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Materials Testing & Sustainability in Composites for Motorsport & Automotive Industries

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1.0 Introduction

Composite materials are widely adopted in automotive and motorsport engineering for their high strength-to-weight ratios, tailored stiffness properties, and customisable layups. In response to growing political and social sustainability demands—particularly within the European Union—there is increasing interest in natural fibre composites and bio-resins as alternatives to traditional carbon and synthetic fibre composites. These materials offer potential benefits including lower embedded CO₂ emissions, improved end-of-life recyclability, and compliance with policies such as the End-of-Life Vehicles (ELV) Directive.

This investigation evaluates the tensile performance of a range of composite laminates, including synthetic fibres (Carbon, Kevlar) and natural fibres (Flax, Hemp), combined with either conventional epoxy or bio-based resin systems. An aluminium specimen served as a metallic baseline. Materials were grouped into three layup categories: woven twill with bio-resin, woven twill with epoxy, and non-woven formats with bio-resin. All samples were tested in tension and compared across material type, layup style and resin used.

Tensile tests were conducted using a Denison universal testing machine, with 14 runs per material to support averaging and outlier exclusion. Due to equipment limitations and brittle failures, strain data could not be reliably recorded; therefore, validation was based solely on ultimate tensile stress (UTS). Each result was benchmarked against reference values from datasheets and literature, with percentage variance calculated to assess reliability.

The aim of this report is to assess both the structural viability and sustainability performance of these materials, identifying practical and environmentally conscious alternatives to conventional composites in engineering design.

2.0 Initial Literature Review

Composite materials are widely used in motorsport and automotive engineering due to their high strength-to-weight ratios, directional stiffness, and customisable layups. Carbon fibre-reinforced polymers (CFRPs) are dominant in structural roles, offering excellent tensile performance and stiffness (*Savage, 1993*). However, their production is energy-intensive, reliant on fossil fuels, and difficult to recycle, raising environmental concerns (*Paraye and R.M. Sarviya, 2024*).

Kevlar is often used where impact resistance is critical, such as crash structures or ballistic protection. While durable, it shares carbon fibre's limitations: high energy production costs, petroleum origin, and poor recyclability (*Environmental_Literacy, 2025*).

Natural fibre composites, including flax and hemp, offer a renewable alternative with lower embodied carbon and safer handling during machining (*Pickering, 2008*). Though typically weaker and more variable than synthetic fibres, these materials are gaining traction in semi-structural and interior components. Advances in weave formats and resin pairing have improved consistency and processing outcomes (*Tseng, 2013*).

Epoxy resins, widely used for their strength and stability, are non-renewable and non-recyclable. Bio-resins, derived from plant feedstocks, reduce carbon footprint during production but remain thermosets, limiting recyclability (*Kousis, Fabiani and Pisello, 2022*).

Current research often isolates either mechanical or environmental performance. Full lifecycle comparisons across diverse composite types remain limited, especially studies that integrate lab testing with sustainability evaluation frameworks. This project contributes to closing that gap by comparing natural and synthetic composite systems using tensile testing, variance analysis, and sustainability scoring methods.

3.0 Experimental Testing

3.1 Test Setup & Methodology

Tensile strength was evaluated for a range of composite materials and an aluminium baseline using a Denison Tensile/Compression machine, simulating structural loads relevant to automotive and motorsport use. Two tensile tests were conducted per material per group, totalling 14 valid tests per material. All specimens were prepared according to the module's Composite Testing Plan (*Appendix A & B*) to ensure consistent layups, resin types, and fibre volumes.

3.2 Sample Preparation

Specimens were manufactured via a resin infusion process using a vacuum bagging method. The tested materials included both natural and synthetic fibre reinforcements with either a bio-based epoxy resin or traditional epoxy resin, allowing comparison of fibre type and matrix effects.

Table 1 - Composite material groups with fibre type, resin, layup details, and approximate fibre mass

Group	Fibre Type	Fibre Form	Resin Type	Layup Details (Layers x g/m^2)	Approx. Fibre Mass (g/m^2)
Baseline	Aluminium	Sheet Metal	-	-	-
Twill & Bio Resin	Kevlar	Twill Weave	Bio	2 x 300 @ $\pm 45^\circ$	600
	Flax	Twill Weave	Bio	3 x 200 @ $\pm 45^\circ$	600
	Carbon	Twill Weave	Bio	3 x 200 @ $\pm 45^\circ$	600
Twill & Epoxy Resin	Carbon	Twill Weave	Epoxy	3 x 200 @ $\pm 45^\circ$	600
Non-Woven & Bio Resin	Carbon	Non-Woven	Bio	1 x 300	300
	Hemp	Non-Woven	Bio	3 x 100	300
	Flax	Non-Woven	Bio	1 x 300	300

All multi-layer samples were laid up at $\pm 45^\circ$ to simulate realistic structural ply orientations commonly used in motorsport and automotive composite applications. The fibre weights were standardised across groups ($\approx 300 g/m^2$) to ensure fair mechanical comparisons.

3.3 Sample Set-Up

Tensile testing was performed using the Denison Tensile/Compression machine configured in tension mode. Each sample was clamped between the machine's upper and lower jaws using mesh-tabbed ends (sample shape displayed in Appendix C-J) to improve grip and prevent slippage. The upper grip remained stationary while the lower grip was displaced downward by a hydraulic actuator, gradually applying a uniaxial tensile force until the specimen fractured. This setup replicates standard material testing procedures used in industry for composite evaluation.

The applied force was continuously measured using a calibrated load cell, with data recorded digitally throughout each test. Although the machine was pre-tensioned before every session to minimise mechanical lag, long-term wear in the internal displacement system introduced inaccuracies in elongation measurement. As a result, strain and modulus calculations could not be reliably extracted.

Due to the brittle failure of several composites—particularly carbon and Kevlar—external extensometers were not used to avoid equipment damage. The focus of analysis was therefore placed on maximum tensile stress, which could be measured accurately and provided a reliable basis for comparison across all materials tested.

3.4 Data Acquisition & Processing

The cross-sectional area (CSA) of each sample was calculated based on manual measurements of gauge width and thickness.

- Stress was calculated and recorded in MPa as:

$$\text{Stress} = \frac{\text{Load (N)}}{\text{Cross Section Area (mm}^2\text{)}}$$

- Maximum stress values were extracted for each test.
- A reference stress value for each material was sourced from manufacturer data or technical literature.

3.5 Validation Approach

Given the inability to measure strain, results were validated using only maximum tensile stress. For each material group, the five results closest to the adjusted reference value were selected. Their average was used for comparison.

$$\% \text{ Variance} = \frac{\text{Measured} - \text{Reference}}{\text{Reference}} \times 100$$

Outliers were identified visually using plotted graphs (Figure 3 – Section 4.1) and statistically using their distance from the expected reference. Although the test setup did not follow a formalised tensile standard, the procedure was designed to follow equivalent principles in terms of uniaxial load application, ply orientation, and repeatability (*ASTM International, 2017*).

3.6 Methodology Limitations & Reliability

Although testing followed a consistent procedure, several limitations affected accuracy and repeatability. The machine lacked an extensometer, and internal wear introduced lag, making strain and modulus data unreliable. Only maximum load and stress were used for analysis.

Manufacturing inconsistencies likely contributed to variance. Differences in vacuum pressure, fibre alignment, or resin flow may have caused resin-rich zones, fibre waviness, or dry spots. Fibre volume fraction (FVF) was not measured directly. Although layup weights were controlled, variations in compaction or resin uptake introduce uncertainty—especially between woven and non-woven materials (*Alarifi, 2022*).

Tests were conducted at ambient temperature and humidity without conditioning. As natural fibres are moisture-sensitive, real-world performance may differ under thermal or environmental stress. Operator influence was another variable. Manual trimming and clamping could alter local stress distributions, particularly for brittle or fraying samples. Mesh tabs and consistent jaw pressure reduced slippage, but minor handling differences were unavoidable.

Despite these factors, the consistent performance of the aluminium samples suggests the methodology was sufficiently reliable for comparative analysis, though findings should be interpreted in light of these limitations.

4.0 Test Results & Material Behaviour

4.1 Result Selection Process & Aluminium Method Validation

To ensure consistent and meaningful comparison across all materials, five tensile results were selected per group based on the smallest percentage variance from a known reference tensile stress. This trimmed averaging method reduced the influence of outliers caused by manufacturing inconsistencies, early failures, or test setup variability.

Aluminium was used as a benchmark for validating this method. Figure 1 presents a raw stress–time result from one aluminium test, demonstrating the typical ductile curve profile: a rapid increase in stress, a clear yielding plateau, and a gradual drop as failure occurs. This predictable behaviour made aluminium an ideal reference to check for equipment reliability and data consistency (Okokpujie and Tartibu, 2022).

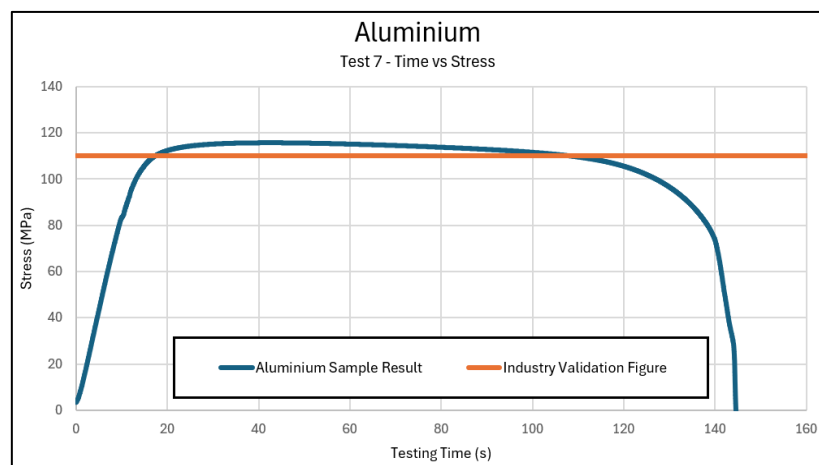


Figure 1 – Aluminium Results Time vs Stress

To illustrate how data was assessed, Figure 2 shows a Kevlar Woven Bio sample, which demonstrates a sharply linear rise followed by abrupt brittle failure — typical of fibre-reinforced composites. This contrast highlights the different material responses captured by the test system and reinforces the importance of validation against a known standard.

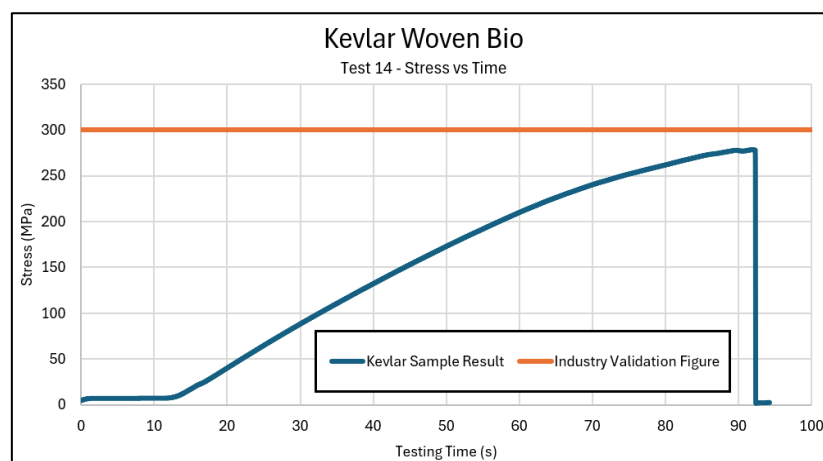


Figure 2 – Kevlar Results Time vs Stress

Figure 3 shows the percentage variance of each aluminium test compared to the reference value. Most results fell within a tight band of deviation, confirming consistent performance across specimens. The five tests with the smallest variance were selected to form the final average dataset.

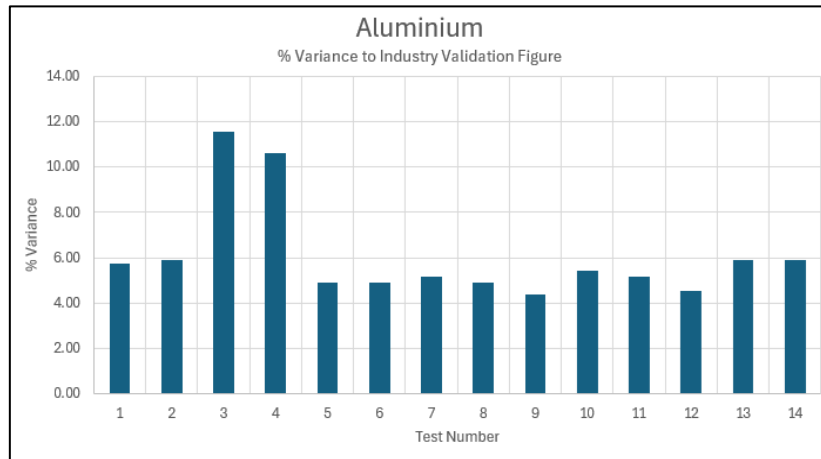


Figure 3 – Aluminium % Variance to Industry Validation Figure

These selected results are displayed in Figure 4, which compares their maximum stress to the validation figure. Their close grouping supports the accuracy of the trimmed averaging method.

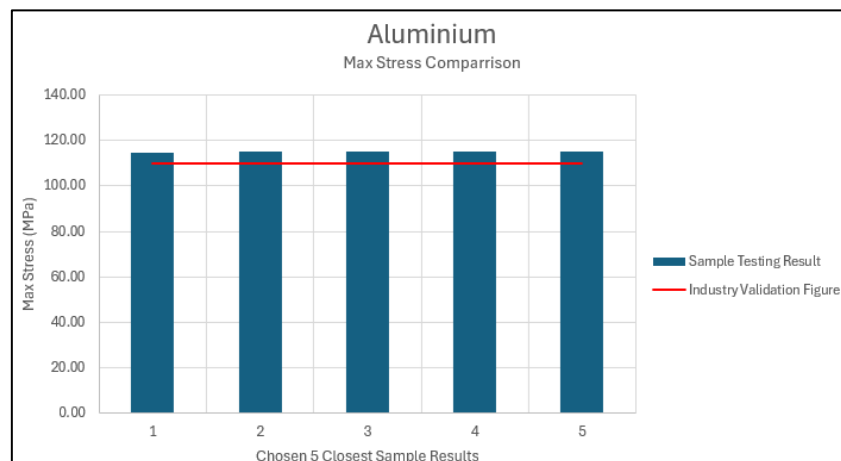


Figure 4 – Aluminium Max Stress Comparison with Industry Validation Figure

This same process was repeated for all composite groups. The selected values were used in the final result table and subsequent feasibility evaluation.

4.2 Composite Tensile Performance Summary

The average maximum tensile stress results for each material are presented in Table 2 below. This summary includes the measured average of the five selected results, the chosen industry or datasheet reference value, the resulting percentage variance and its source. These values form the basis for the performance comparison and sustainability assessments in the following sections.

Table 2 - Average tensile stress results for each material compared to reference values, with calculated percentage variance and corresponding data sources

Material	Average Measured Stress (MPa)	Reference Value (MPa)	% Variance	Reference Value Source
Aluminium	115.19	110	4.72	(Korff Group (EN), 2015)
Kevlar Woven Bio	302.75	300	3.93	10% Adaptation (Easy Composites Ltd, 2025)
Flax Woven Bio	79.30	60	32.16	(EcoTechnilin, 2023)
Carbon Woven Bio	408.97	650	37.08	(Niutta et al., 2023)
Carbon Woven Epoxy	450.81	716	37.04	(Niutta et al., 2023)
Carbon Non-Woven Bio	223.29	246.5	13.09	(Easy Composites Ltd, 2024)
Hemp Non-Woven Bio	33.88	46	26.34	(EcoTechnilin, 2023)
Flax Non-Woven Bio	40.18	37	11.46	(EcoTechnilin, 2023)

Due to the absence of a standardised reference value for Kevlar–bio resin composites, only 10% of the typical Kevlar–epoxy tensile strength was used as a conservative benchmark. This approach aligns with published guidance that recommends caution when comparing unvalidated layups or unfamiliar matrix combinations, particularly where resin type, fibre architecture, and cure conditions can significantly reduce performance (You et al., 2022). While an approximation, this conservative baseline ensured meaningful variance comparisons without overstating expected strength.

Starting with the aluminium baseline, the measured average of 115.19 MPa was closely aligned with the reference value of 110 MPa, producing a low variance of 4.72%. This provided a strong validation for the testing method, confirming that the setup could deliver accurate and consistent data.

Among natural fibre composites, hemp non-woven bio delivered the lowest tensile strength overall (33.88 MPa), falling well below its expected reference. Its 26.34% variance reflects the unpredictable structure of non-woven mats and low stiffness of the hemp fibres. Flax non-woven showed slightly better performance (40.18 MPa), with a smaller variance of 11.46%, possibly due to a more uniform mat structure or better bonding (Dittenber and GangaRao, 2012). Flax woven bio, while still a natural fibre composite, achieved significantly higher strength (79.30 MPa) but with a high 32.16% variance, indicating that although the woven format offers more structure, consistency remains a limitation.

For synthetic reinforcements, carbon woven epoxy achieved the highest average tensile stress (450.81 MPa) yet also showed a substantial 37.04% variance. This suggests that while the material is extremely strong, minor inconsistencies in layup or resin infusion can have a large impact on its repeatability (*Guo et al., 2022*). Carbon woven bio followed closely in strength (408.97 MPa) with a nearly identical variance, confirming that although bio-resins can be used with carbon fibre, they may introduce slightly greater variability or reduced bonding effectiveness.

Carbon non-woven bio, while still a carbon-based material, showed a marked drop in performance compared to the woven variants (223.29 MPa), though with a relatively moderate 13.09% variance. This highlights the importance of reinforcement structure in mechanical performance — woven carbon offers significantly more load-bearing capability than its non-woven counterpart.

Kevlar woven bio stood out for its balance of performance and consistency. Achieving 302.75 MPa with just 3.93% variance, it closely matched its reference value and outperformed several other materials, including some carbon variants. This result suggests that the bio-resin bonded well with the Kevlar fibres and that the woven architecture delivered stable load distribution under tensile stress.

In terms of percentage variance, the most consistent performers were Kevlar woven bio and aluminium, both with under 5% deviation from their reference values. In contrast, the carbon woven composites showed the greatest inconsistency, despite their high tensile strength. This highlights that materials with superior mechanical performance are not necessarily more repeatable. In practical engineering contexts, performance consistency is often as important as peak capacity. It is also likely that the greater variability observed in some composites—particularly the carbon samples—was influenced by the limitations of the laboratory manufacturing process, which lacks the precision and quality control of professional composite production.

Overall, this table demonstrates the wide performance spread across fibre types, layup structures, and resin systems. These figures will be integrated into the upcoming feasibility matrix and sustainability assessment, where trade-offs between strength, repeatability, environmental impact, and practical application will be considered.

4.3 Failure Mode Observations & Visual Comparison

In addition to tensile strength, the failure behaviour of each material was closely observed to gain insight into fibre–resin interaction, structural consistency, and practical implications for real-world use. Representative fracture photos were taken for each material, with selected examples included in this section and the full image set presented in Appendix C.

4.3.1 Aluminium

The aluminium specimens showed classic ductile behaviour. As expected, most samples exhibited permanent deformation before fracture, with visible necking and stretching around the failure point. In some cases, slight shearing occurred near the clamping edges, suggesting a gradual yield before complete failure.



Figure 5 - Aluminium fracture surface showing necking and ductile tearing.

4.3.2 Carbon Woven Epoxy

Carbon woven epoxy specimens failed abruptly with sharp, straight fracture lines across the gauge section, typical of a brittle failure mode. The majority of the break surface appeared clean and uniform, but closer inspection of the specimen in Figure 6 reveals small protruding fibre strands along the fracture edge. These suggest that while the failure was sudden, some limited fibre pull-out occurred, indicating partial fibre–matrix interaction. This may be attributed to localised resin-rich regions or minor misalignment during layup. Overall, the failure mode supports the mechanical results observed — extremely high tensile strength with little energy absorption, making the material strong but unforgiving under overload conditions.



Figure 6 - Carbon Woven Epoxy specimen after failure

4.3.3 Flax Non-Woven Bio

Natural fibre composites, particularly flax non-woven, displayed highly variable failure patterns. Some samples tore unevenly across the surface, while others exhibited edge delamination or frayed splitting. These inconsistencies are likely due to fibre misalignment, non-uniform resin distribution, and weak interfacial bonding.



Figure 7 – Flax Non-Woven tear with irregular fibre breakage

4.3.4 General Observations

- Woven fibres produced clean, consistent fractures due to structured load paths.
- Non-woven fibres failed unpredictably, often tearing or fraying due to random orientation.
- Natural fibres showed delamination and fibre pull-out, reflecting weak resin bonding and lower stiffness.
- Carbon composites failed suddenly with sharp breaks — high strength, low warning.
- Kevlar showed fibre bridging and pull-out, indicating toughness and energy absorption.
- Bio-resins tended to crack first, with fibres remaining intact — pointing to weaker matrix integrity.
- Epoxy systems exhibited unified failure, with fibre and matrix breaking simultaneously — producing a brittle but consistent fracture.

These failure modes mirror the mechanical trends and highlight trade-offs between strength, consistency, and damage tolerance — all critical for real-world composite applications.

5.0 Sustainability & Feasibility Analysis

While tensile strength is essential, long-term viability depends increasingly on sustainability, safety, and policy alignment—especially in the automotive and motorsport sectors.

5.1 Lifecycle and Environmental Impact

Natural fibres such as Flax and Hemp are renewable, low in embodied carbon, and biodegradable in landfill. Their cultivation captures CO₂ and typically demands less energy than synthetics. However, environmental benefits rely on responsible sourcing, water efficiency, and minimal fertiliser use (*Thompson, 2012*).

Carbon and Kevlar offer high strength but are derived from fossil fuels and require energy-intensive production. Recycling remains limited—especially for carbon fibre—resulting in a significant environmental burden.

Bio-resins reduce reliance on petrochemicals and cut emissions during manufacture. However, they are still thermosets, meaning they cannot be remoulded or recycled (*Morici and Dintcheva, 2022*). Their biodegradability is also inconsistent and often overstated, depending on crop source and processing transparency.

Epoxy resins are well-established but non-renewable and non-recyclable. They lock fibres into permanent structures, complicating recovery at end-of-life (*Feng et al., 2024*).

Aluminium stands apart. Though its primary production is energy-heavy, it can be recycled repeatedly at a fraction of the energy cost. Its global infrastructure supports high circularity, and its mechanical properties remain consistent post-recycling—making it a benchmark for end-of-life sustainability (*Schmitz et al., 2014*).

All tested composites used thermoset matrices, which fundamentally limit recyclability to inefficient downcycling or incineration. This lack of circularity remains a key flaw in composite sustainability.

5.2 Health, Safety & Ethics

Machining carbon and Kevlar generates fine, hazardous dust. Carbon fibre is also conductive, requiring stricter handling (*Pilling et al., 1979*). Epoxy resins release skin irritants and VOCs during curing. Natural fibres are safer to process, producing less harmful dust and posing lower health risks, but they absorb moisture and degrade without sealing.

Crop-based materials must be sourced responsibly to avoid competition with food crops and prevent negative land-use change. These risks are manageable with transparent supply chains and sustainable agricultural practices (*Thompson, 2012*).

Aluminium, once processed, is chemically inert and safe. While bauxite mining has impacts, widespread recycling infrastructure significantly offsets these concerns.

5.3 Regulatory Alignment

Policy drivers increasingly prioritise circularity and low emissions. The EU End-of-Life Vehicles (ELV) Directive mandates 80% material recovery by 2031—favouring recyclable materials like aluminium. Thermoset composites currently fall short of this standard (*EBM ADMIN Team, 2025*).

Natural fibres and bio-resins support several UN Sustainable Development Goals (More specifically, 12 and 13), but only if sourced ethically and processed cleanly. UK initiatives such as the Green Deal and Circular Economy Package further pressure industries to adopt sustainable materials, making lifecycle considerations as crucial as strength (*United Nations, 2015*).

6.0 Feasibility Matrix & Comparative Evaluation

While performance and sustainability have been discussed separately, no material offered a perfect balance of both. A structured scoring approach was therefore used to evaluate each material across multiple weighted criteria, combining mechanical, environmental, and practical factors into a single feasibility score.

6.1 Scoring Methodology

A feasibility matrix was used to compare all materials, combining experimental tensile stress results with sustainability and practical criteria. Each material was assessed across ten weighted categories based on data from test results, technical datasheets, literature, and lab observations.

Each category was scored from 1 (poor) to 5 (excellent), producing a maximum possible score of 50. Higher scores reflect greater overall feasibility for sustainable, real-world applications.

Table 3 – Definitions of the ten feasibility categories used to score each material across sustainability, performance, and practical application metrics

Category	Definition
Renewability	Is the materials (Fibre/Resin) derived from Renewable Sources?
Mechanical Performance	Based on testing average % variance from the Industry Validation Figure
CO ₂ Footprint	Estimated emissions from Fibre and Resin production
Manufacturing Ease	Simplicity of lay-up and resin compatibility success
Worker Safety	Dust/Fume Hazards, Handling Difficulty, PPE Requirements
Recyclability	End-of-Life options; Reuse, Regrind, Energy Recovery, True Recyclability
Cost	Estimated Material Price and Process Costs
Availability	Sourcing Feasibility and Supply Chain Reliability
Ethical Impact	Social/Political Impact
Industrial Compatibility	Suitability for Resin Infusion and typical Motorsport Tooling methods

Scoring decisions were based on a combination of experimental results, supplier datasheets, peer-reviewed research, and established sustainability policies.

6.2 Feasibility Matrix Results and Discussion

Table 4 – Feasibility matrix scoring each material across the ten weighted criteria to evaluate overall suitability in automotive and motorsport applications

Material	Renewability	Mechanical Performance	CO ₂ Footprint	Manufacturing Ease	Worker Safety	Recyclability	Cost	Availability	Ethical Impact	Industrial Compatibility	Total (?/50)
Aluminium	1	4	2	5	5	5	3	5	3	5	38
Carbon Woven Epoxy	1	5	1	2	2	2	1	4	2	4	24
Carbon Woven Bio	2	5	3	3	3	1	2	3	4	4	30
Carbon Non-Woven Bio	3	3	3	4	4	2	3	3	3	4	32
Kevlar Woven	1	4	2	2	2	2	3	4	3	4	27
Flax Woven Bio	5	1	5	4	5	2	4	4	5	4	39
Flax Non-Woven	5	2	5	5	5	3	5	4	5	4	43
Bio-Hemp Non-Woven	5	2	4	5	5	3	5	3	5	4	41

6.3 Final Scores and Material Ranking

The scoring results confirm that no material offers a perfect balance of mechanical strength and sustainability. While carbon fibre composites dominate in tensile performance, their environmental impact, cost, and poor end-of-life options significantly reduce their overall feasibility.

In contrast, natural-fibre materials — particularly non-woven flax and hemp — achieved the highest overall scores, driven by renewability, low CO₂ footprint, and handling safety. However, these gains came at the cost of reduced strength and greater variability, limiting their structural applications.

Aluminium emerged as a strong all-round option. Despite being non-renewable, its recyclability, industrial maturity, and consistent behaviour secured a high feasibility score.

These outcomes directly inform the following recommendations, which consider not just material performance, but realistic adoption in automotive and motorsport contexts.

7.0 Conclusion & Recommendations

This study compared eight composite materials and an aluminium baseline using tensile testing, sustainability criteria, and a weighted feasibility matrix. The results highlighted a fundamental trade-off between strength and sustainability. Carbon fibre laminates achieved the highest tensile performance but were limited by high emissions, low recyclability, and health risks. Natural fibre composites, particularly non-woven flax and hemp, performed best in terms of environmental impact and safety, but showed reduced strength and greater variability.

Aluminium offered moderate mechanical performance but excelled in end-of-life circularity and industrial readiness, making it a strong reference point for future sustainable material design.

7.1 Material Recommendations

- For high-load structural applications, Carbon Woven Epoxy remains the most effective option, with Carbon Woven Bio offering a more sustainable compromise where slight strength reductions are acceptable.
- For semi-structural or cosmetic parts, Flax Woven Bio and Carbon Non-Woven Bio offer strong environmental credentials and adequate mechanical performance for panels, fairings, and covers.
- For low-stress components, Flax Non-Woven and Hemp Non-Woven are ideal. Their renewability, safety, and cost-effectiveness make them suitable for interior linings and secondary panels where structural demand is minimal.
- Bio-resins are recommended where possible to reduce fossil resource use. However, as they remain thermosets, end-of-life strategies must address limited recyclability through approaches like mechanical grinding or hybridisation with recoverable components.

7.2 Future Work

- Further testing should include flexural and impact properties to better represent composite performance under real-world loading conditions.
- Strain and Young's Modulus data should be revisited once accurate extensometer or improved testing equipment becomes available.
- A full Life Cycle Assessment (LCA) is needed to validate sustainability assumptions and quantify real environmental benefits of fibre and resin choices across the full product lifecycle.

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9.0 Appendix

Composite Testing Plan

For this coursework you will be undertaking a series of tests using the Denison Tensile/Compression test equipment in the Science Lab IQ007. You will work in groups (of up to 4 students) to test a range of materials and to collect load against time data from the test machine. Mark Fall, our Science Lab Technician, will be aiding you with the testing. While in IQ007 and using the Denison Test Equipment you must follow all Health & Safety guidelines and **wear the appropriate PPE**.

The tests will evaluate a range of reinforced fibre composite materials, (traditional and natural fibres) and a base metal as a comparison. The test pieces have been made using a resin infusion process. Additional mesh material has been added to the process to enable the test pieces to be gripped by the machine. The material has all been sourced from Easy Composites and the data sheets provided from the company are available on TEAMS. For the Carbon and Kevlar material, assume a 50:50 volume fraction between the fibres and the epoxy. For all other materials the information is available on the data sheets.

For each material listed below, two tensile tests will be conducted per group to determine an average failure load for each material. At the end of the week, there will have been 14 tests completed per material. Mark will collate all of the results and upload them to TEAMS. This means that you will then be able to analyse a wide set of results in your coursework.

Baseline – Aluminium

Twill materials with Bio Resin – Kevlar, Flax and Carbon

Twill materials with Traditional Resin – Carbon

Non-woven materials with Bio Resin – Flax, Hemp and Carbon

Composite materials will be laid up as follows

- *For the twill materials; it is 3 layers of the 200g Flax Twill and 200g Carbon Twill and 2 layers of 300g Kevlar Twill (therefore for each material is 600g)*
- *For non-woven materials, it is 1 layer of the 300g non-woven Flax and 300g non-woven Carbon and 3 layers of the 100g non-woven Hemp (therefore for each material is 300g)*
- *Where multiple layers are used they will be placed at 45 degrees to each other.*

Before conducting the test you will need to measure the sample, to calculate the area, which along with the load information collected, will enable you to calculate the stress and strain.

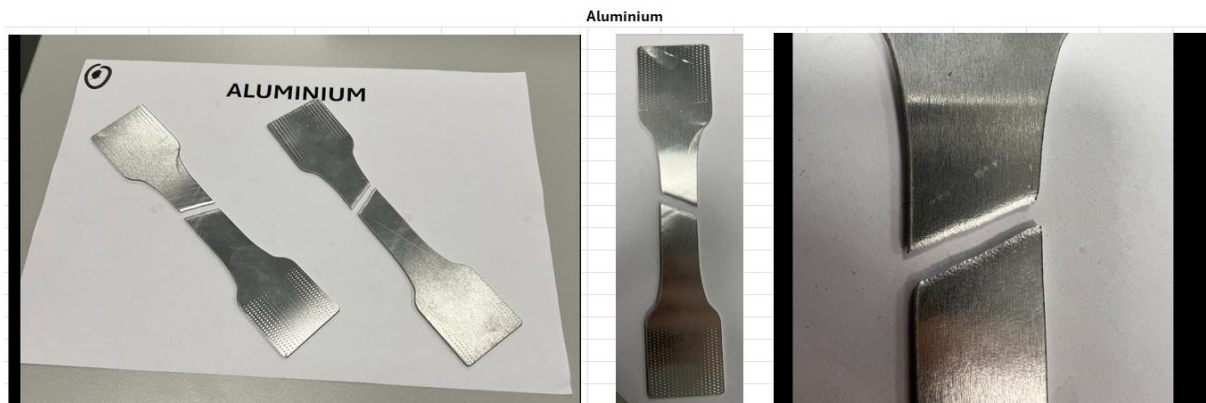
The files obtained with the data will be as a CSV file, which you will then need to open within Excel. The steps to do this are below;

1. Open Excel.
2. Click **New**, then click on **Blank workbook**.
3. Click on the **Data** tab.
4. Click **From Text/CSV**
5. Navigate to the CSV-formatted file saved on your system, select it, then click Open (When browsing to find the file, set browser to look for All Files or for Text Files)

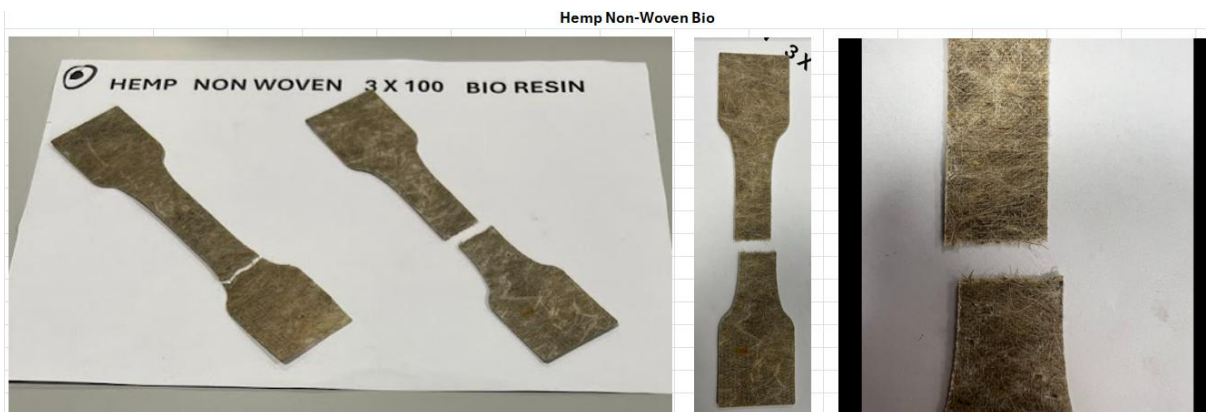
The files will contain a range of data, you will need to ignore the data on stress, strain and elongation as these will not be accurate for a composite material.

When analysing your data/results, you will need to consider

- What comparisons to carry out?
 - o Baseline
 - o Twill vs Non-Woven
 - o Epoxy vs Bio-Epoxy
 - o Etc
- Effect of plies being at 45 degrees
 - o Upper boundary = longitudinal
 - o Lower boundary = transverse
- What did you witness during the testing?
- Is there anything visible in the samples that is worth noting or exploring further?



Appendix C – Aluminium Sample Photos



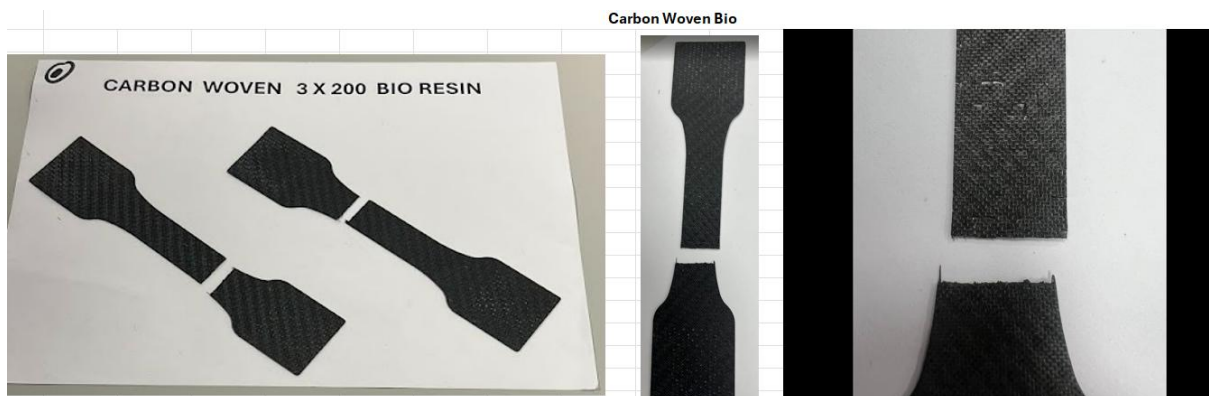
Appendix D – Hemp Non-Woven Bio Sample Photos



Appendix E – Carbon Non-Woven Bio Sample Photos



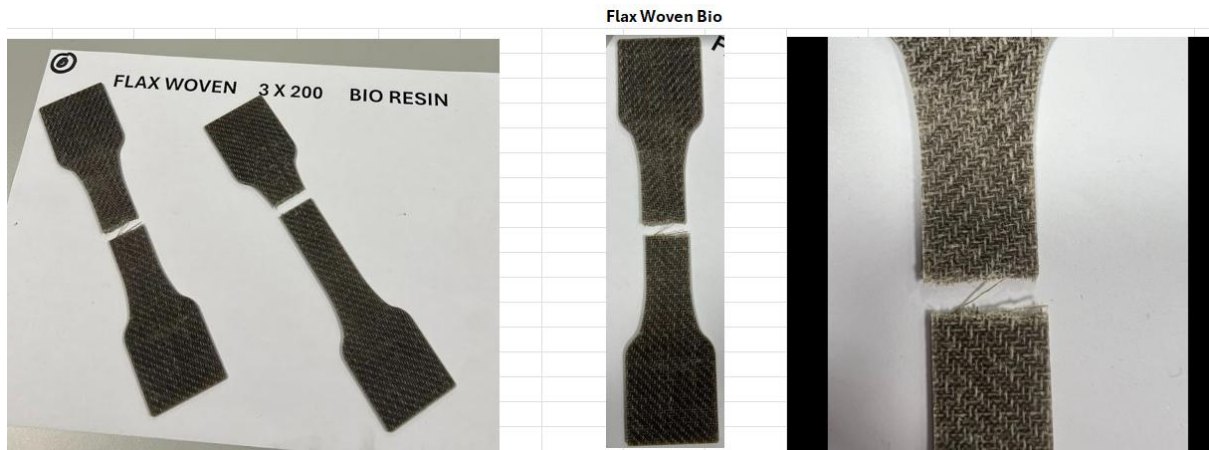
Appendix F – Carbon Woven Epoxy Sample Photos



Appendix G – Carbon Woven Bio Sample Photos



Appendix H – Flax Non-Woven Bio Sample Photos



Appendix I – Flax Woven Bio Sample Photos



Appendix J – Kevlar Woven Bio Sample Photos