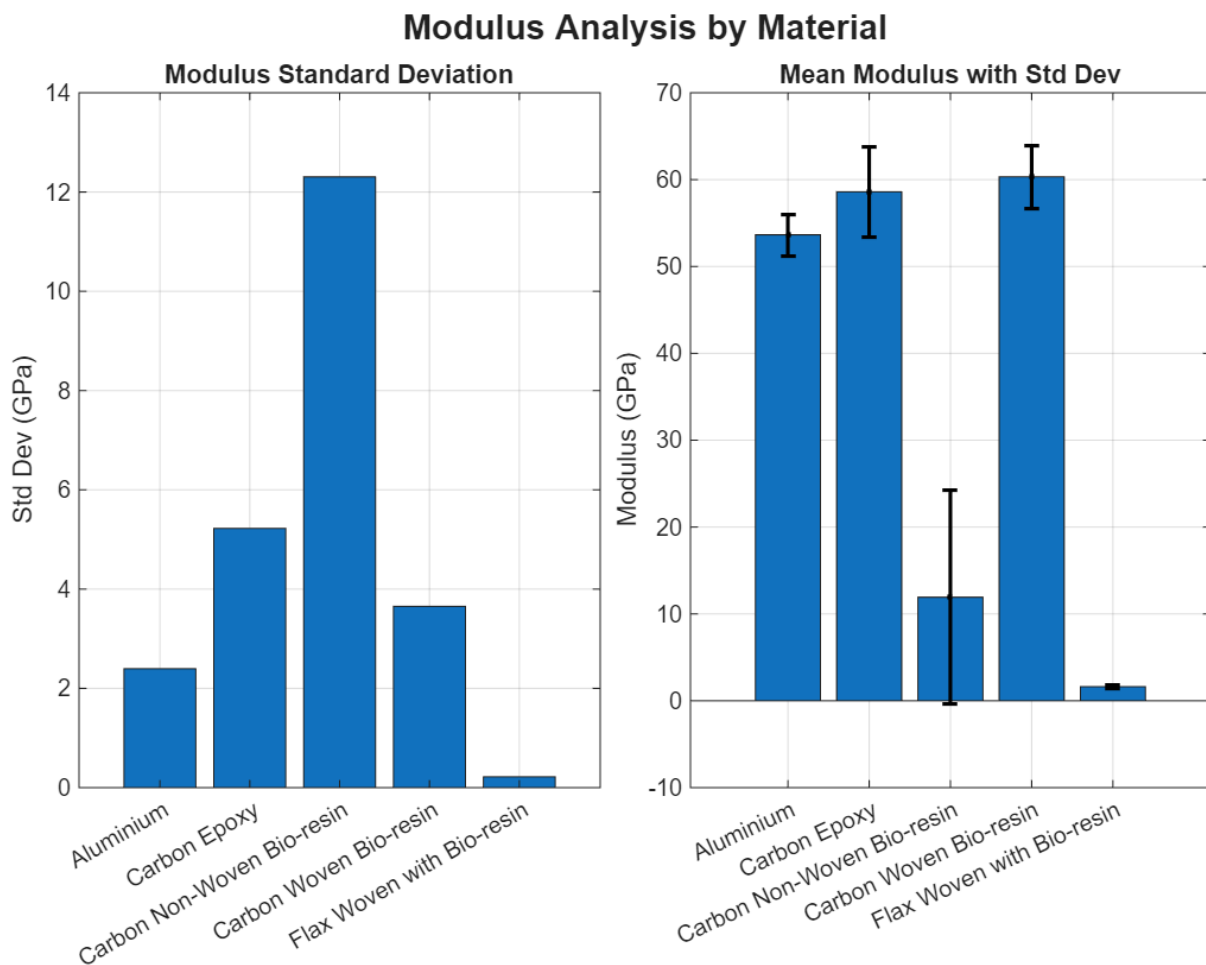


Figure 4.1: Elastic modulus standard deviation analysis of each material

4.2 Results Validation

4.2.1 Aluminium

To validate the baseline material (aluminium) the stress-strain curve can be compared to literature findings (Safdarian, 2018).

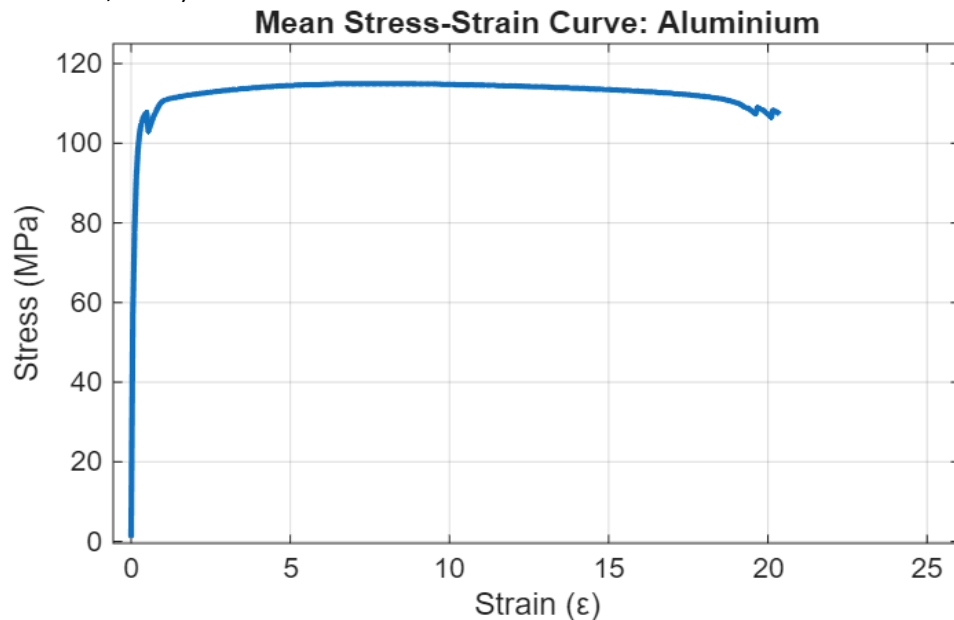


Figure 4.2: Aluminium mean stress vs strain graph

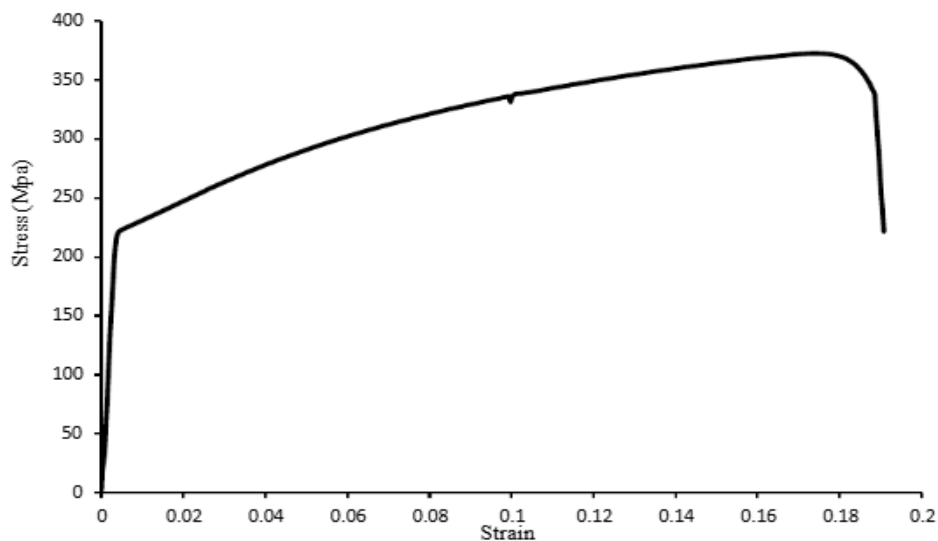


Figure 4.3: Tensile test stress vs strain graph of 6061 aluminium sheet (Safdarian, 2018)

The difference between strain values is because the literature uses decimals instead, it is the same unitless scale, just appears as decimal numbers. From this it can be evaluated that the overall trend seen in the present tensile testing matches literature trends, with a sharp increase in stress followed by a slower period of increased strain, as stretching occurs before failure. The grade of aluminium directly affects this through differing stiffness, impacting ductility. The aluminium in the present study shows a lower stiffness, with a larger ductility period, and lower stress resistance. This suggests the literature source had a higher grade material, with the 6061 having a higher elastic modulus at 69GPa (Material Properties, 2026).

4.2.2 Carbon Fibre Non-Woven Bio-resin

To perform further validation on the composite testing, manufacturer datasheets for the samples has been provided. Some datasheets provide transverse and longitudinal values; however, as the laminates were oriented at $\pm 45^\circ$ or were non-woven, the test conditions did not align with either case directly. Therefore, these values are used as an approximate range for comparison.

Table 4.1: Comparison of Carbon Fibre Non-woven tensile test values to manufacturer datasheet (Easy Composites, 2024a)

Property	Tensile Test Mean	Tensile Test Std Dev Range	Transverse Data Sheet	Longitudinal Data Sheet
Tensile Strength (MPa)	163.38	163.38 ± 44.30	330	290
Elastic Modulus (GPa)	11.92	11.92 ± 12.31	35	25

The carbon non-woven elastic modulus seen in this test fell below the manufacturer's values however, upper standard deviation values for elastic modulus were close, suggesting the material can perform as intended, but not consistently.

4.2.3 Flax Fibre Woven Bio-resin

Another validation would be useful on a woven sample, shown below using the flax material.

Table 4.2: Comparison of Flax Fibre Woven tensile test values to manufacturer datasheet (EcoTechnilin, 2023)

Property	Tensile Test Mean	Tensile Test Std Dev Range	Transverse Data Sheet	Longitudinal Data Sheet
Tensile Strength (MPa)	81.03	81.03 ± 10.12	58 ± 2	61 ± 6
Elastic Modulus (GPa)	1.63	1.63 ± 0.22	6 ± 1	7 ± 1

The flax fibre performed with slightly below the expected stiffness and with low deviation, suggesting consistently more ductile properties than specified. The tensile strength observed was higher than the datasheet range in every test, suggesting a consistent strength over-representation. The remaining materials were compared quantitatively with manufacturer datasheets (Appendix B).

While this validation does not confirm absolute accuracy, trends consistent with literature were observed in the aluminium stress–strain response. For the composites, elastic modulus values fell consistently below manufacturer ranges, indicating reduced stiffness under the tested conditions. This could be due to fibre misalignment and manufacturing defects not reflected in idealised datasheet values. A limitation would be that data analysed within this study was limited to three groups as further processing wasn't possible due to time constraints on large quantities of invalid data removal. A larger dataset would likely improve mean value accuracy.

4.2.4 Rule of Mixtures

The elastic modulus of a composite can be estimated using the rule of mixtures (E_c):

$$(4.1) \quad E_c = V_f E_f + V_m E_m$$

Equation (4.1) Rule of mixtures

E_f and E_m are the elastic modulus of the fibre and matrix respectively, and V_f and V_m are the volume fractions of resin to fibre. This attempts to predict elastic modulus using composite fabrication information.

Table 4.3: Modulus experimental, predicted and datasheet

Material Case [REF]	Experimental Modulus (GPa)	Rule of Mixtures Approximation (GPa)	Datasheet Modulus (GPa)	% Difference EXP vs ROM	Key Interpretation
Carbon Fibre Epoxy Resin [1,2]	58.6	118.7	~234	-50.6%	Reduced stiffness due to fibre orientation and defects
Carbon Fibre Non-Woven Bio-resin [3,4]	11.92	47.95 ± 8.35	25 – 35	-69.9% to -78.8%	Very low stiffness due to random fibre orientation
Carbon Fibre Woven Bio-resin [1,4]	60.33	118.5	~234	-49.1%	Reduced stiffness due to fibre orientation and defects
Flax Fibre Woven Bio-resin [4,5]	1.63	6.5 ± 0.5	6.5 ± 1.5	-72.8% to -76.7%	Lower than expected due to ductile behaviour

[1] – Carbon Fibre Datasheet (MITSUBISHI RAYON CO.,LTD., 2013)

[2] – Epoxy Resin Datasheet (Easy Composites, 2024b)

[3] – Non-woven Carbon Mat Datasheet (Easy Composites, 2024a)

[4] – Bio-resin Datasheet (Easy Composites, 2026)

[5] – Flax Fibre Datasheet (EcoTechnilin, 2023)

Experimental modulus values are lower as the rule of mixtures assumes perfectly aligned fibres under longitudinal loading. Woven and non-woven architectures, ply orientation, and defects such

as misalignment and voids reduce load transfer efficiency. Consequently, the model overestimates stiffness and represents a theoretical prediction. Experimental modulus values were consistently below the rule of mixtures prediction, explaining the extra factors considered in the real test negatively influenced the modulus, which was an expected outcome.

4.3 Material Comparison

Mean stress and strain values were calculated and used consistently across all comparisons to ensure each material was represented accurately using the available data.

4.3.1 Composite & Metal

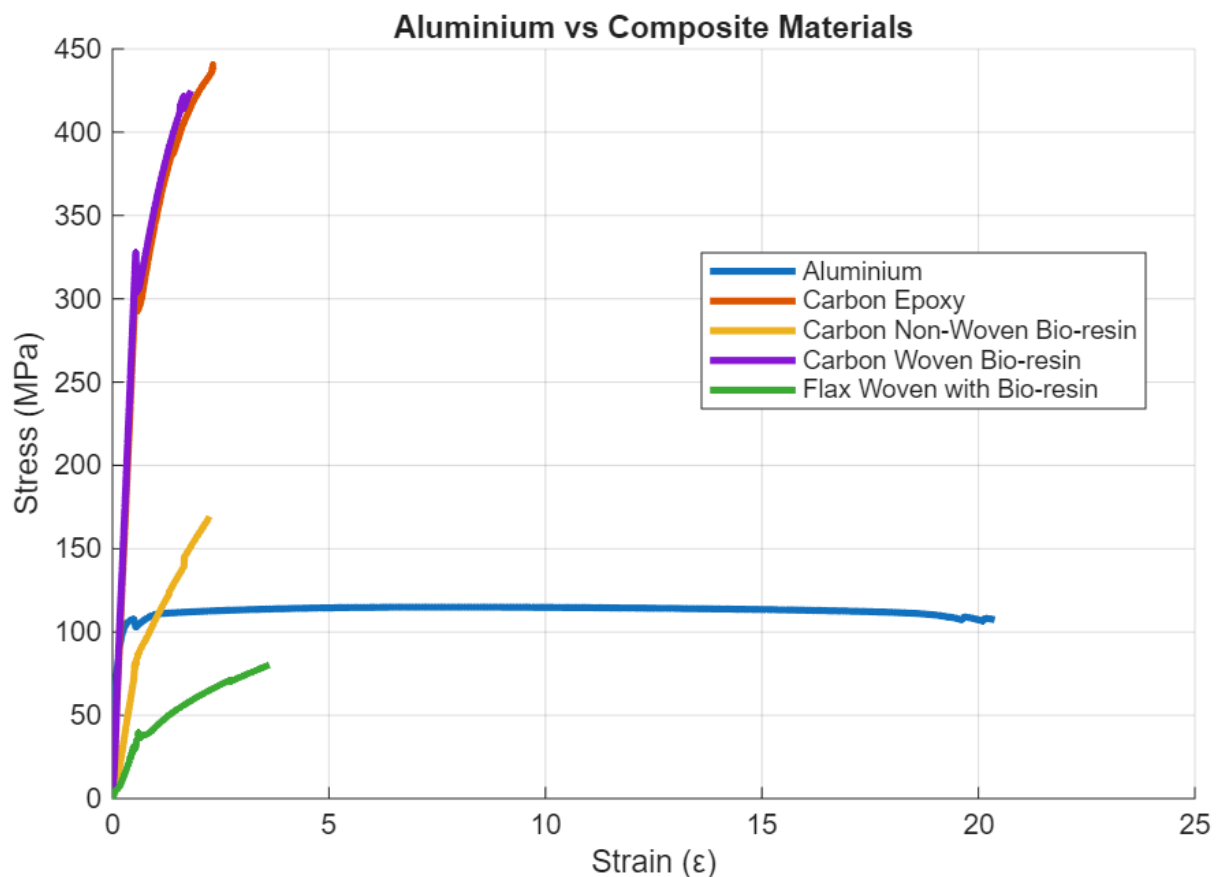


Figure 4.4: Aluminium vs composite stress vs strain graph

Aluminium exhibits clear ductile behaviour with a large strain region prior to failure, whereas the composite materials show relatively brittle behaviour with limited strain before fracture. The composites demonstrate significantly higher ultimate tensile strength compared to aluminium, indicating greater load-carrying capacity, but with a more abrupt failure.

4.3.2 Natural & Synthetic Fibres

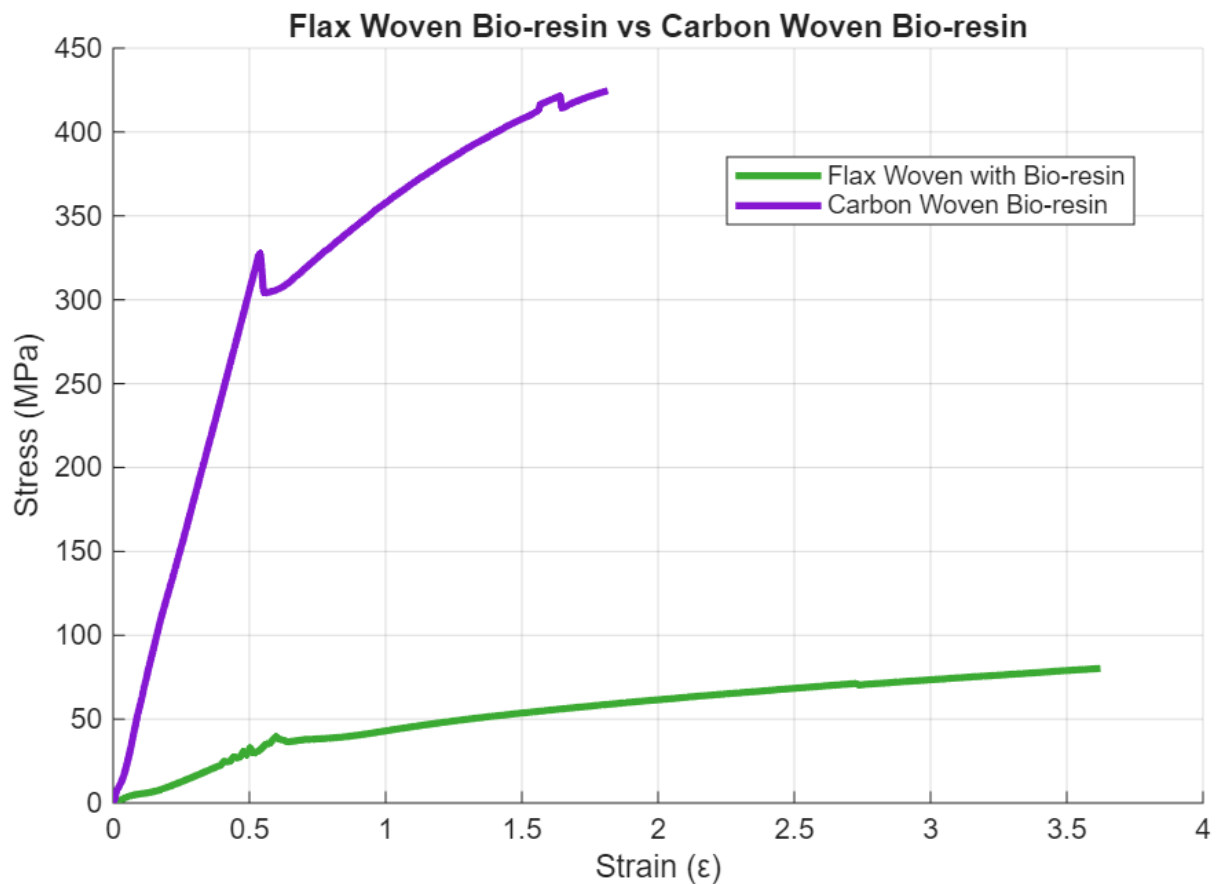


Figure 4.5: Flax fibre woven vs carbon fibre woven with equal resin stress vs strain graph

Flax fibre composites demonstrate greater strain to failure compared to carbon fibre composites, indicating increased ductility. However, despite this higher deformation capacity, flax exhibits significantly lower tensile strength, shown by the inability to withstand the same stress levels as carbon fibre before failure.

4.3.3 Bio & Polymer Resins

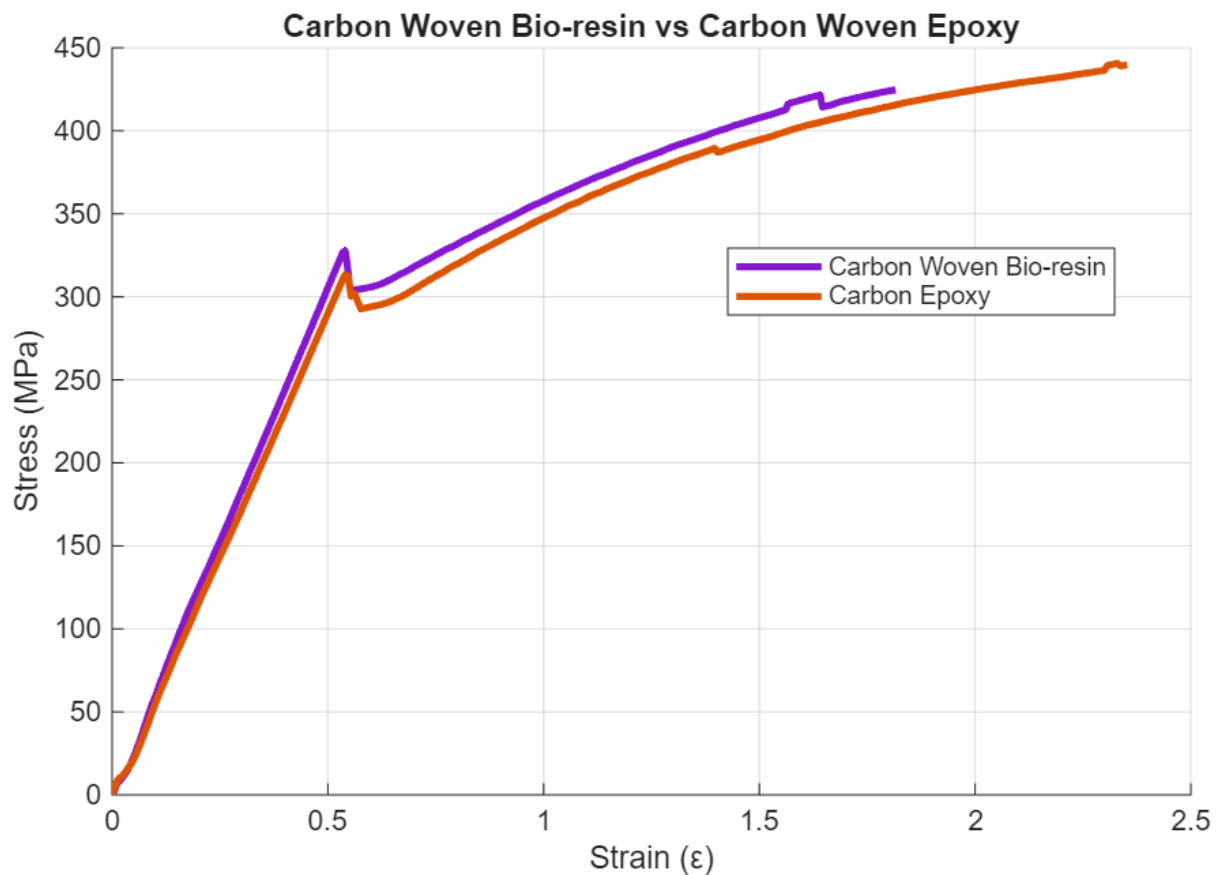


Figure 4.6: Carbon fibre epoxy resin vs carbon fibre bio-resin stress vs strain graph

Although the bio-resin composite exhibits slightly higher stress in the initial and mid-strain regions, the epoxy-based composite continues to sustain increasing stress over a larger strain range. This results in a higher ultimate tensile strength and greater strain to failure for the epoxy resin system. Consequently, epoxy demonstrates improved overall load-carrying capacity and toughness compared to the bio-resin system.

4.3.4 Woven & Non-woven

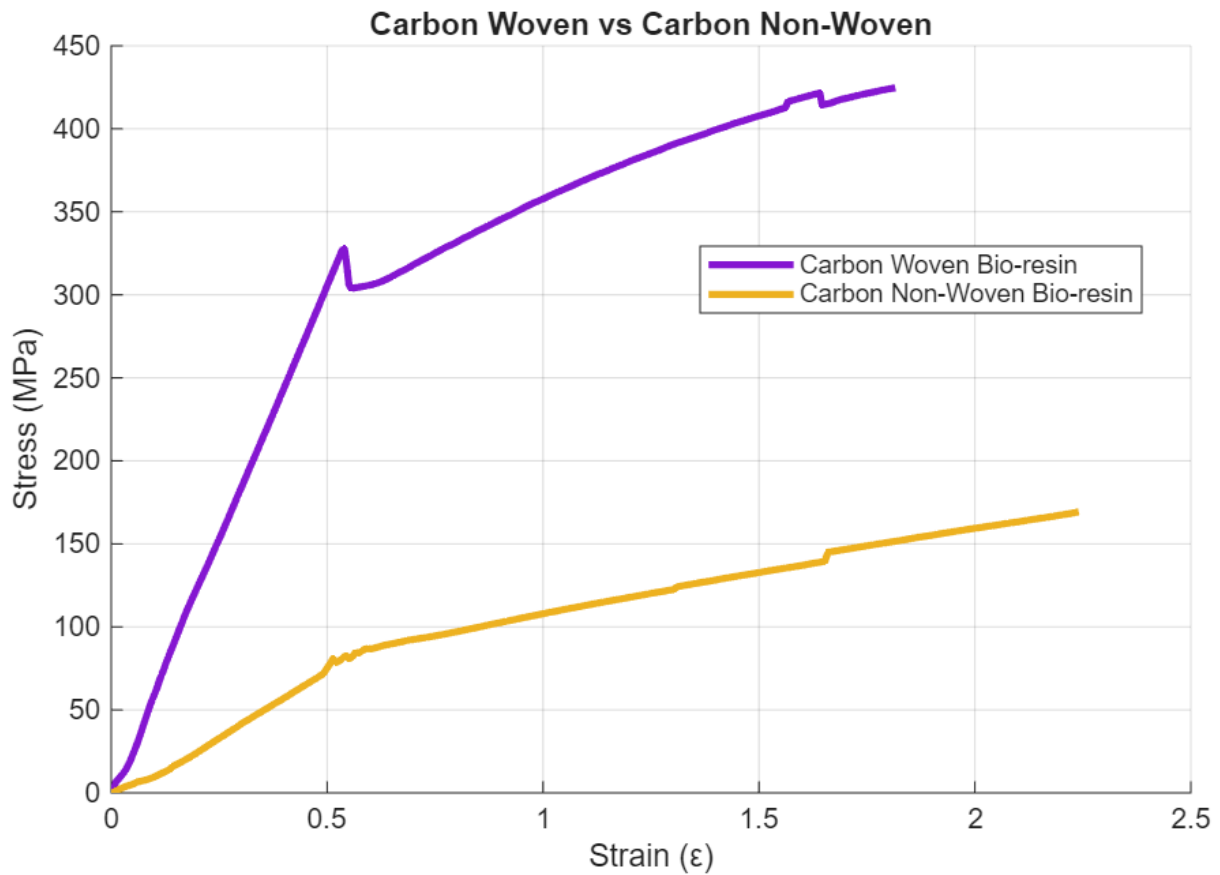


Figure 4.7: Carbon fibre woven vs carbon non-woven with equal bio-resin stress vs strain graph

Non-woven composites exhibit slightly greater ductility, as indicated by increased strain to failure. However, their tensile strength is significantly lower than woven composites due to the random fibre orientation, which reduces load transfer efficiency compared to the more aligned fibre architecture in woven materials.

4.4 Failure Observations

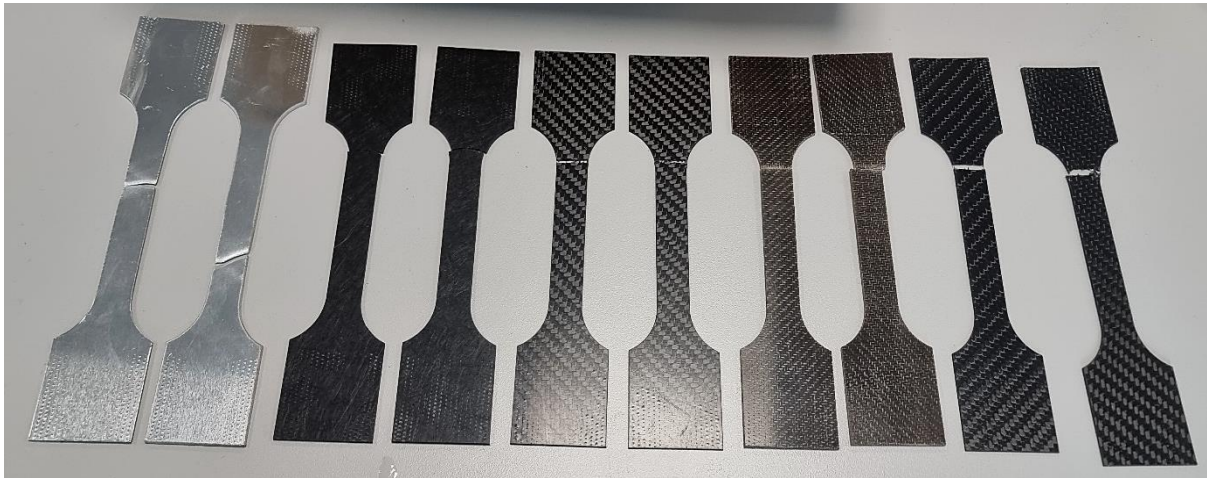


Figure 4.8: The failed group 2 samples at the end of the test
(from left aluminium, carbon non-woven, carbon woven bio-resin, flax woven, carbon epoxy)

Table 4.4: Failure observations

Material	Failure Type	Fracture Location	Fracture Surface	Key Observation
Aluminium	Ductile	Central gauge section (necking region)	Rough, necked	Visible necking and thinning in centre, with gradual reduction in cross-section
Carbon Non-Woven Bio-resin	Brittle	Upper gauge	Irregular	Uneven fracture edge with less defined structure compared to woven samples
Carbon Woven Bio-resin	Brittle	Upper gauge	Slightly rough	Fracture aligned across fibres with visible woven pattern at break
Flax Woven Bio-resin	Semi-brittle	Upper gauge	Fibrous, rough	Fracture shows frayed fibres and rough edges, indicating gradual separation
Carbon Woven Epoxy Resin	Brittle	Upper gauge	Clean, sharp	Cleaner fracture with less visible deformation



Figure 4.9: Aluminium sample before (top) and after tensile test (bottom)

The aluminium specimens exhibited clear ductile behaviour, with visible necking and significant thinning occurring within the central gauge section prior to failure, as shown in Figure 4.9. The fracture surface appears irregular, consistent with plastic deformation and gradual failure. In contrast, the composite materials displayed distinctly different fracture characteristics, which are summarised in Table 4.4. These failure observations support the differences in mechanical behaviour identified in the stress–strain analysis.

5 Sustainability Analysis

To analyse the materials featured in this testing program a full life cycle sustainability analysis will be carried out from material extraction to end-of-life and recycling. Legislation will provide an insight into the importance of sustainable practice within motorsport.

5.1 Raw Materials

The material to fibre process is an important sustainability consideration as this is where manufacturing emissions become important for analysis.

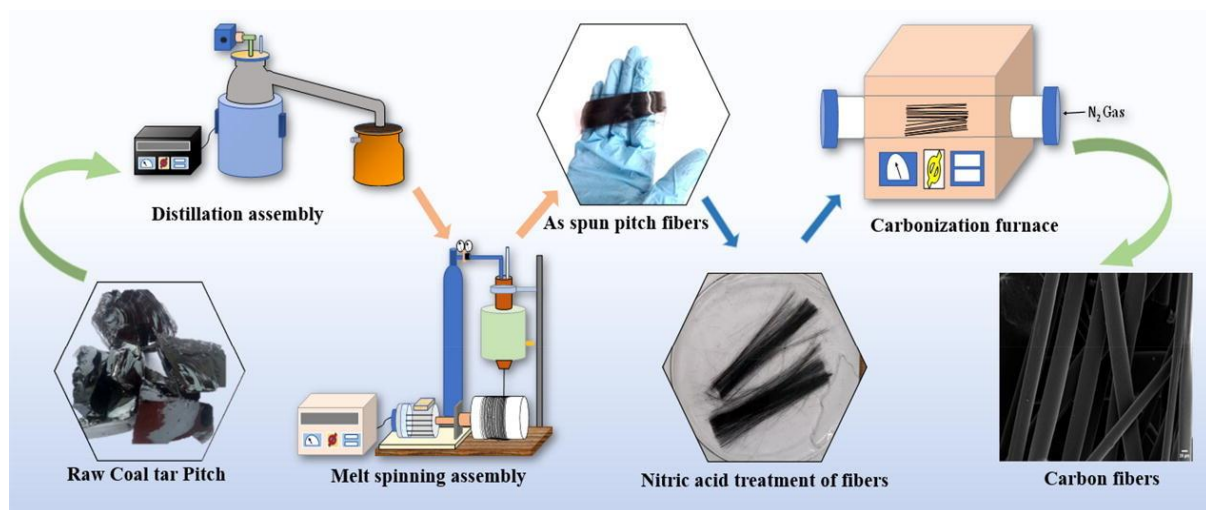


Figure 5.1: Coal tar raw material to carbon fibre process (Rani et al., 2023)

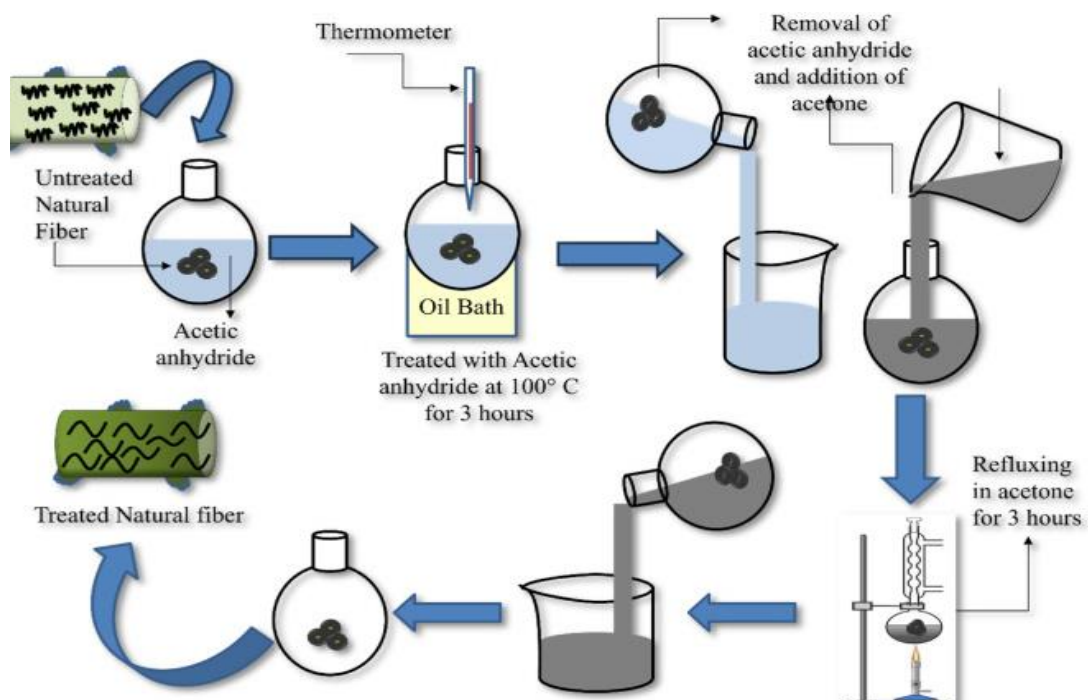


Figure 5.2: Acetylation treatment to remove moisture and condition fibres (Mundhe and Kandasubramanian, 2024)

Table 5.1: Raw material extraction process with sustainability impact

Material	Literature Data Source	Material Origin	Typical CO ₂ Emissions (kg CO ₂ /kg material)	Main Emission Sources	Key Sustainability Insight
Carbon Fibre	(Das, 2011) (Rani <i>et al.</i> , 2023)	Oil-based (petroleum)	24 – 31	Very high heat needed to make fibres + chemical processing	Very high environmental impact
Flax Fibre	(Mundhe and Kandasubramanian, 2024)	Plant (grown crop)	1 – 1.5	Farming (machines, fertiliser) + fibre processing	Low impact, renewable material
Epoxy Resin	(Boustead, 2005)	Oil-based chemicals	5.7	Chemical production + energy use	Non-renewable and hard to recycle
Bio-Resin	(CarbonCloud, 2026)	Plant oils + some oil-based chemicals	2.82	Farming + reduced chemical processing	Lower impact than epoxy, hard to recycle

From a sustainability perspective, the main difference between the materials lies in their reliance on renewable versus fossil-based resources. Flax fibre represents a shift towards renewable raw materials, as it is grown rather than extracted, reducing dependence on finite resources and lowering overall carbon emissions. Similarly, bio-resins aim to improve sustainability by partially replacing petrochemical with plant-based inputs, reducing emissions associated with conventional chemical production. In contrast, carbon fibre and traditional epoxy resin remain heavily dependent on fossil resources and energy-intensive processing, resulting in higher environmental impact at the raw material stage.

5.2 Composite Manufacturing

Composite manufacturing can contribute significantly to environmental impact due to both energy consumption and material inefficiencies. Energy use during fabrication is often underestimated, with values reported up to 40 MJ/kg for composite fabrication process alone, in addition to the raw material processing (Wang *et al.*, 2025). Autoclave curing is particularly energy-intensive, as it requires elevated temperatures and pressures over extended periods, with a large proportion of energy used to heat the surrounding air before being transferred to the component. This is primarily used for mass production applications to speed up curing times.

Alongside energy demand, fabrication losses further reduce sustainability credentials, as excess resin, trimming waste, and rejected components end up as production waste. The need for wasteful trimming is due to traditional composite fabrication processes needing excess material outside the mould. This may require further machining resources, in some cases trimming robots, which increases with scale of production (Quantum Mouldings Ltd., 2026).



Figure 5.3: Composite trimming robot increasing fabrication energy requirements (Quantum Mouldings Ltd., 2026)

5.3 Material in Use

During the use phase, the sustainability benefits of the tested materials are closely linked to their mechanical performance and resulting strength-to-weight. The tensile results showed that carbon fibre composites exhibited the highest stiffness, meaning less material is required to achieve structural performance. Comparatively, flax-based composites showed lower modulus values, reducing their potential for weight-related energy savings. Additionally, natural fibres such as flax may be more susceptible to environmental degradation, particularly from moisture absorption, which can affect long-term durability (Prapavesis *et al.*, 2026). Composite repair remains complex compared to traditional materials, as damage can be difficult to detect and restore, potentially rendering large parts as waste due to structural damage.

The use-phase benefits of bio-resin systems are largely unchanged compared to traditional epoxy, as their mechanical behaviour remains similar, meaning their sustainability advantages are primarily in earlier lifecycle stages.

5.4 End-of-Life & Recycling

The end-of-life stage represents a major sustainability challenge for composite materials due to their limited recyclability. Unlike metals, fibre-reinforced composites are designed for durability and chemical processes during fabrication are difficult to reverse (McBeath and O'Rourke, 2000). Carbon fibre composites can be recycled however, the fibres typically become shorter and exhibit reduced mechanical properties, limiting their reuse. Natural fibre composites, such as flax, offer some advantages due to their lower environmental impact and partial biodegradability however, the use of resin restricts full decomposition. The resin system is therefore a key limitation, as conventional thermoset epoxy and bio-resins are energy intensive to recycle and result in degraded materials (Engineer Live, 2025).

5.5 Legislation & Motorsport Context

Motorsport governing bodies such as the FIA aim to improve sustainability through initiatives such as the Environmental Accreditation Programme (FIA, 2023). Although the FIA promotes carbon neutrality, this is primarily achieved through operational measures and carbon offsetting rather than direct control of material selection. As a result, high-emission materials such as carbon fibre composites remain widely used, with their environmental impact often mitigated rather than reduced at source. This highlights a disconnect between carbon reduction targets and the continued reliance on less sustainable materials within motorsport.

The End-of-Life Vehicles Directive requires that 95% of a vehicle's mass must be recovered, with at least 85% recycled, leaving only a small proportion permitted as waste (European Parliament and Council of the European Union, 2000). Although this directive does not directly apply to motorsport, it creates indirect pressure on composite sustainability through the supply chain. Many motorsport teams are closely linked to automotive suppliers, which must comply with strict recyclability and recovery targets. As motorsport often acts as a development platform for road vehicle technologies, the continued use of non-recyclable materials such as carbon fibre doesn't align with these requirements (Downes, 2025). This drives the need for more sustainable alternatives, including recyclable and bio-based composites, to align motorsport materials with broader automotive sustainability legislation.

6 Recommendations

Table 6.1: Recommendations based on report findings and use-case

Area	Recommendation	Justification
Fibre Architecture	Prioritise woven composites over non-woven	Non-woven showed very low modulus (~11.9 GPa) due to random orientation, reducing strength
Material Selection	Use carbon fibre selectively for high-load areas	Highest stiffness (~60 GPa) enables weight reduction, but high CO ₂ (24–31 kg/kg)
Sustainable Material	Use flax composites for non-critical components	Much lower CO ₂ (1–1.5 kg/kg), but low stiffness (~1.63 GPa) limits structural use
Resin System	Replace epoxy with bio-resin where possible	Lower emissions (2.82 vs 5.7 kg CO ₂ /kg) with similar mechanical capabilities observed
Manufacturing	Continue resin infusion over autoclave	Lower energy demand, as autoclave requires high energy
End-of-Life	Improve carbon fibre recycling processes	Current recycling reduces fibre quality - limits reuse

From a motorsport team perspective, material selection should be driven by a balance between structural efficiency and overall environmental impact. High-performance areas require careful optimisation of composite layup and fibre orientation to maximise load transfer and minimise unnecessary material usage. Greater consideration should be given to integrating lower-impact materials like flax fibre into non-structural components, supporting overall sustainability targets without compromising critical performance areas. Manufacturing strategies should focus on improving process efficiency and reducing waste, particularly in trimming and excess material use. Additionally, teams should begin incorporating lifecycle thinking into design decisions, considering how components will be managed beyond their service life. This includes working with suppliers to improve material traceability and recycling potential, ensuring alignment with increasing regulatory and sustainability pressures within the wider automotive and motorsport industries.

7 Conclusion

This study evaluated the mechanical performance and sustainability of composite materials relevant to motorsport applications. The tensile testing results demonstrated that carbon fibre composites provide superior stiffness and strength, particularly in woven configurations, while non-woven structures showed significantly reduced performance due to random fibre orientation. Flax fibre composites offered a lower environmental impact but exhibited limited stiffness, restricting their structural application. The sustainability analysis identified that the primary environmental concerns are caused by raw material extraction and end-of-life emissions, particularly for carbon fibre and thermoset resins. While bio-resins reduce emissions at the production stage, they do not significantly alter use-phase performance or recyclability.

Overall, the findings highlight a clear trade-off between mechanical performance and environmental impact, emphasising the need for improved material selection, manufacturing efficiency, and recycling technologies to support more sustainable composite use.

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Appendices

Appendix A - Stress vs Strain Raw Data Graphs

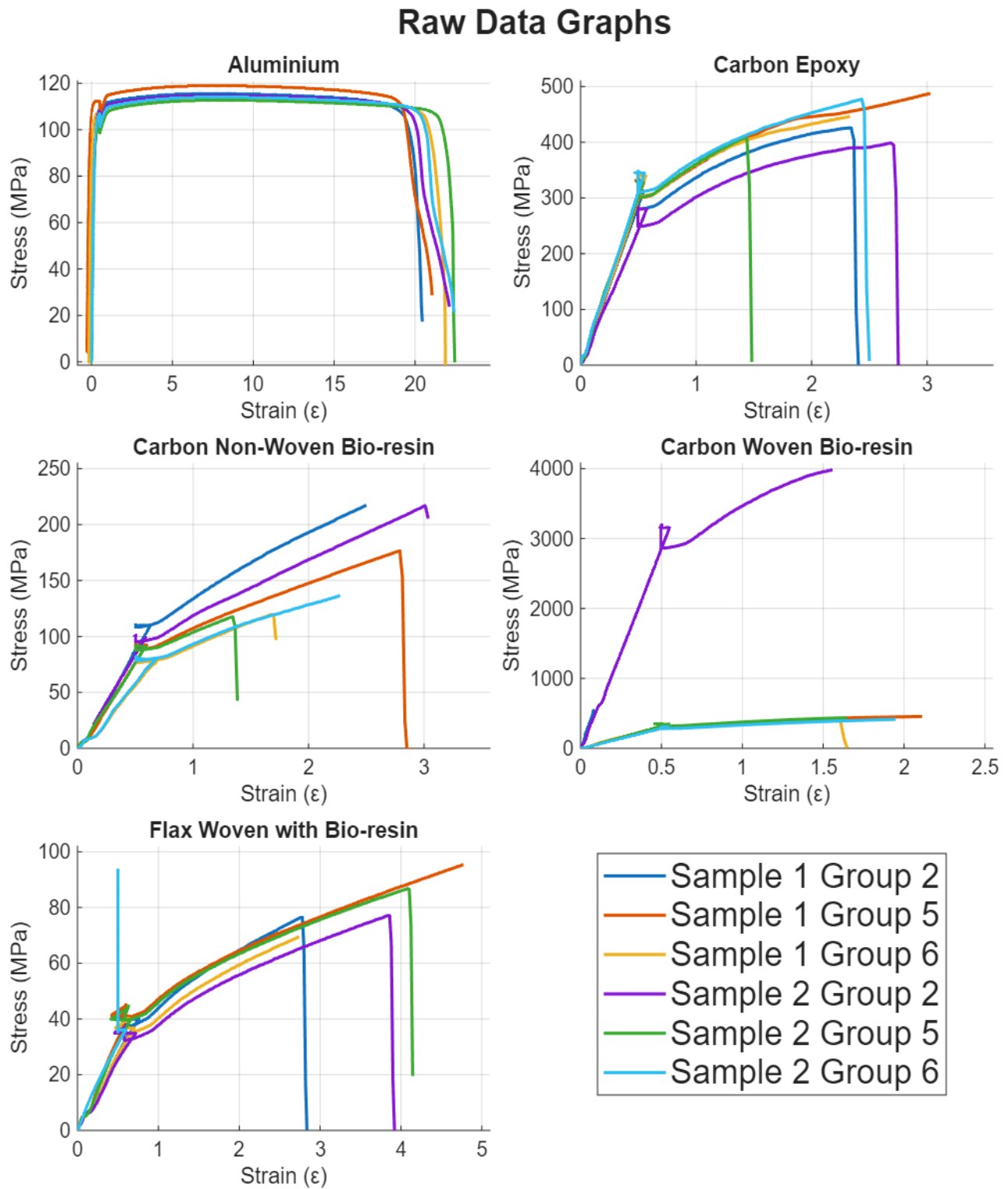


Figure A.1: Stress vs strain raw data graphs for each material tested, showing invalid test outliers and variation in failure points between samples

Appendix B - All Data Values vs Datasheets

Table B.1: Tensile strength and elastic modulus from Denison output compared to datasheet values

Material	Property	Tensile Test Mean	Tensile Test Std Dev Range	Transverse Data Sheet [REF]	Longitudinal Data Sheet [REF]
Carbon Fibre Non-woven	Tensile Strength (MPa)	163.38	163.38 ± 44.30	330 [1]	290 [1]
	Elastic Modulus (GPa)	11.92	11.92 ± 12.31	35 [1]	25 [1]
Flax Fibre Woven Bio-resin	Tensile Strength (MPa)	81.03	81.03 ± 10.12	58 ± 2 [2]	61 ± 6 [2]
	Elastic Modulus (GPa)	1.63	1.63 ± 0.22	6 ± 1 [2]	7 ± 1 [2]
Carbon Fibre Woven Epoxy Resin	Tensile Strength (MPa)	440.46	440.46 ± 36.17	4120 [3]	4120 [3]
	Elastic Modulus (GPa)	58.60	58.60 ± 5.22	~234 [3]	~234 [3]
Carbon Fibre Woven Bio-resin	Tensile Strength (MPa)	427.99	427.99 ± 22.60	4120 [3]	4120 [3]
	Elastic Modulus (GPa)	60.33	60.33 ± 3.65	~234 [3]	~234 [3]

[1] – Non-woven Carbon Mat Datasheet (Easy Composites, 2024a)

[2] – Flax Fibre Datasheet (EcoTechnilin, 2023)

[3] – Carbon Fibre Datasheet (MITSUBISHI RAYON CO.,LTD., 2013)