



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

University of Wales Trinity Saint David

School of Engineering

Materials Testing & Sustainability in Composites
for Motorsport & Automotive Industries.

ACHA6012

Automotive Materials and Sustainability

04/05/2025

Word Count: (3291 Words)

Ross Burnside

Motorsport Engineering

2110614

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1.0 [Introduction.](#)

Composite materials consist of two or more materials that, when combined, produce better performance than the individual materials. They offer high strength-to-weight ratios, improved durability, and greater design flexibility; characteristics that make them ideal for use in automotive and motorsport applications.

This investigation focuses on the mechanical performance and sustainability of a range of fibre-reinforced composite materials, including carbon, Kevlar®, Flax, and Hemp fibres, bonded with both traditional epoxy and bio-based resin systems. Tensile testing was carried out on pre-manufactured testing strips using a Universal Testing Machine (UTM), and the results were compared against a baseline aluminium sample. The findings are analysed in terms of strength, failure behaviour, and sustainability potential, with the aim of informing material selection for lightweight, efficient vehicle components.

2.0 Literature Review.

2.1 Composite Infusion Resin.

Two epoxy resin systems were used in this investigation: IN2 (Epoxy Infusion Resin), a conventional petroleum-based epoxy infusion resin, and IB2 (Epoxy Infusion Bio Resin), a plant-based bio epoxy alternative. Both are specifically formulated for vacuum-assisted resin transfer moulding (VARTM).

IN2 is a high-performance, ultra-low-viscosity resin that provides strong mechanical properties and a clean visual finish, particularly when used with carbon and aramid (Kevlar®) fibres. Its tensile strength reaches up to 80MPa, with a flexural modulus of 3500MPa and a maximum glass transition temperature (T_g) of 98 °C depending on hardener selection (Easy Composites – 2024).

IB2, by contrast, offers a significantly lower environmental impact while maintaining comparable processing characteristics. The resin is derived from plant-based epichlorohydrin sourced from glycerol, rather than petroleum-based propylene.

Importantly, “the raw materials going into *[the]* bio resins are co-products or waste products of other industrially important processes,” meaning they do not displace food crops or agriculture. The overall bio content is 31%, which is among the highest currently available in commercial resin systems (Easy Composites – 2024).

Mechanically, IB2 performs well in structural applications. Post-cure tensile strength reaches 68MPa, and its flexural strength can exceed 109MPa, depending on the cure cycle (Easy Composites – 2024). It is especially well-suited for use with natural fibres like Flax and Jute, making it a strategic option in sustainability-focused composite design.



Figure 1: IN2 Resin
(Easy Composites – 2024)



Figure 2: IB2 Bio Resin
(Easy Composites – 2024)

2.2 [Carbon Fibre.](#)

2.2.1 – [Non-woven Carbon Fibre.](#)

Non-woven carbon fibre differs significantly in structure and performance from woven formats. Rather than being interlaced, fibres are distributed randomly or aligned in specific directions and bonded using heat, pressure, or resin. This structure allows for more isotropic mechanical properties, meaning strength can be more evenly distributed regardless of direction (JPS Composite Materials – 2021).

Advantages of non-woven fabrics are improved drapability, allowing them to conform to complex geometries with fewer wrinkles or bridging. They also tend to be lighter and less expensive due to simpler manufacturing methods. However, non-woven materials typically exhibit lower tensile strength and are more prone to deformation under load compared to woven types, making them more suitable for non-structural or semi-structural components in automotive composites (JPS Composite Materials – 2021).

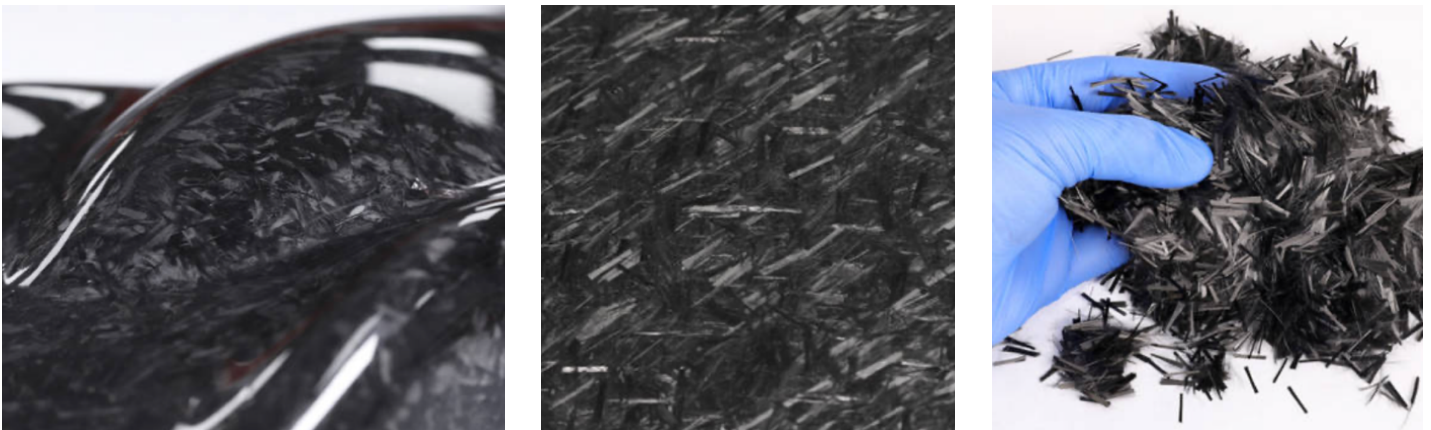


Figure 3: Examples of non-woven carbon structures and fibre-matting, made up of chopped carbon fibre tow; “often used as reinforcement in compression moulded carbon fibre components, often referred to as forged carbon fibre” (Easy Composites – 2024).

2.2.2 – Woven Carbon Fibre.

Woven fabrics are especially effective in applications requiring predictable strength and stiffness across multiple directions, such as structural automotive parts (Fairmat – 2024).

2.2.3 – Twill vs Plain Weave.

The weave style of carbon fibre has a direct influence on both mechanical behaviour and handling characteristics in composite manufacturing. Two common weave patterns are Twill weave and Plain weave, offering distinct advantages depending on application requirements.

A Plain weave (figure 6) features a simple over-under pattern that provides excellent stability and resistance to distortion during layup. Its tightly woven structure helps maintain consistent fibre alignment, making it ideal for applications requiring dimensional stability and uniform mechanical behaviour. However, due to the frequent interlacing of fibres, plain weave is generally less flexible and may not conform as easily to complex shapes (SMI Composites – 2024).

A Twill weave (figures 4 & 5) follows a diagonal pattern with fibres crossing over two or more strands at a time, resulting in a fabric that is more pliable and drapes better over curved surfaces, reducing the risk of wrinkles/bridging during layup. While it sacrifices a small degree of in-plane stability compared to plain weave, twill typically provides a slightly improved mechanical performance in terms of shear strength and fatigue resistance (SMI Composites – 2024).

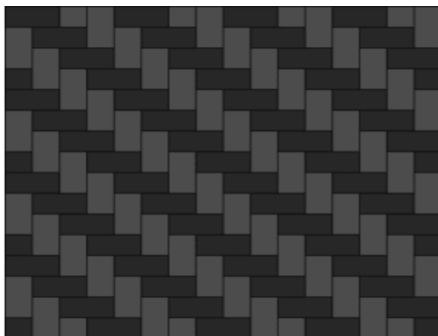


Figure 4: Example of a 2x2 Twill Weave (Olliges, R. – 2019)

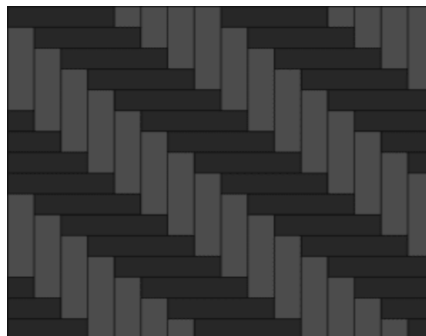


Figure 5: Example of a 4x4 Twill Weave (Olliges, R. – 2019)

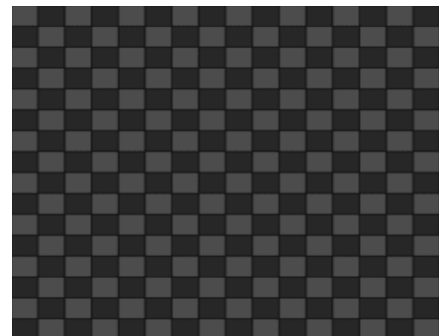


Figure 6: Example of a Plain Weave (Olliges, R. – 2019)

2.3 Kevlar.

Woven Kevlar is used for its exceptional impact resistance, durability, and lightweight performance. Originally developed for ballistic protection, Kevlar's strong and flexible fibre structure allows it to absorb and disperse energy, making it ideal for high-stress applications.

It should be noted that Aramid is a category of synthetic fibres, Kevlar® is a specific type of aramid fibre developed by DuPont.

2.3.1 – Woven Kevlar.

“Kevlar® helps enhance durability and performance in critical automotive components, such as hoses, brake pads, clutches, and body panels.” In composite form, it is often used in multilayer laminates where impact resistance is a priority, such as underbody panels, wheel wells, and reinforcement zones (DuPont – 2025).

Kevlar's® tensile strength is high, but it does not offer the same stiffness as carbon fibre, meaning it is typically used where energy absorption and toughness are more important than rigidity. Its woven structure allows it to maintain integrity under load without brittle failure, an advantage in crash-relevant zones or components subject to high-frequency vibration (DuPont – 2025).

Furthermore, Kevlar® is resistant to corrosion and chemical degradation, contributing to the long-term reliability of parts exposed to harsh environments.

Kevlar® has a tensile strength of approximately 3,620MPa and a tensile modulus of around 131GPa, making it significantly stronger than steel on a per-weight basis. Kevlar also performs exceptionally well in high-temperature environments, with thermal decomposition beginning at approximately 500 °C. Its density is 1.44g/cm³, which contributes to its effectiveness in lightweight structural applications (DuPont – 2025).



Figure 7: Kevlar® enhances the durability and performance of brake pads, maintaining integrity in extreme environments. (DuPont – 2025).

2.4 Flax.

Flax is a natural fibre known for its strength, durability, and sustainability. As a reinforcement in composite manufacturing, it offers good mechanical integrity with the added benefit of being lightweight and biodegradable. Unlike synthetic fibres, flax “requires less water and energy to cultivate”, and its production “generates little waste since every part of the plant has a use” (CFDA – 2025).

In non-structural applications such as door panels and boot linings, flax fibre composites offer significant benefit, including up to 30% weight reduction compared to glass fibres, without any changes to existing tooling (InnovationInTextiles – 2023).

Crucially, these flax composites have been shown to deliver comparable mechanical performance to conventional glass-fibre-reinforced materials, making them a viable replacement in many interior and semi-structural parts; providing “strength and stiffness with vibration damping and a significantly smaller carbon footprint” for automotive manufacturers (InnovationInTextiles – 2023).



Figure 8: An example of Flax, woven into a fibre mat to be “thermo-compressed and injection moulded.”
(Nehls, G. - 2022)



Figure 9: An example of Flax and Hemp used as a textile automotive dashboard.
(Gomez, R. - 2024)

Recent guidance from an Easy Composites new article highlights key differences in the performance and processing between woven and non-woven flax reinforcements in composite applications. While both offer environmental benefits, “woven flax fabrics provide improved load distribution and dimensional stability”, making them more suitable for structural and semi-structural components (Easy Composites – 2025).

In contrast, “non-woven flax mats tend to offer superior surface conformity and ease of moulding”, but at the cost of lower mechanical strength (Easy Composites – 2025). The article further emphasises that flax is well-suited to vacuum infusion processes, provided that careful attention is paid to resin flow and fibre wet-out. However, compared to synthetic fibres, flax can be more absorbent, meaning “resin uptake may be higher than expected”, potentially affecting part weight and cost.

2.5 Aluminium.

Aluminium was used as a baseline material in this investigation due to its well-established role in the automotive industry, offering a reliable reference point for evaluating the mechanical performance and sustainability of composite alternative.

2.5.1 – Aluminium in the Automotive and Motorsport Industry.

“Aluminium is valued for racers and motorsport vehicles as it is the lightest available high-strength metal. Aluminium alloys are corrosion-resistant, making them perfect for manufacturing engine components. Like titanium, aluminium can take on high pressure and stress without distortion” (AllMetalServices – n.d.). Aluminium continues to play a vital role in automotive manufacturing due to its balance of reduced weight, strength, and cost-effectiveness. According to a study by Prof. Mark White of the University of London, aluminium is “strong, stiff, and absorbs twice as much crash energy as mild steel by weight” (White, M. 2023). This makes it highly effective for both structural and safety-critical components.

The material is widely used in body panels, crash structures, and suspension components. Its corrosion resistance adds to long-term durability, especially in structural areas exposed to weather conditions. The metal’s lightweight nature directly supports fuel efficiency and lower emissions production.

Additionally, it should be considered that, as the industry shifts toward electrification, aluminium’s role becomes even more prominent “as we move towards electric vehicle that need to offset heavy battery packs with lightweight structures” (White, M. – 2023).



Figure 10: An image to show a modern aluminium monocoque chassis, designing the chassis as integral with the body (Haomei Auto Aluminium – 2025).

2.5.2 – Aluminium Composites

Aluminium-based hybrid composites are increasingly used in automotive applications due to their lightweight nature and enhanced mechanical properties.

These materials are commonly applied in components such as pistons, engine cylinder, brake discs, and drive shafts, where both performance and weight reduction are essential. The addition of reinforcement materials like Silicone Carbide (SiC), Graphite (C), and Aluminium Oxide (Al₂O₃) improves key characteristics. (Stojanovic, B. – 2015)

Aluminium alloys are particularly favoured for their balance of strength, weight, and tribological performance. As production volumes increase, cost reductions follow, which further enlarge their applications” across the automotive sector (Stojanovic, B. – 2015).



Figure 11: An aluminium matrix composite with silicone carbide particles (AlSiC) Piston (Stojanovic, B. – 2015).

3.0 Experimental Testing.

Tensile testing was carried out using a Denison Universal Testing Machine (UTM) (figure 12) to evaluate the mechanical performance of various composite specimens.

A total of 14 dog-bone-shaped samples were tested, comprising of two composite strips for each material configuration; including both woven and non-woven formats with epoxy and bio-based resins.

The UTM applied axial tensile force via wedge grips, gradually increasing the load until specimen failure. Load data was recorded throughout each test, providing the basis for calculating key mechanical properties such as tensile strength and strain behaviour.



Figure 12: Universal Testing Machine (UTM), used to evaluate the tensile strength and failure of different materials (Burnside, R. – 2025).

3.1 Aluminium Testing

Aluminium served as the baseline material in this investigation, with tensile testing conducted on 14 strip specimens across seven student groups. Due to inconsistencies in the UTM's default output, stress values were recalculated manually using:

$$\text{Stress (MPa)} = \frac{\text{Load (kN)} \times 1000}{\text{Cross Sectional Area (mm}^2\text{)}}$$

Stress data was plotted against time and load for all specimens, Group 2's testing displayed significantly higher and an unusually steep curve, caused by incorrect calibration and an excessive test speed. These results were considered outliers and excluded from the final results average. The remaining datasets showed consistent behaviour with clear elastic and yield regions, providing a reliable performance benchmark for comparison with composite specimens.

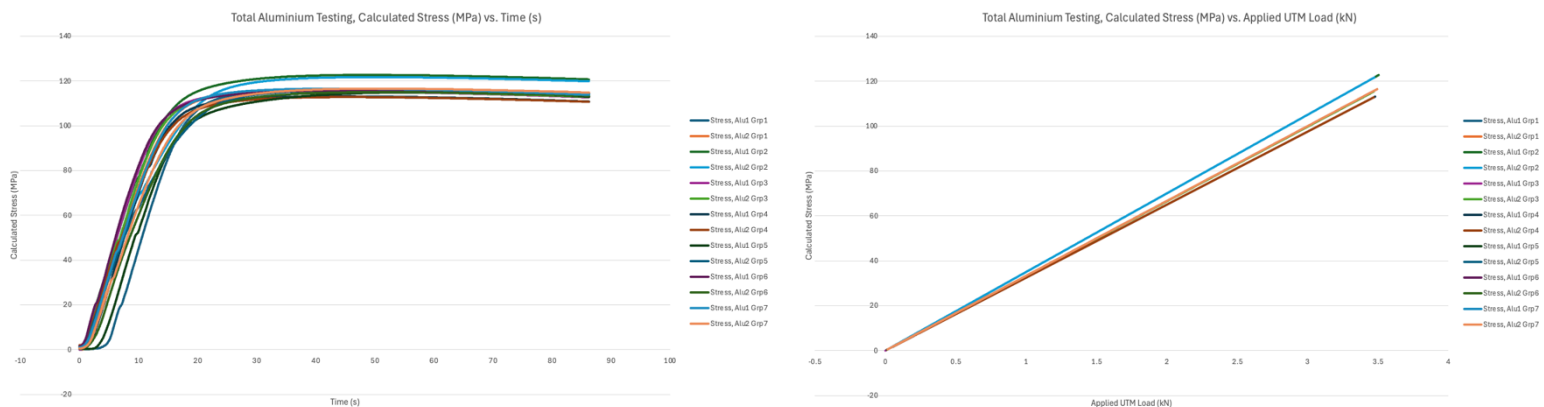


Figure 13: Combined stress-time and stress-load plots for all aluminium tensile tests, showing consistent elastic-plastic behaviour across most datasets. Outlier results from Group 2 have been excluded from analysis.

3.1.1 – Average Aluminium Results:

To calculate the average maximum stress across all valid aluminium tensile tests, the following equation was used:

$$\text{Avg. Max. Stress} = \frac{\sum \text{Max Stress Values}}{n}$$

A total of 14 aluminium specimens were tested across seven groups, with two tests per group. However, Group 2's data was excluded due to incorrect machine calibration and excessively high loading rates, which produced outlier values. After excluding these, 12 valid maximum stress values remained.

The average of these was calculated to be 115.26MPa, representing the benchmark tensile strength for the aluminium baseline samples in this investigation.

Group	Alu Test	Max. Stress (MPa)
Group 1	Alu1	116.33
	Alu2	116.5
Group 2	Alu1	122.72
	Alu2	121.67
Group 3	Alu1	115.36
	Alu2	115.36
Group 4	Alu1	113.17
	Alu2	112.85
Group 5	Alu1	114.83
	Alu2	116
Group 6	Alu1	115.67
	Alu2	115
Group 7	Alu1	116.5
	Alu2	116.5

Figure 14: Max. stress values recorded across all aluminium baseline tests. Group 2 results were excluded due to invalid loading conditions.

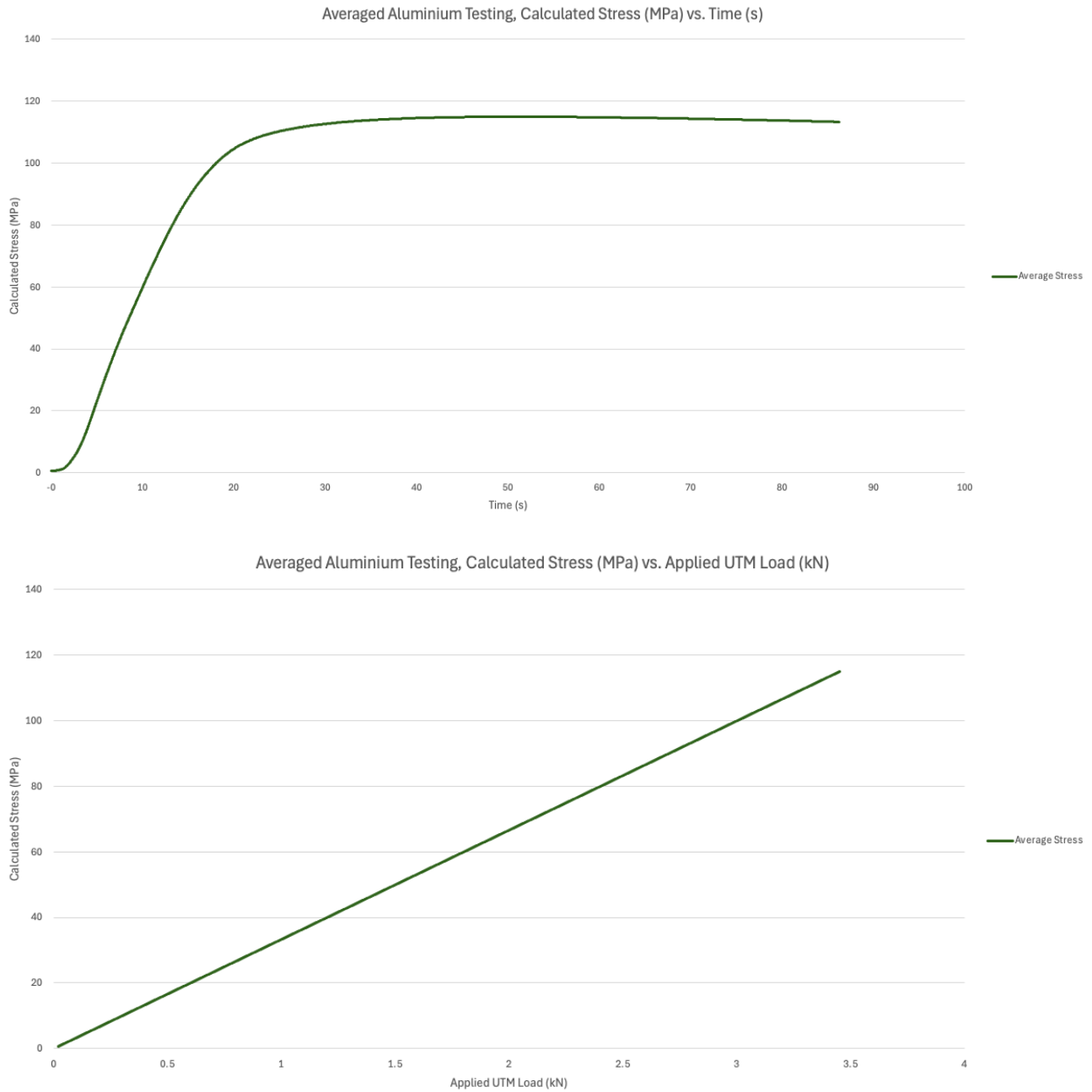


Figure 15: Averaged stress-time and stress-load plots for all aluminium tensile tests, excluding the outlier results from Group 2.

3.2 Twill Woven Carbon Fibre Testing

3.2.1 – IN2 vs. IB2 Epoxy Resin Comparison - Calculated Stress vs UTM Load

Tensile tests were conducted on twill-woven carbon fibre samples using two resin systems: IN2 epoxy infusion resin and IB2 bio-based epoxy resin. Both systems were tested with identical layup configurations, allowing for a comparison of resin effects on mechanical performance.

The stress-load and time graphs show that specimens infused with IN2 resin consistently reached higher stress values and exhibited steeper elastic gradients. Maximum stress values for IN2 samples ranged from 337MPa to 513MPa, while IB2 samples ranged from 153MPa to 444MPa, with the lowest values occurring in Group 4, likely due to manufacturing inconsistencies. Group 3 (IN2) recorded the highest overall performance at 513MPa.

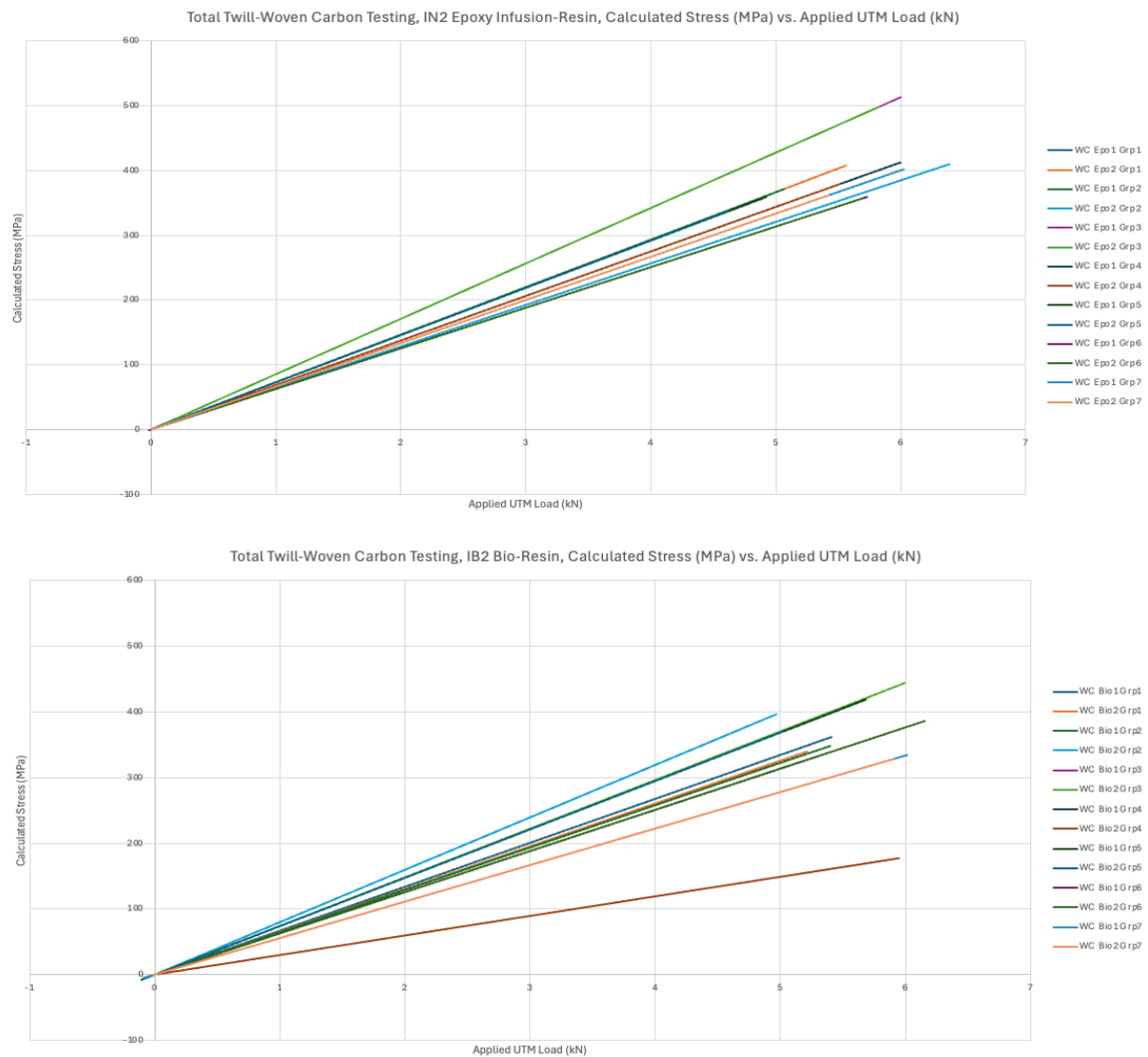


Figure 16: Calculated Stress vs. UTM load for IN2 and IB2 epoxy infused with twill-woven carbon fibre.

While both resin systems cured successfully and produced useable laminates, the IN2 epoxy group showed less variation between tests, indicating more consistent mechanical behaviour. The IB2 group displayed wider variance and more frequent early failures, such as Group 4's samples, which peaked significantly below the rest. These inconsistencies suggest experimental set-up error, or possible variation in laminate quality or fibre wet-out during the infusion process (Easy Composites – 2024).

3.2.2 – IN2 vs. IB2 Epoxy Resin Comparison - Calculated Stress vs Time.

The observed performance disparity reinforces the importance of resin selection in composite systems. As evident in the testing, twill-woven carbon fibre laminates using IN2 epoxy infusion resin consistently outperformed those produced with IB2 bio-resin in terms of maximum stress capacity. The strongest IN2 sample recorded a tensile strength of 513.25MPa (Group 3), while the highest IB2 result reached 443.75MPa (Group 3). Meanwhile, the lowest-performing IB2 laminate (Group 4) failed at just 153.13MPa, highlighting greater variance and indicating sensitivity to manufacturing inconsistencies such as peer fibre wet-out or incomplete curing; alongside possible experimental set-up errors or misalignments between group testing.

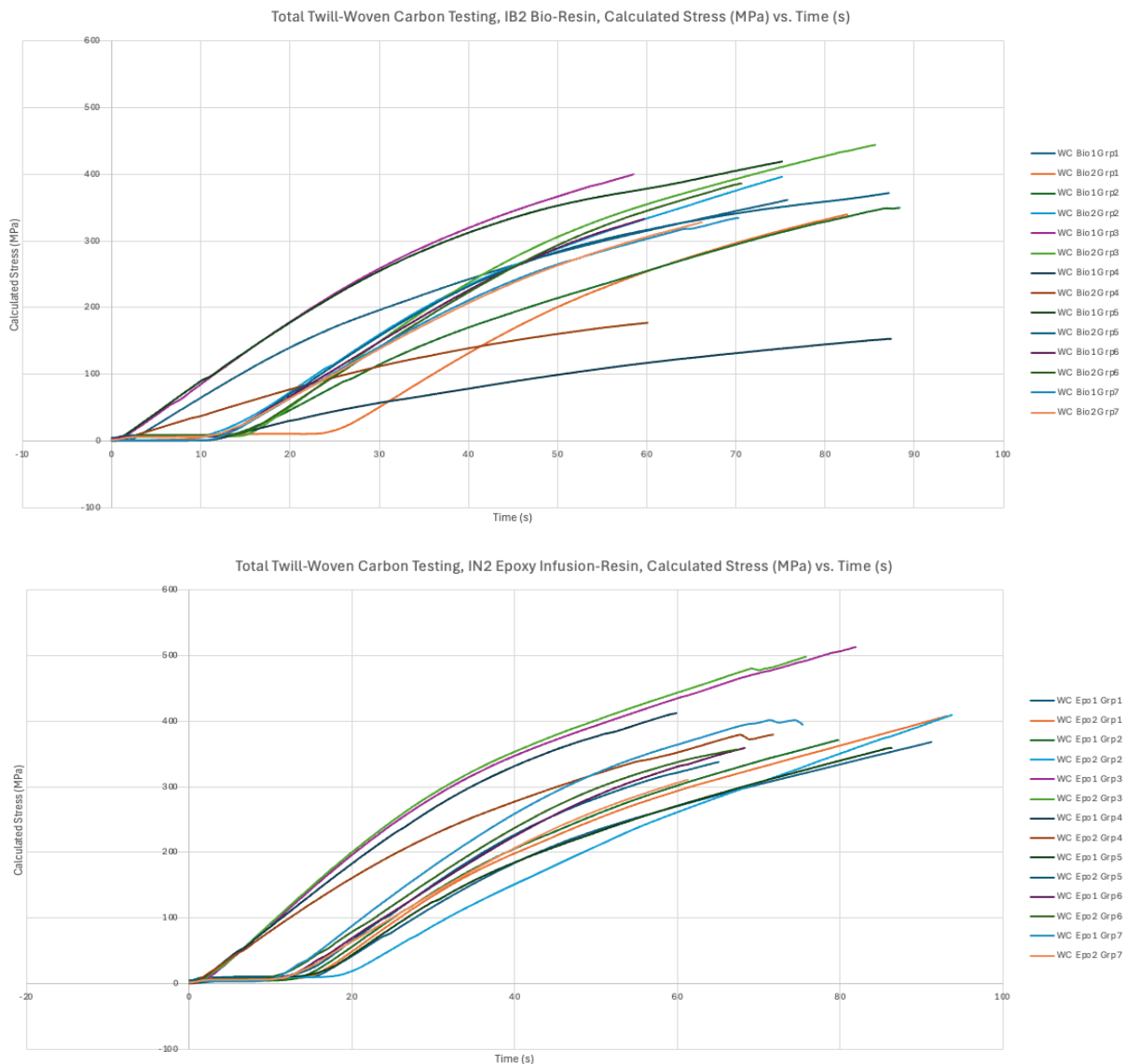


Figure 17: Calculated Stress vs. Time for IN2 and IB2 epoxy infused with twill-woven carbon fibre.

Comparatively, the published properties of high-performance carbon fibres such as Mitsubishi's TR50S12L and TR50S15L indicate tensile strengths of up to 500MPa and beyond (Mitsubishi Rayon Co. Ltd. – 2013). This aligns closely with the upper range of the IN2 samples, suggesting the epoxy infusion system improves the potential of woven fibre reinforcement, enabling closer conformity with the manufacturer performance expectation. The interlaced nature of the woven format contributed to the consistency seen in IN2 specimens, which exhibited tighter grouping and steeper elastic gradients.

The averaged stress results reinforce trends observed in the individual datasets. IN2 epoxy laminates displayed higher average stress values and a steeper rise in both time and load, indicating superior laminate strength. This aligns with observations that “epoxy-based systems such as IN2 tend to offer higher stiffness and better fibre-matrix bonding” (Easy Composites – 2024), enhancing load distribution across the laminate. The IN2 specimens suggest a more uniform mechanical response and improved wet-out, typical of epoxy-resin systems.

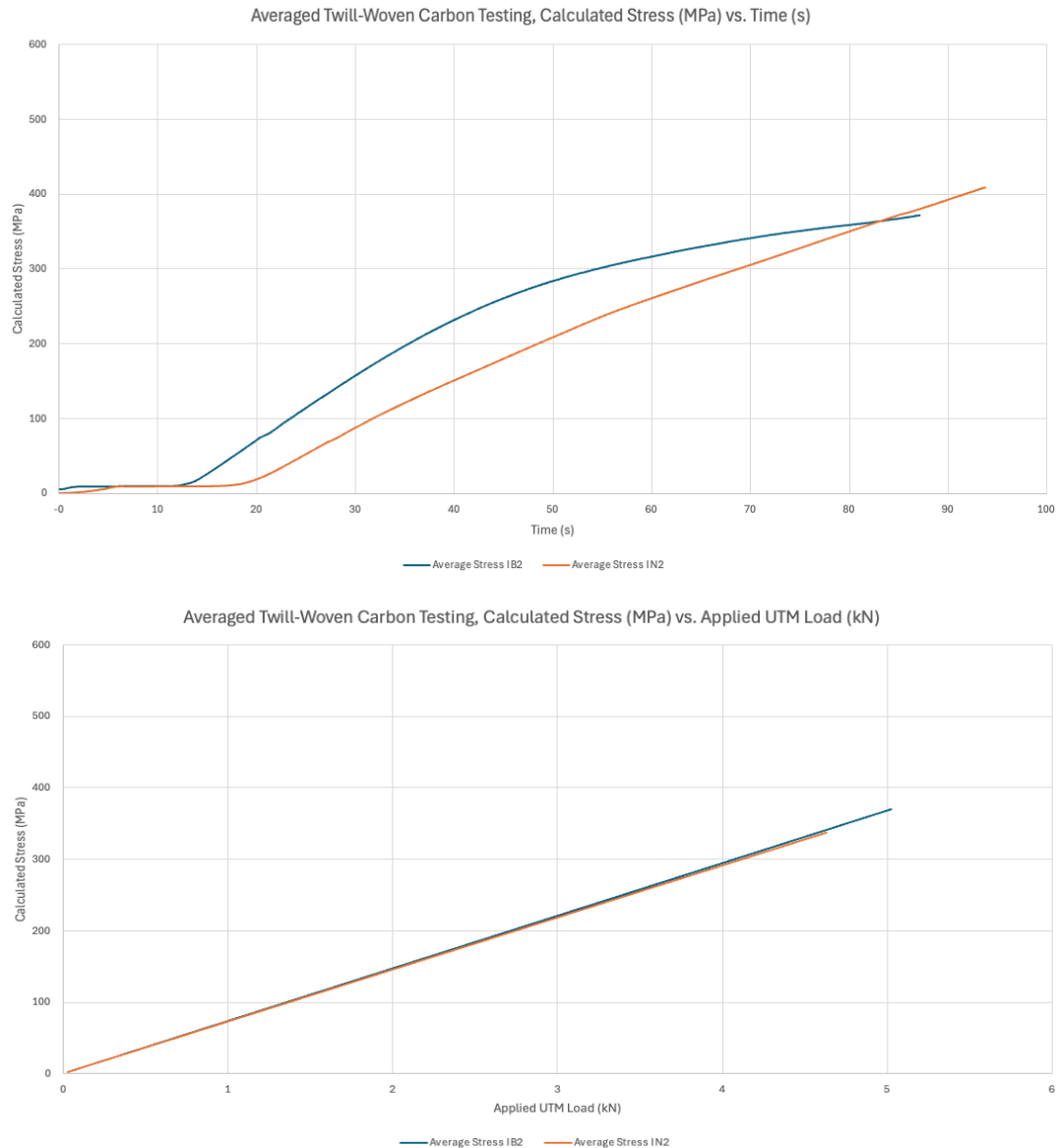


Figure 18: Averaged stress-time and stress-load plots for all twill-woven carbon fibre tensile tests.

In contrast, the IB2 samples exhibited a more gradual increase in stress and broader variation between tests, indicative of user error, or inconsistent curing or fibre impregnation. This reflects the challenges highlighted in the literature, where bio-resins are noted to “sacrifice mechanical performance for sustainability (Easy Composites – 2024) and may suffer from “variation in laminate quality of fibre wet-out during the infusion process” (Fairmat – 2024). These characteristics underscore the trade-off between environmental benefit and mechanical reliability in structural composite applications.

The final stress data summary tables below present the maximum tensile strength values obtained across all twill-woven carbon fibre specimens tested. These test results clearly demonstrate the superior mechanical performance of the IN2 epoxy resin system, which consistently outperformed the IB2 bio-based counterpart. The data reinforces earlier observations of tighter grouping, higher peak stresses, and improved consistency in the IN2 results; aligning with manufacturer expectations and literature claims regarding fibre-matrix compatibility and resin reliability (Easy Composites – 2024; Mitsubishi Rayon Co. Ltd. – 2013).

Group	WCTest	Max. Stress (MPa)	Group	WCTest	Max. Stress (MPa)
Group 1	Bio1	361.631	Group 1	Epo1	268.269
	Bio2	339.844		Epo2	407.692
Group 2	Bio1	349.549	Group 2	Epo1	371.429
	Bio2	396.332		Epo2	409.615
Group 3	Bio1	400.074	Group 3	Epo1	513.248
	Bio2	443.745		Epo2	498.291
Group 4	Bio1	153.125	Group 4	Epo1	412.027
	Bio2	177.083		Epo2	379.381
Group 5	Bio1	418.999	Group 5	Epo1	358.965
	Bio2	371.502		Epo2	337.464
Group 6	Bio1	333.02	Group 6	Epo1	359.336
	Bio2	385.893		Epo2	356.516
Group 7	Bio1	334.444	Group 7	Epo1	401.667
	Bio2	328.056		Epo2	326

Figure 19: Maximum calculated stress (MPa) values per test for IB2 and IN2 resin-treated carbon fibre.

3.2.3 – IB2-Infused Woven Kevlar Investigation.

The results from the IB2-infused woven Kevlar® tests revealed a wide disparity in mechanical performance across groups. While DuPont reports tensile strengths for Kevlar 49 yarns as high as 3600MPa (DuPont – 2025), only Group 7's specimens came close to this figure, peaking at 2782.5MPa and 2665.0MPa respectively. All other groups returned significantly lower values, often falling below 500MPa, suggesting laminate limitations or inconsistencies in the composite construction.

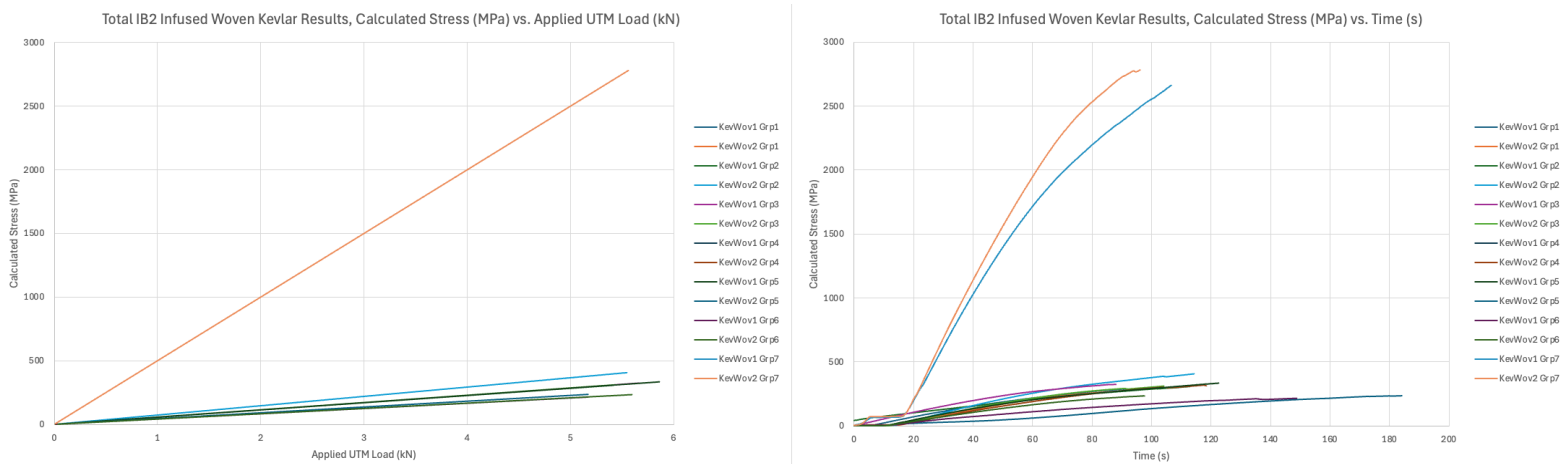


Figure 20: IB2-infused woven Kevlar® results, displaying two test results coming close to the known tensile strength of Kevlar®, with others falling short of this mark.

This contrast may stem from the resin matrix. As outlined in the IB2 technical data sheet, though marketed as high-performance and environmentally responsible, IB2 exhibits a post-cure tensile strength of only 68MPa (Easy Composites – 2024). While this figure reflects cured resin alone, it highlights a potential discrepancy between the resin's capabilities and the mechanical potential of aramid fibres such as Kevlar®.

Moreover, the IB2 datasheet stresses the importance of strict mix ratios and complete post-cure cycles, noting that failure to comply could result in “greatly reduced mechanical properties”. This raises the possibility that Groups 1-6 either experienced poor resin cure, incorrect mixing, or inadequate infusion/wet-out during layup; particularly critical with Kevlar, which is notoriously difficult to wet out due to its surface chemistry and tight weave structure (Easy Composites – 2025).

However, literature findings were that Kevlar’s® tensile strength is high but does not offer the same stiffness as carbon fibre, meaning it is typically used where energy absorption and toughness are more important than rigidity.

These findings highlight the complex interaction between reinforcement and resin in composite design. While Kevlar® possesses exceptional intrinsic properties, including a tensile strength exceeding 3600MPa and outstanding impact resistance (DuPont – 2025), the realised performance in IB2-infused laminates was heavily dependent on manufacturing precision and resin compatibility. This supports earlier claims that Kevlar® composites “can be applied alone or combined with other reinforcement fabrics to create a composite with excellent strength and impact durability,” but only when fibre wet-out and cure conditions are properly controlled (Easy Composites – 2024).

Due to the lack of confidence in result accuracy, Kevlar® results were not directly compared to twill-woven Carbon Fibre specimens.

3.3 Flax Testing

3.3.1 – Woven Flax Results.

The twill-woven flax samples infused with IB2 resin displayed notably consistent mechanical performance across all groups. Maximum stress values ranged from 75.180MPa to 97.874MPa, with all specimens exceeding 75MPa, highlighting strong inter-fibre cohesion and good resin integration.

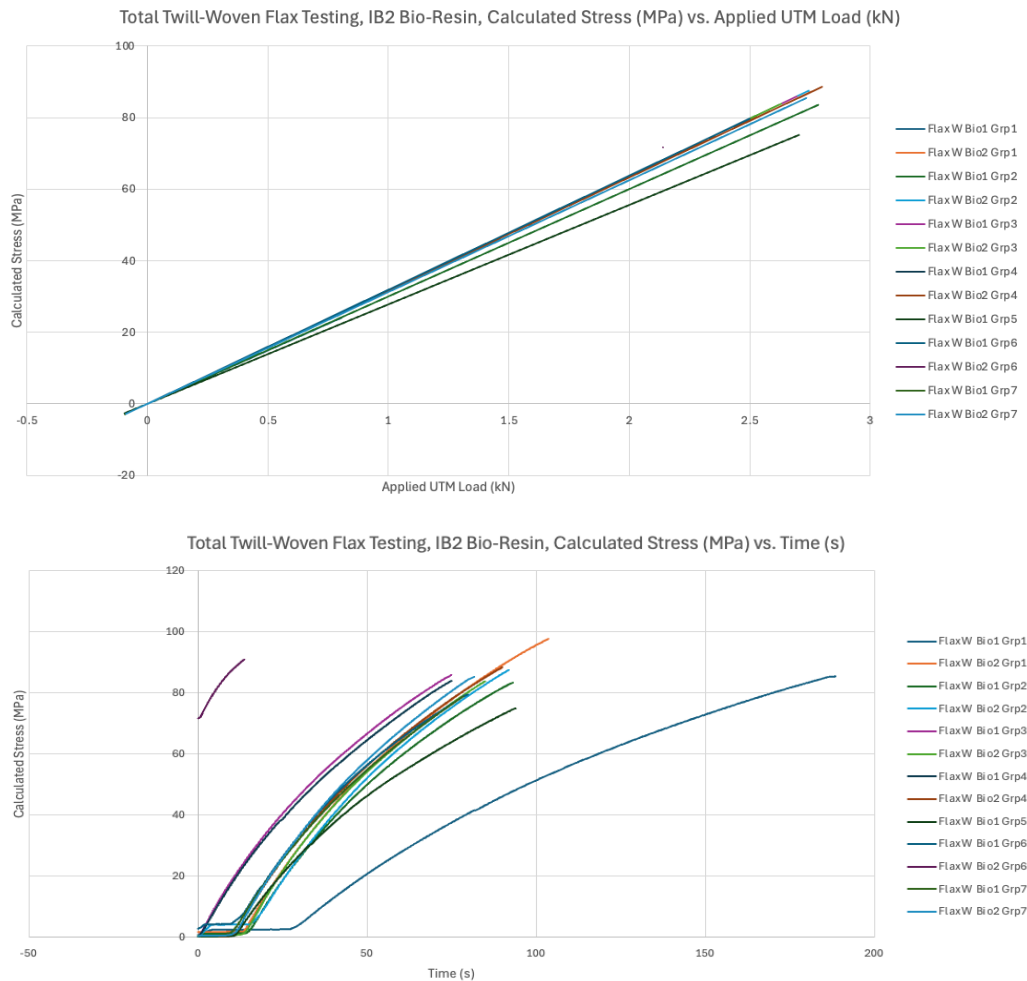


Figure 21: Twill-woven Flax testing results, infused with IB2 Bio-Epoxy Resin.

The grouped stress time and load plots show predictable curves with only minor deviation, although one trace (Group 3, W Bio1) displayed an unusually steep initial rise, likely due to experimental misalignment or a defective gauge reading; this result was excluded from the final results average. Nonetheless, overall performance aligns with literature noting that woven flax structures “maintain integrity under load” and deliver improved stress transfer through their fibre interlock (Easy Composites – 2025).

3.3.2 – Non-Woven Flax Results.

In contrast, the non-woven flax groups demonstrated broader inconsistency and lower mechanical output. Stress peaks varied between 30.723MPa and 62.615MPa, with a majority of samples failing to exceed 50MPa. The stress vs applied load graph reveals a clear outlier (Group 2, NW Bio2) with values exceeding 60MPa; well beyond the remainder of the dataset.

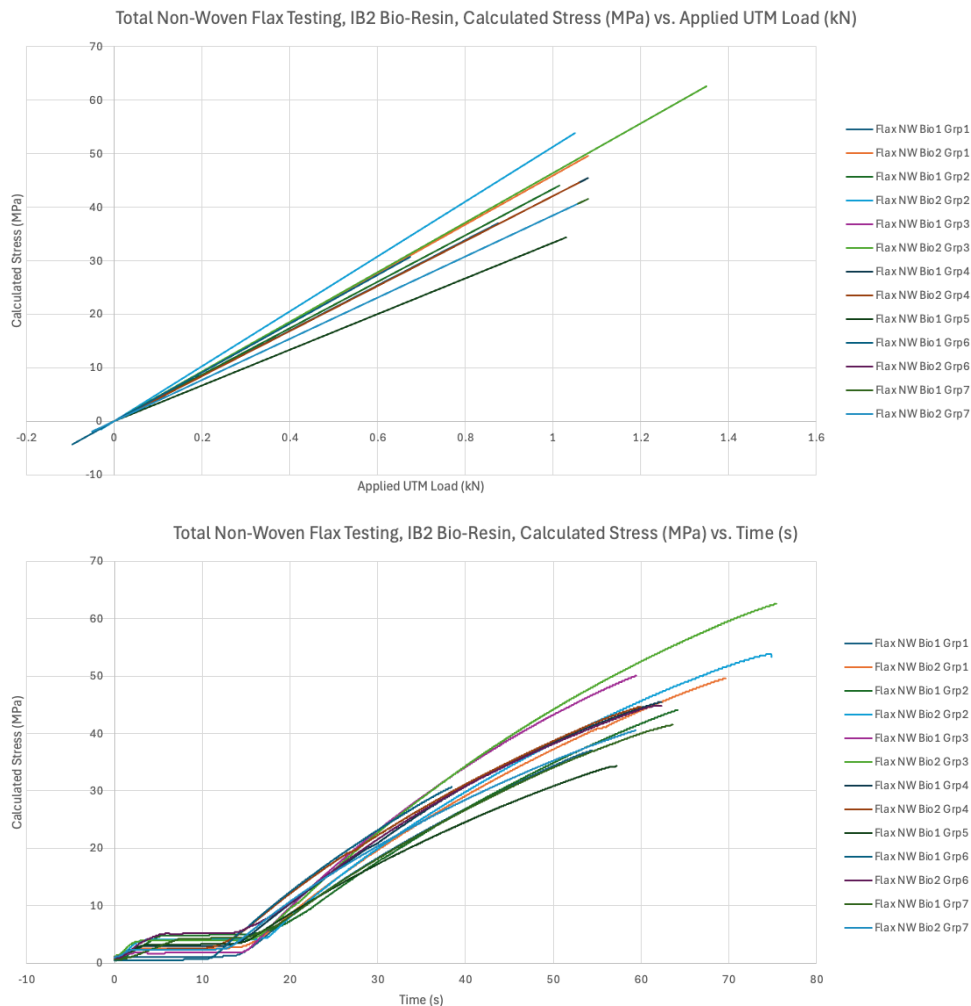


Figure 22: Non-woven Flax testing results, infused with IB2 Bio-Epoxy resin.

While this could represent a well-infused sample, it more likely reflects experimental variation. Additionally, Group 5's NW Bio2 data was missing from the composite test files, so it could not be contributed towards averaged results. Easy Composites (2025) highlights the difficulty of wetting out flax in non-woven form due to fibre clustering, which may explain the underperformance and sensitivity to infusion inconsistencies.

3.3.2 – Average Flax Results Comparison.

The averaged results comparison in figure 23 clearly supports the mechanical superiority of woven flax specimens. The woven group maintained higher stress throughout the applied load curve and ultimately recorded an average maximum stress approximately 25-30% greater than that of non-woven samples.

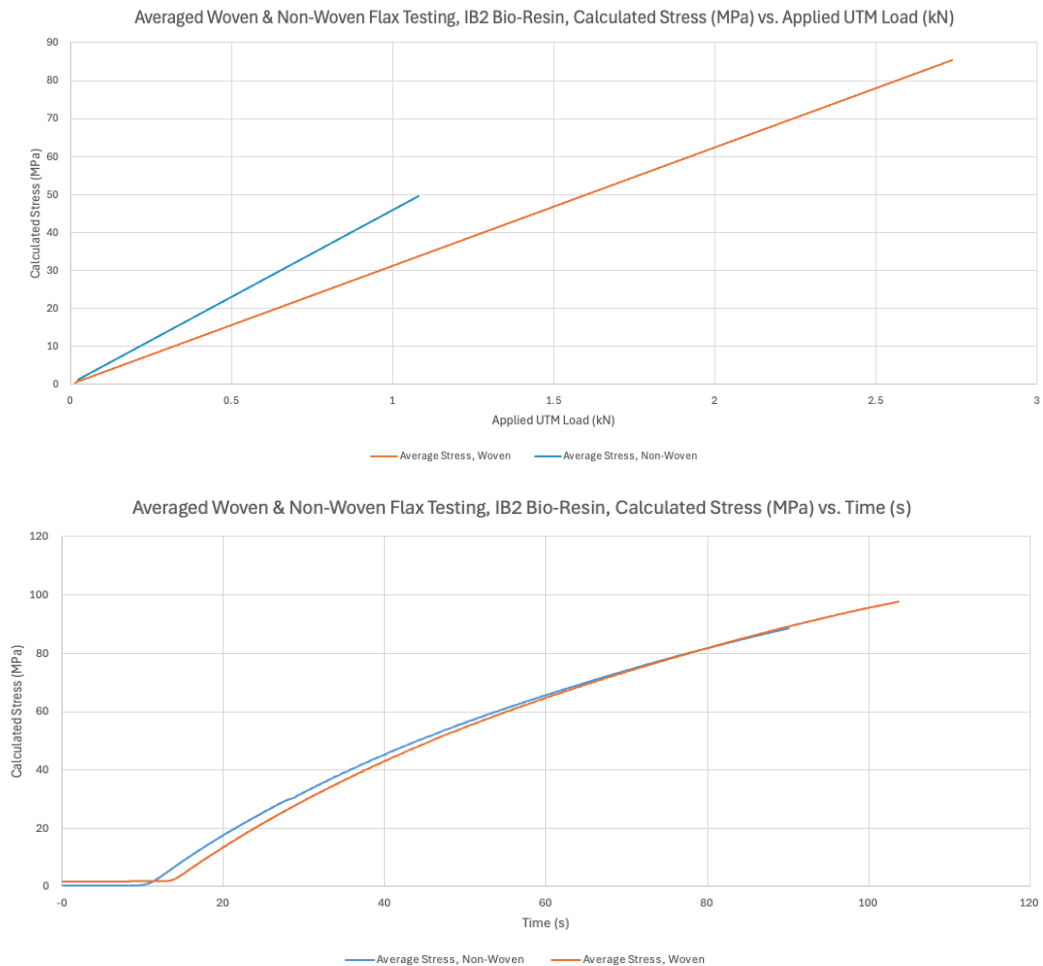


Figure 23: Averaged Woven & Non-Woven Flax test results, displaying a clear advantage in woven structure.

This aligns with claims from InnovationInTextiles (2023), which report that woven flax delivers “strength and stiffness with vibration damping” and can rival glass-fibre-reinforced alternatives in non-critical components.

Group	Test	Max. Stress (MPa)	Group	Test	Max. Stress (MPa)
Group 1	W_Bio1	85.547	Group 1	NW_Bio1	37.013
	W_Bio2	97.874		NW_Bio2	49.586
Group 2	W_Bio1	83.583	Group 2	NW_Bio1	44.053
	W_Bio2	87.531		NW_Bio2	53.846
Group 3	W_Bio1	85.937	Group 3	NW_Bio1	50.092
	W_Bio2	83.864		NW_Bio2	62.615
Group 4	W_Bio1	84.018	Group 4	NW_Bio1	45.454
	W_Bio2	88.6		NW_Bio2	44.612
Group 5	W_Bio1	75.18	Group 5	NW_Bio1	34.356
	W_Bio2	78.932		NW_Bio2	(no data)
Group 6	W_Bio1	79.719	Group 6	NW_Bio1	30.723
	W_Bio2	91.122		NW_Bio2	44.829
Group 7	W_Bio1	79.062	Group 7	NW_Bio1	41.538
	W_Bio2	85.468		NW_Bio2	40.576

Figure 24: Maximum Stress (MPa) results for each test carried out on the Flax specimen strips.

4.0 Sustainability Analysis & Recommendations.

A sustainability comparison of the tested materials was carried out using LCA considerations outlined in ISO 14040 and ISO 14044 (SETAC – 1993; ISO – 2006). Key environmental impact phases were considered, including raw material extraction, production energy, end-of-life recyclability, and overall carbon footprint. Mechanical performance was balanced against these sustainability factors to guide material recommendation.

Material	Recyclability	Production Energy Use	Biodegradability	CO2 Footprint	Avg Max. Stress	Sustainability Score
Aluminium	High (well-established infrastructure)	High	Poor	Moderate	115.26MPa	[3/5]
Woven Carbon + IN2	Very Low (difficult fibre recovery)	High	Poor	High	433.40MPa	[2/5]
Woven Carbon + IB2	Very Low	High	Poor	High	361.60MPa	[2/5]
Woven Kevlar + IB2	Very Low	High	Poor	High	2723.75 (Grp7 only)	[2/5]
Woven Flax + IB2	Moderate (recoverable)	Low	High	Low	85.60MPa	[4/5]
Non-Woven Flax + IB2	Moderate	Low	High	Very Low	45.20MPa	[4/5]

Figure 24: Sustainability analysis table, incorporating an end-of-life analysis to assess material impact throughout production, use, and recyclability.

Aluminium offers strong recyclability with established infrastructure, allowing repeated reuse without quality loss (recycle-more – 2025). Though its embodied energy is high, its moderate CO2 footprint and circularity make it a balanced material option.

Woven Carbon+ IN2 achieved the highest average tensile strength, but recyclability remains poor due to different fibre recovery (CompositesUK – 2025). High production energy and limited end-of-life options reduce its sustainability appeal.

Woven Carbon + IB2 showed reduced mechanical performance with limited recyclability. While bio-resin slightly improves eco-credentials, overall environmental impact remains high (CompositesUK – 2025).

Woven Kevlar + IB2 displayed excellent strength in Group 7, but inconsistencies and complex recycling processes (Peacockfibres – 2025) diminish its sustainability. High production energy further limits its environmental value.

Woven Flax + IB2 stood out for low production energy, full biodegradability, and moderate recyclability. Its farming and processing are waste-free and CO2 efficient (Safilin – 2021), making it ideal for sustainable composites.

Non-woven Flax + IB2 shared similar benefits, though mechanical performance was lower. Its ease of composting and bio-based composition support circular design, especially in low-load applications.

5.0 Conclusion.

This investigation assessed the tensile performance and sustainability of several composite material systems, benchmarked against aluminium. Woven carbon fibre with IN2 resin delivered the highest mechanical strength, while natural reinforcements like flax offered superior environmental credentials. Kevlar showed promise in isolated cases but suffered from inconsistency. Flax, particularly in woven format with IB2 resin, emerged as the most balanced option, offering moderate strength and strong sustainability benefits. Material selection should be driven by application requirements, weighing structural demands against recyclability, production impact, and end-of-life considerations.

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