FIBREGY

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ICCM 23 BELFAST 2023

UNIVERSITY OF LIMERICK OLLSCOIL LUIMNIGH | Bernal Institute

Characterization and post-repair performance of infusible thermoplastic-based composites under compression

Presenters: Gursahib Singh Bhatia, Akshay Hejjaji, Jayaram R. Pothnis, Kieran Fahey, Anthony Comer
Organization: Bernal Institute, University of Limerick (ULIM)

TWENTY-THIRD INTERNATIONAL CONFERENCE ON COMPOSITE MATERIALS (ICCM23), Belfast, 2023

Contents

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Introduction : FibreGY

Offshore energy :

- Great potential to help reach climate goals
- Reduced CO_2 levels.

Aggressive Open Sea Environment

Economics of Large Scale Installations

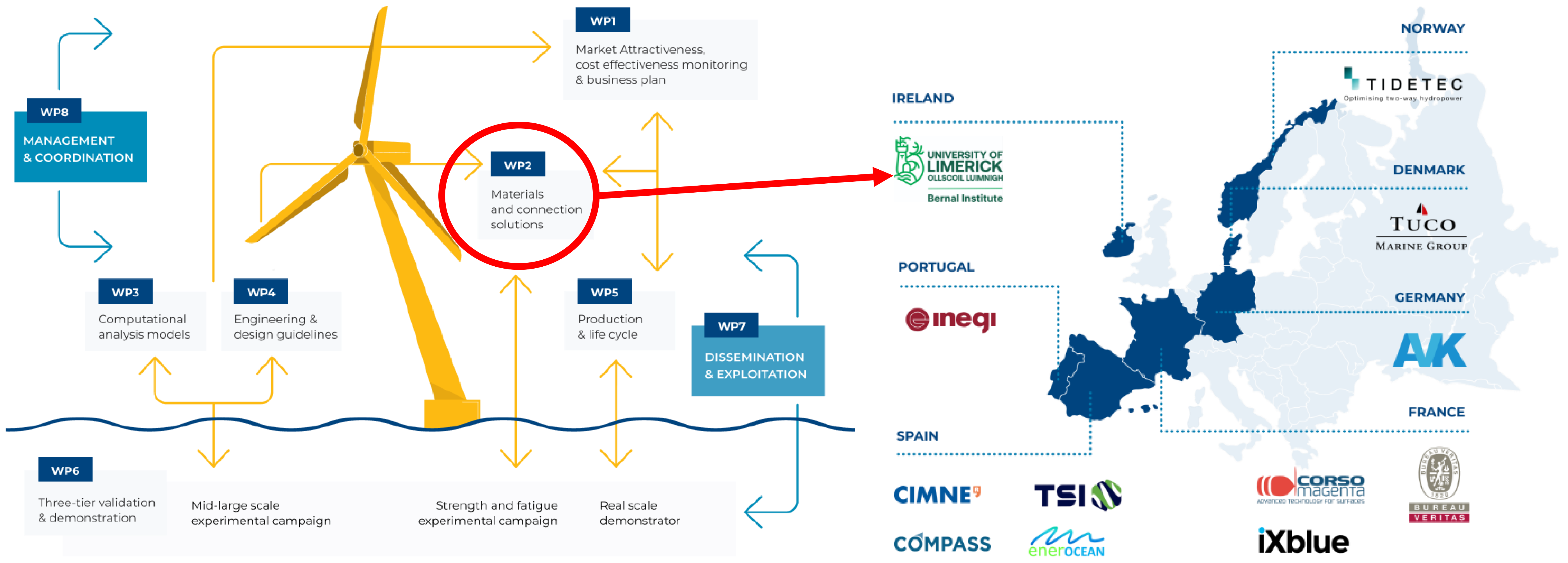
High Costs of Preventive Maintenance

Material Concerns

Can use of Fiber Reinforced Plastic (FRP) composites be a solution to this problem ?

FibreGY– Enable extensive use of FRP materials in next generation offshore wind and tidal power platforms.

- Design the structural components of the wind power platform and tidal turbine in FRP materials.
- Develop, qualify & audit innovative FRP materials.
- Elaborate new design procedures & guidelines.



Materials : Offshore Energy Structures

Sustainability
-Low environmental impact
-End of Life options

Endurance
-Resistance to Corrosion
-Fatigue performance

Requirements & Limitations

Manufacturability
- Vacuum Infusible
-Close to ambient cure cycle

Industrial Viability
-Reliable supply chain
-Cost effective

Selected thermoplastic: Elium

- ✓ Compatible with vacuum infusion for large parts demonstrated in ongoing ZEBRA wind blade project
- ✓ Recyclable at the end-of-life
- ✓ Very competitive on cost
- ✓ Only infusible thermoplastic available commercially

Materials Used	
Resin	**Thermoplastic Acrylic** (Elium 188O, Elium 188XO)
Fabric	**Non-Crimp Glass fibre (GF)** Saertex U-E 1182 g/m^2
	Non-Crimp Carbon fibre (CF) Saertex U-C 438 g/m^2

Compression Tests- Characterization

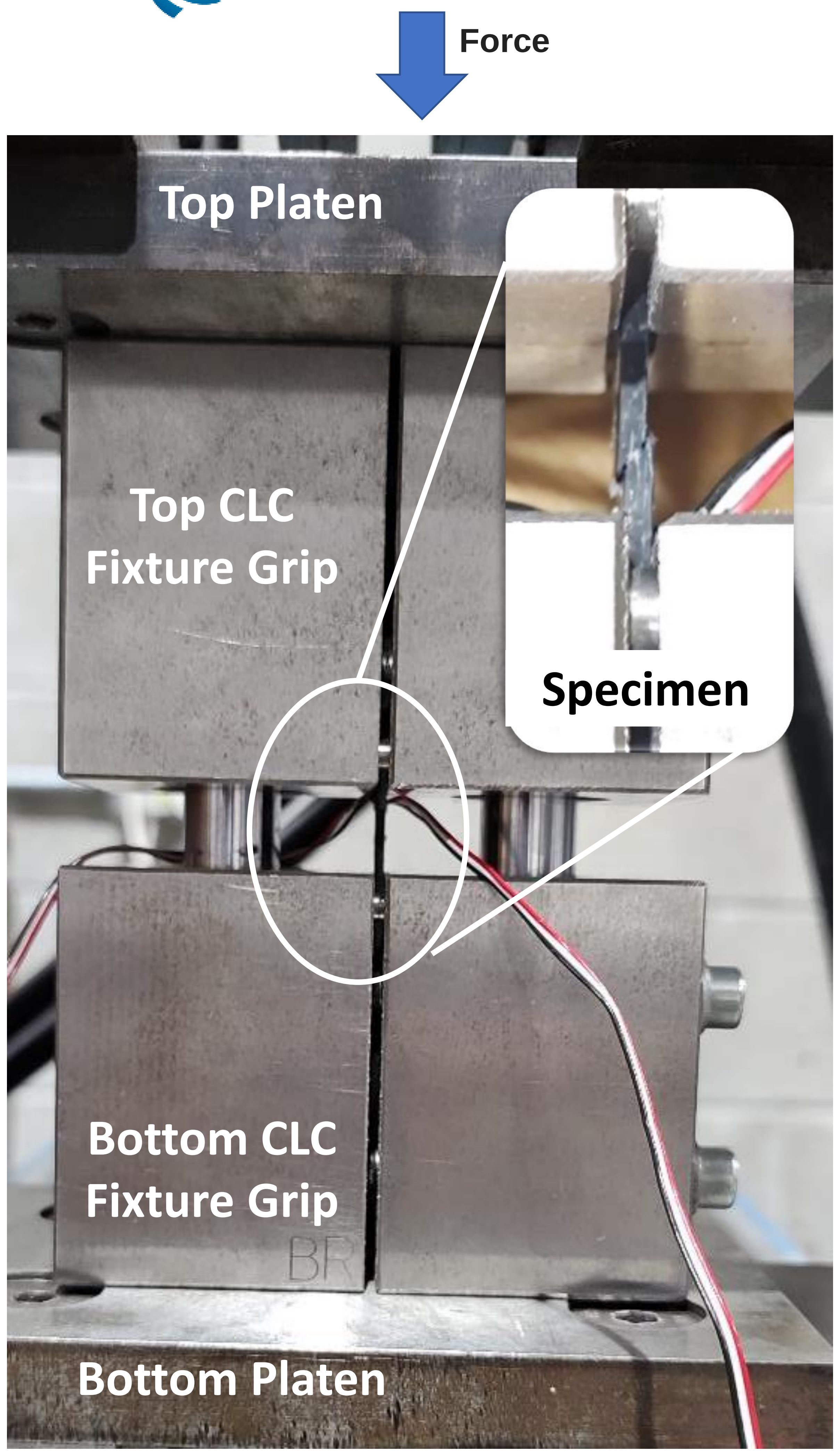
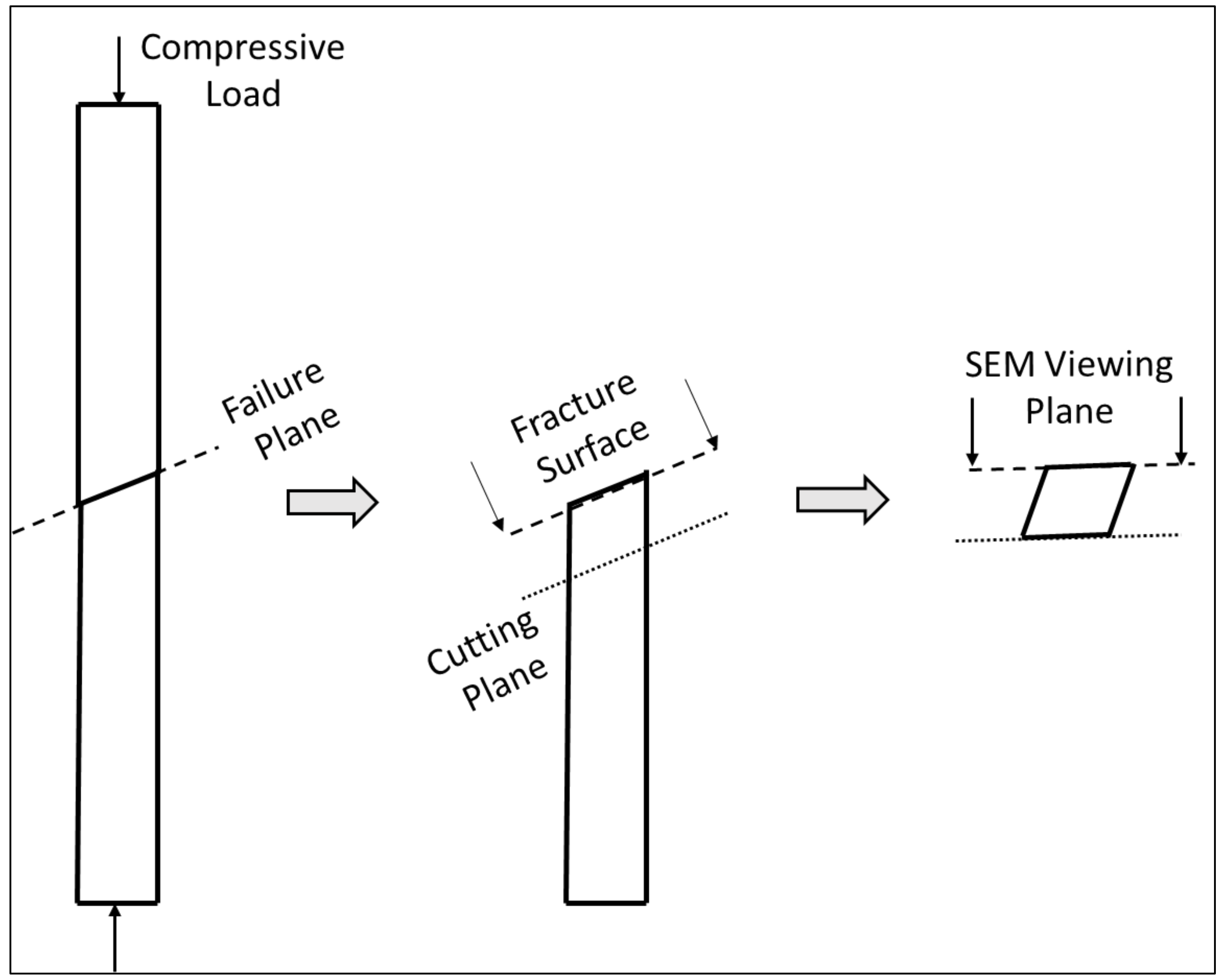
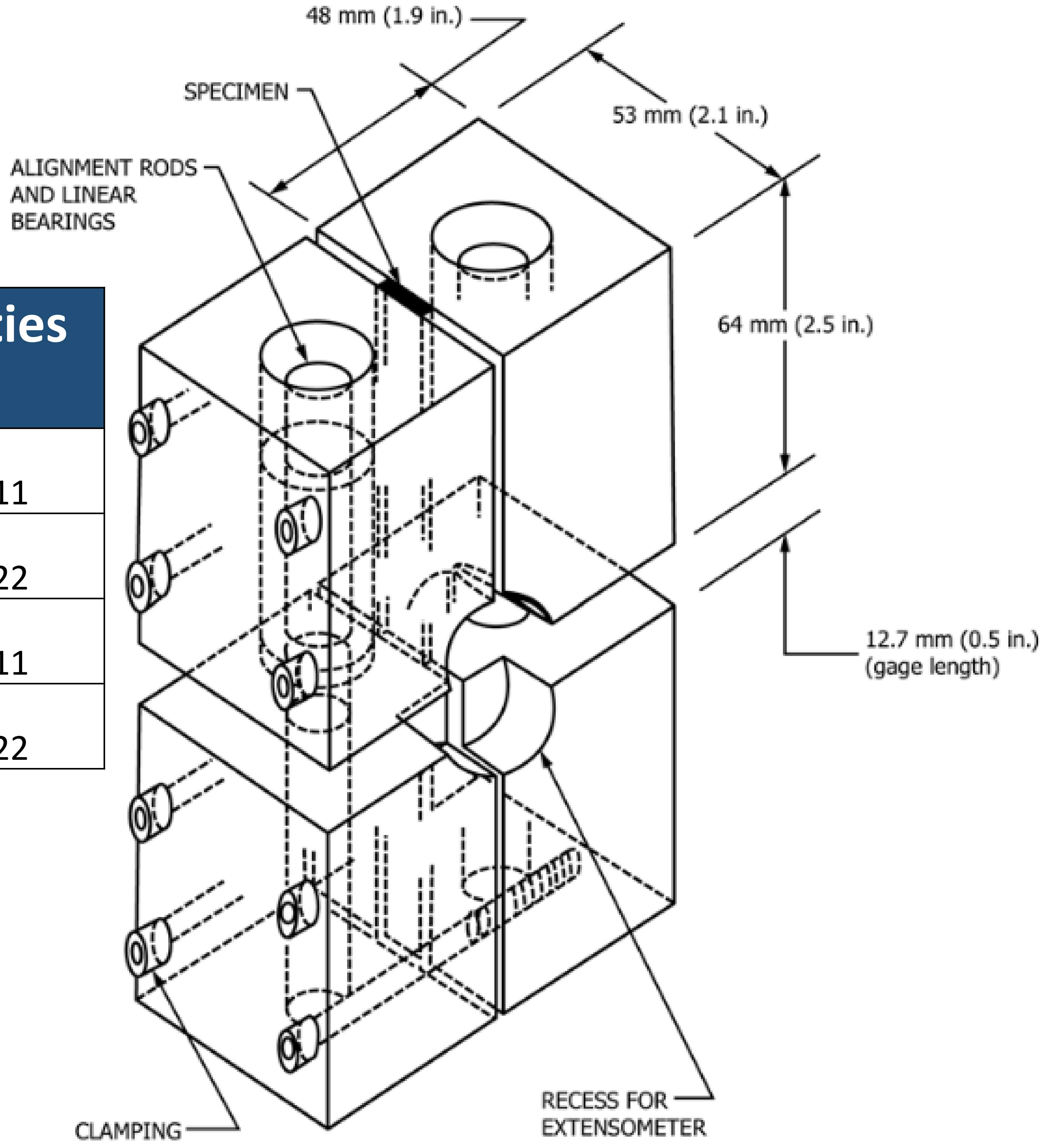


Figure: Compression Test Fixture (ASTM D6641) (ULIM)

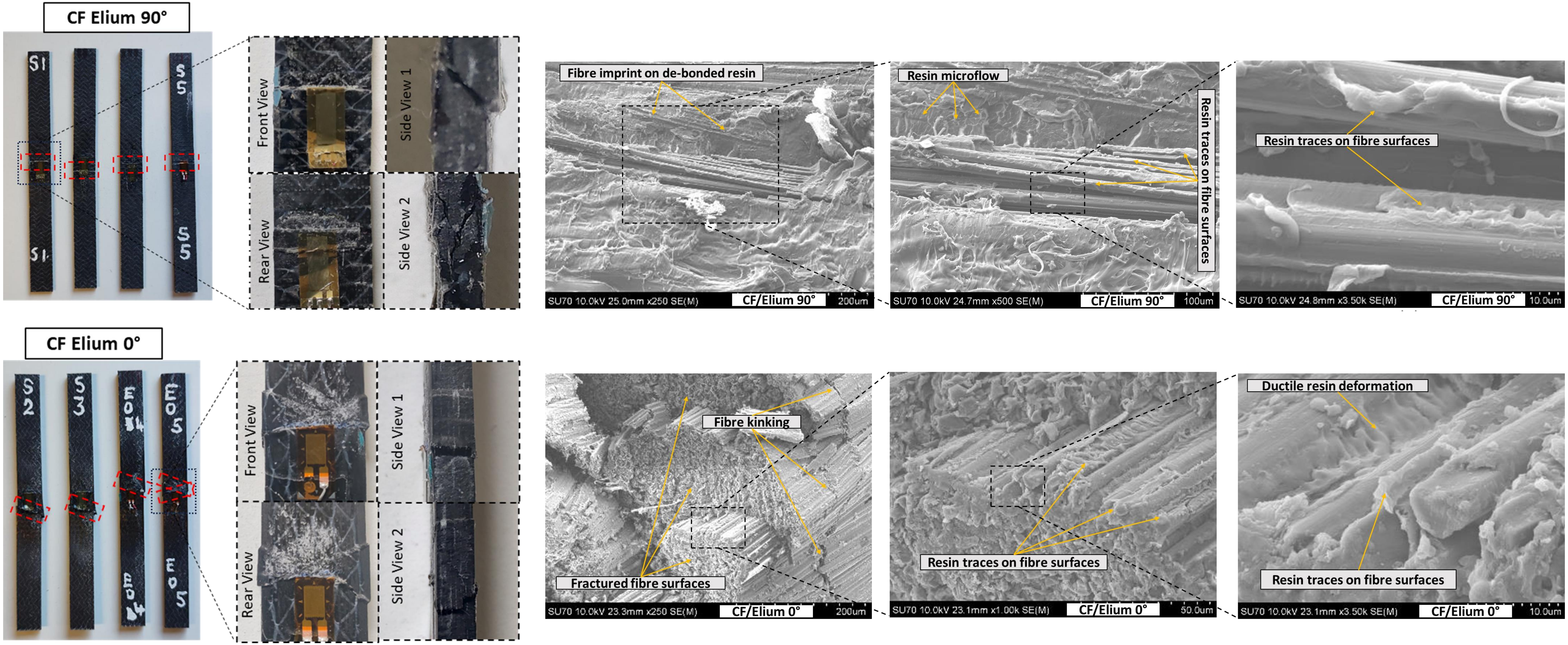
Sr. no.	Laminate Material (Notation)	Stacking Sequence	Properties
1.	Carbon Fibre/Elium (GF/E)	$[0]_{2S}$	σ_{11}, E_{11}
		$[90]_{2S}$	σ_{22}, E_{22}
2.	Glass Fibre/Elium (CF/E)	$[0]_{4S}$	σ_{11}, E_{11}
		$[90]_{2S}$	σ_{22}, E_{22}





ASTM D6641

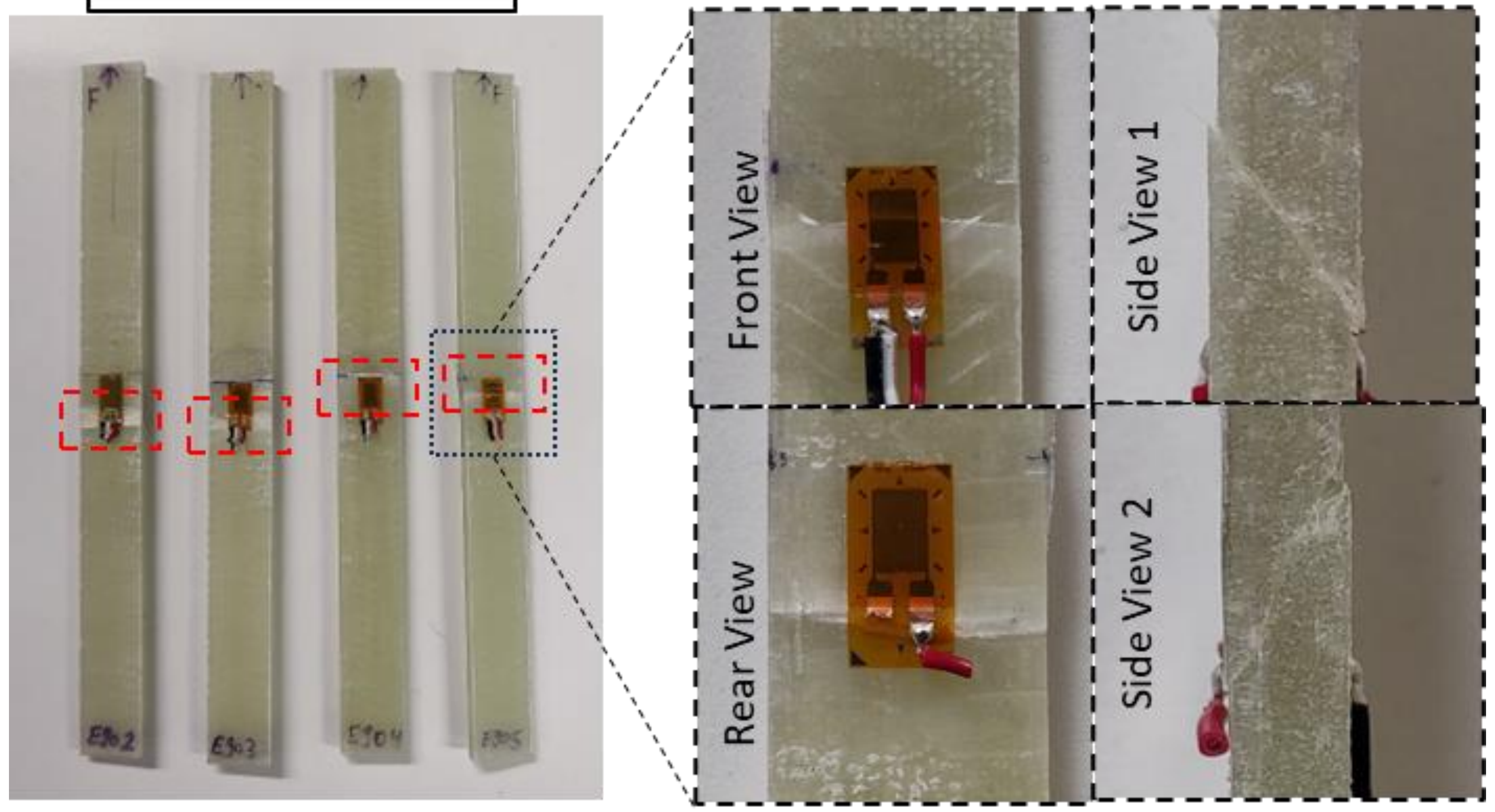
Results - Failure modes and Fractography

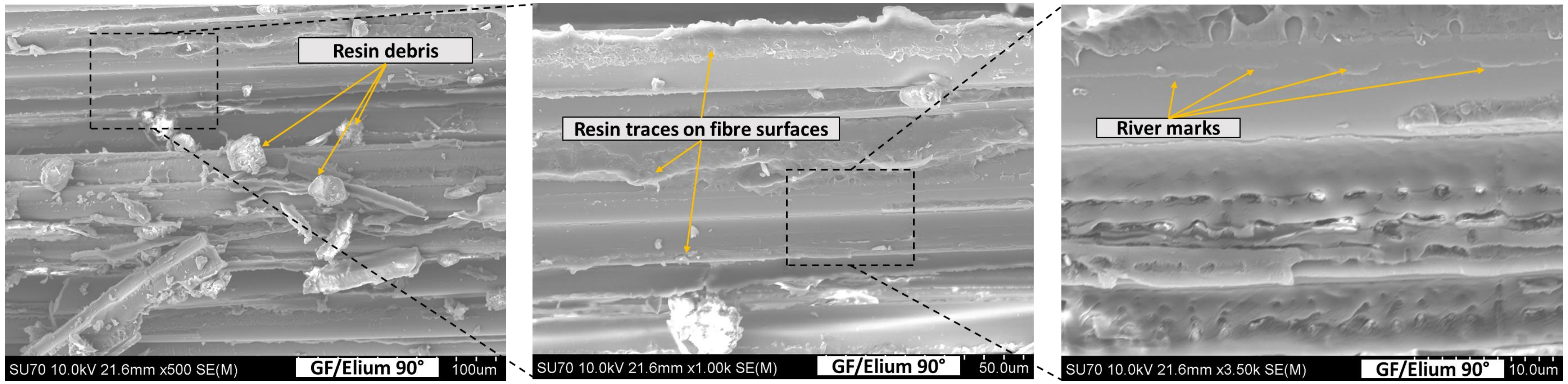


- Evidence of plastic behavior
- Traces of Elium at fibre-matrix interface

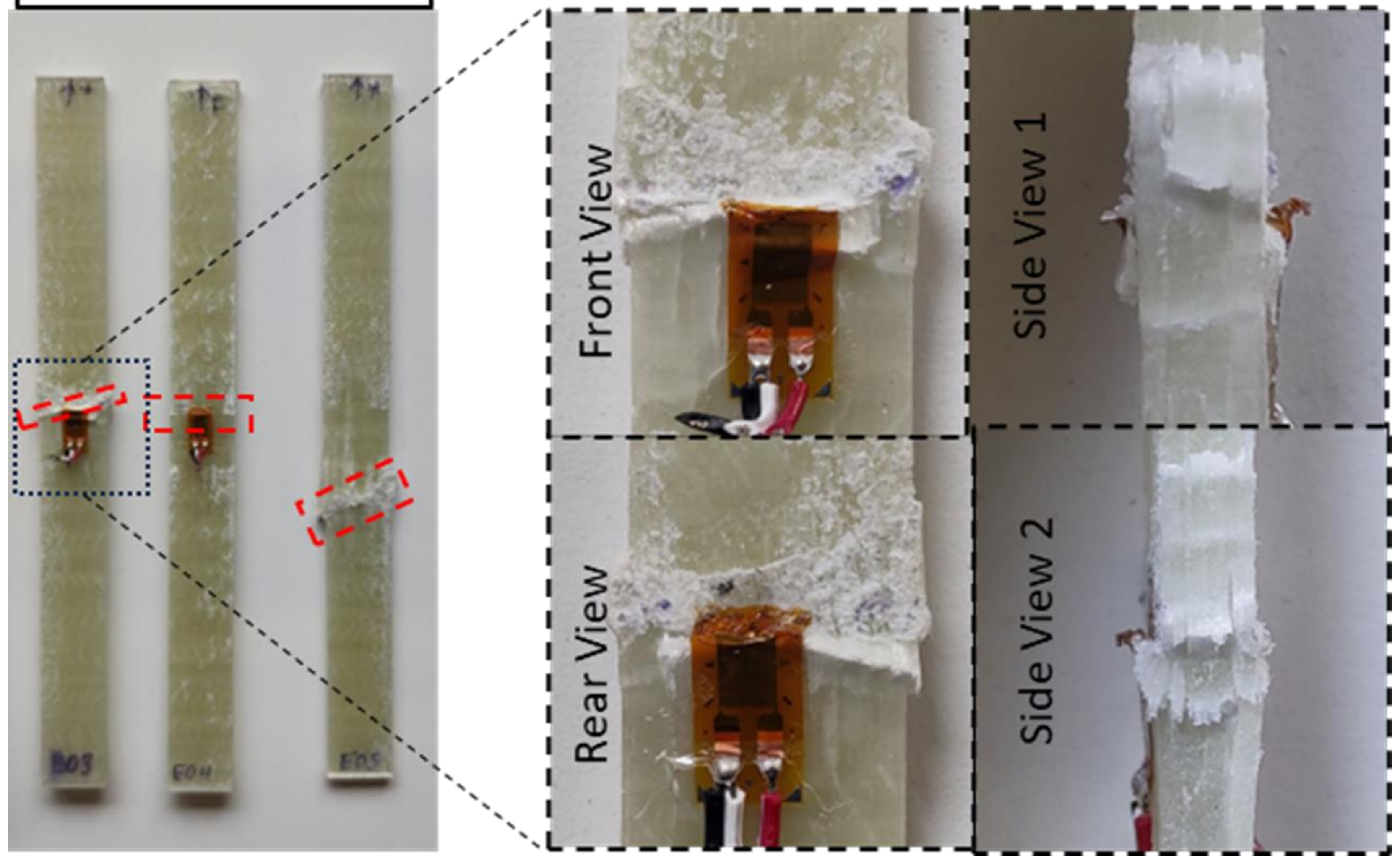
Results – Failure modes and Fractography

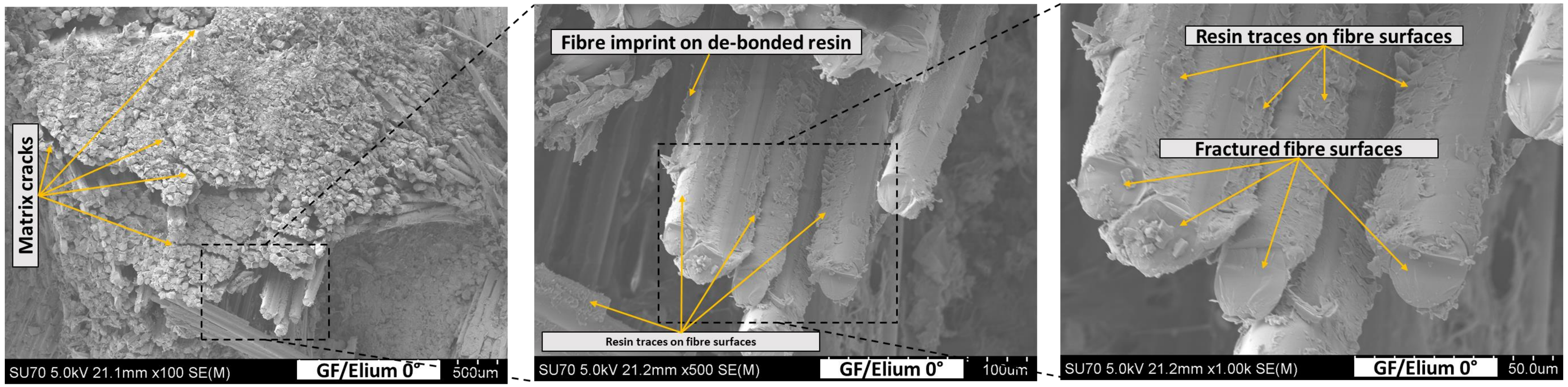
GF Elium 90°





GF Elium 0°



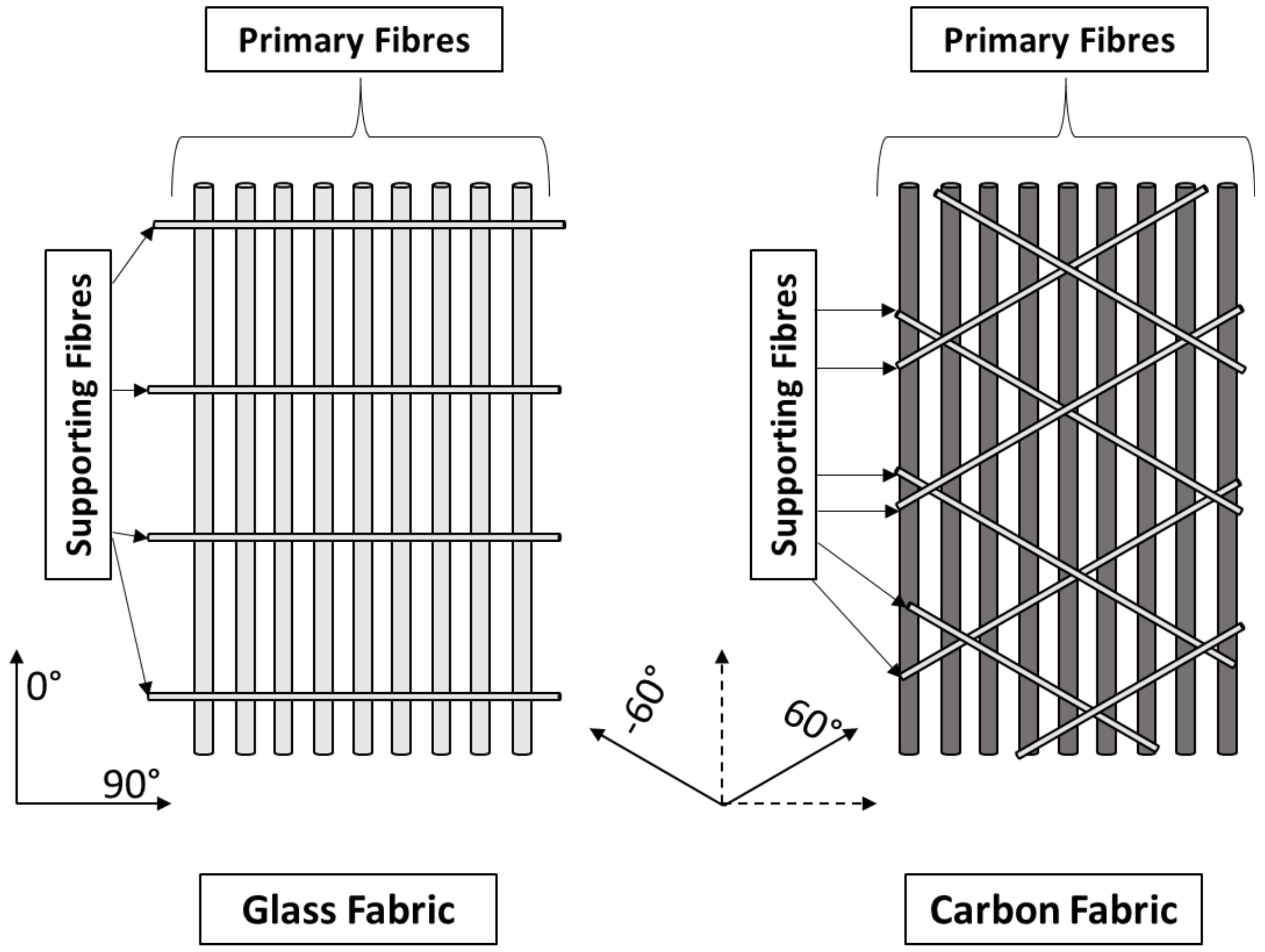


- Evidence of plastic behavior
- Traces of Elium at fibre-matrix interface

Results: Characterization

Laminate	Properties	Determined Properties	
		GF/Elium®	CF/Elium®
0°	σ_{11}^{max} (MPa)	676.0 [612.5*] (96.8)	577.9 [649.5*] (42.8)
	σ_{11}^{f} (MPa)	670.3 [607.4*] (94.4)	553.9 [622.5*] (42.3)
	E_{11} (GPa)	46.6 [42.2^] (3.3)	96.6 [108.6^] (2.9)
	V_f (%)	60.70	48.94
90°	σ_{22}^{max} (MPa)	149.0 (10.8)	133.0 (5.6)
	σ_{22}^{f} (MPa)	145.9 (10.7)	132.3 (4.8)
	E_{22} (GPa)	16.7 (0.7)	7.7 (0.3)

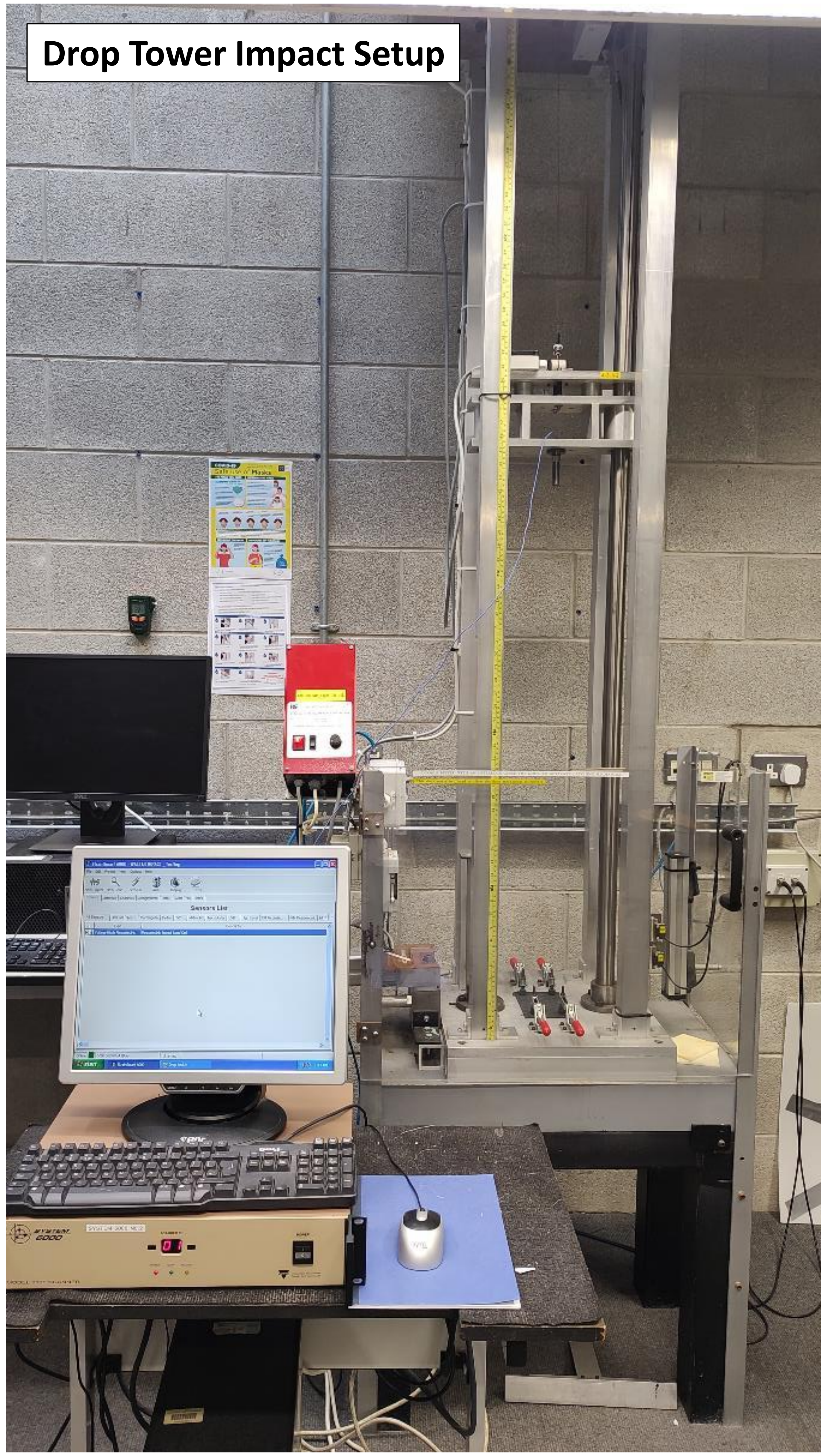
- Good compression properties for Elium based laminates.
- Effect of fibre architecture observed on transverse properties.



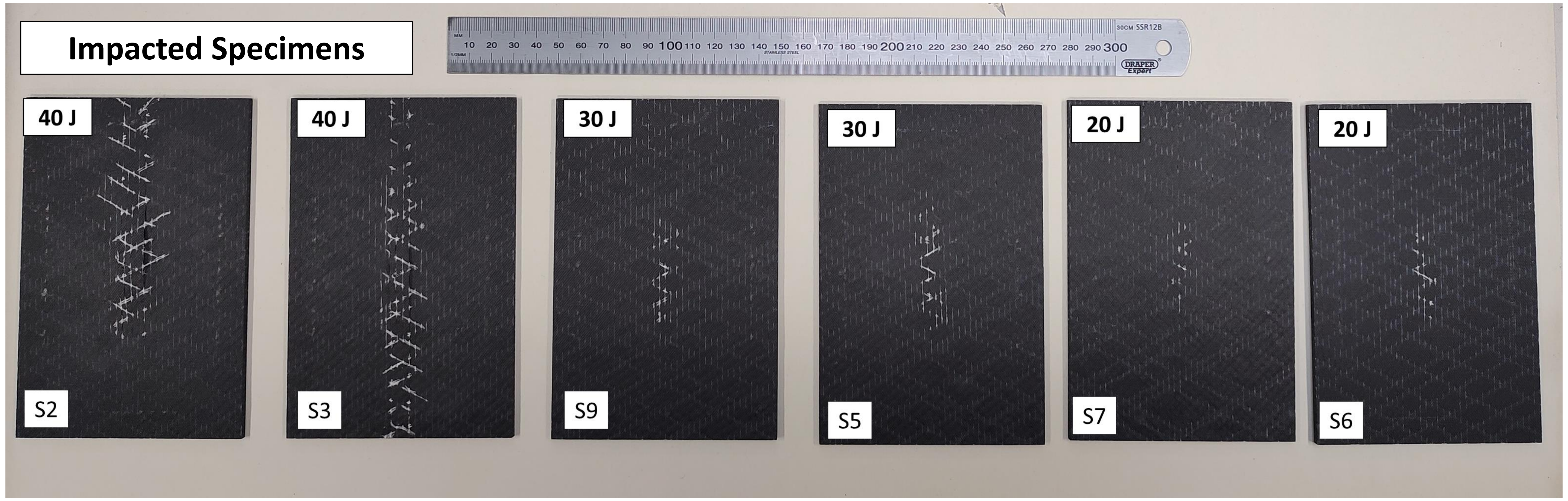
Fabric Architecture

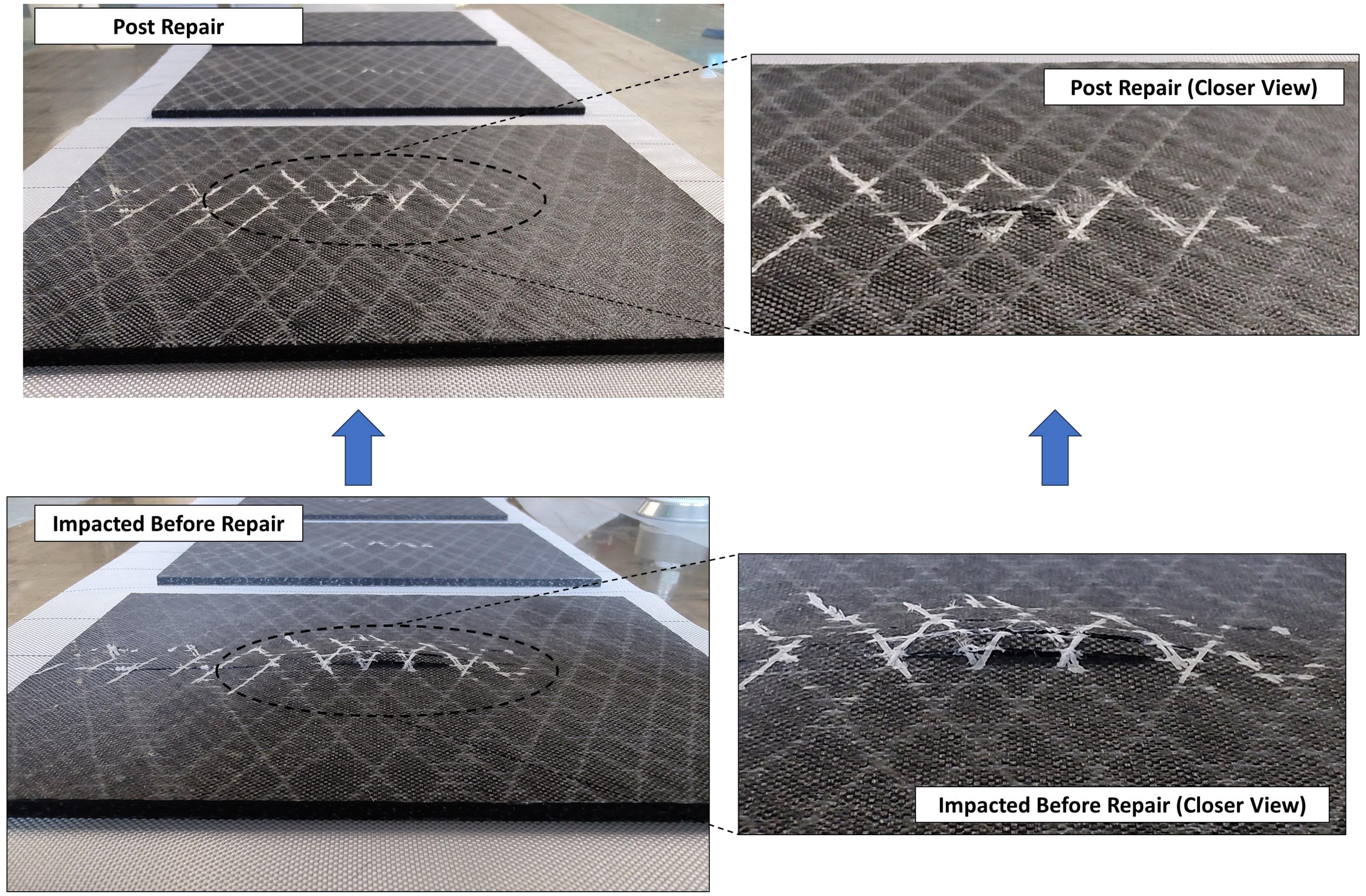
Note- GF: Glass Fibre, CF: Carbon Fibre; σ_{11}^{max}= Maximum compressive strength in fibre direction, σ_{11}^{f}= Compressive strength at failure in fibre direction, E_{11}= Modulus in fibre direction, σ_{22}^{max}= Maximum compressive strength transverse to fibre direction, σ_{22}^{f}= Compressive strength at failure transverse to fibre direction, E_{22}= Modulus transverse to fibre direction, V_f= Fibre volume fraction, Failure is defined here as the instance during the test where first significant drop in load is observed, the specimen may still be bearing the load beyond failure initiation and reach a peak value. Standard deviation values in round parenthesis; Normalized values in square brackets. *Normalized Strength =Strength × 0.55/Absolute V_f; ^Normalized Modulus=Modulus × 0.55/Absolute Vf

Impact Testing



CF/Elium $[0/45/90\text{-}45]_s$





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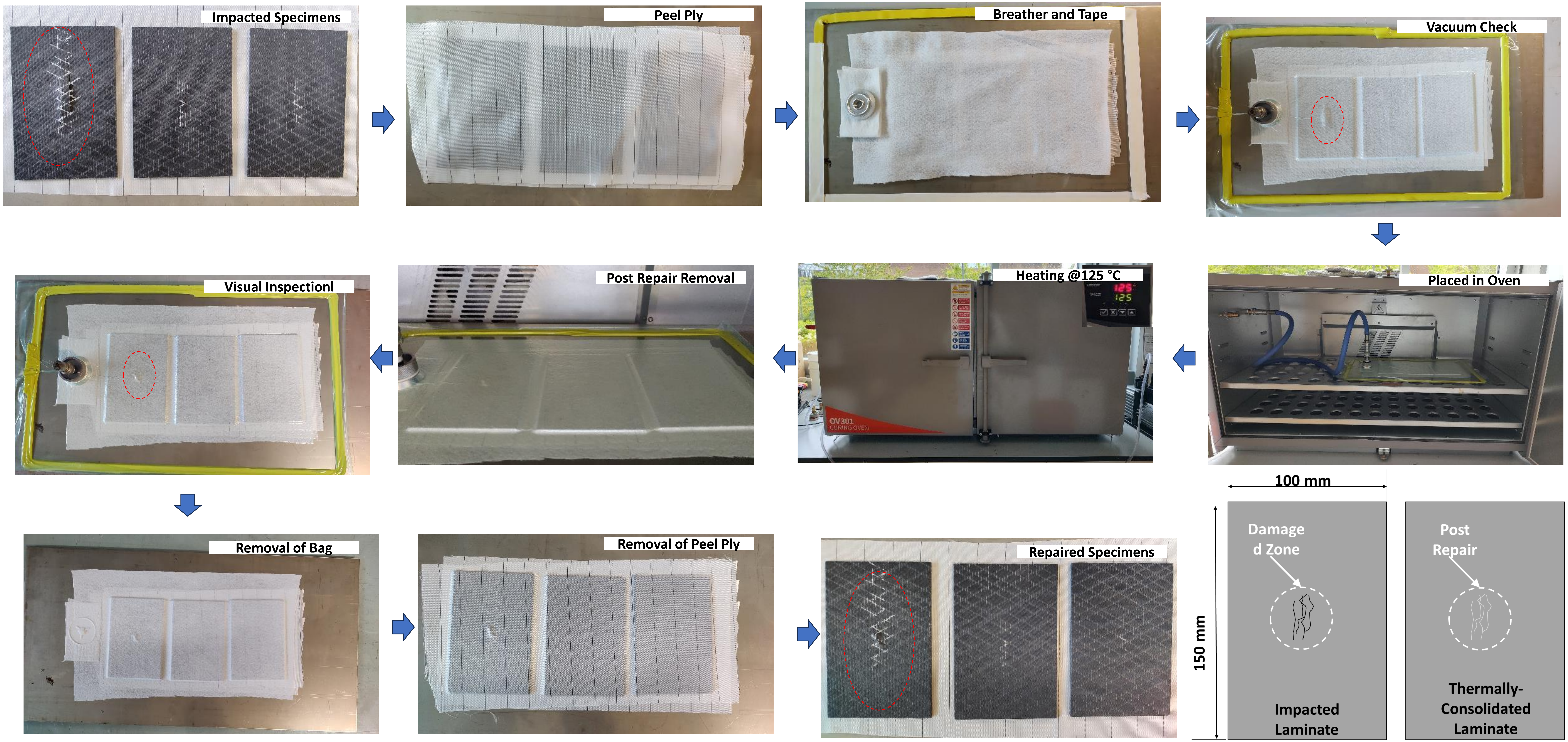
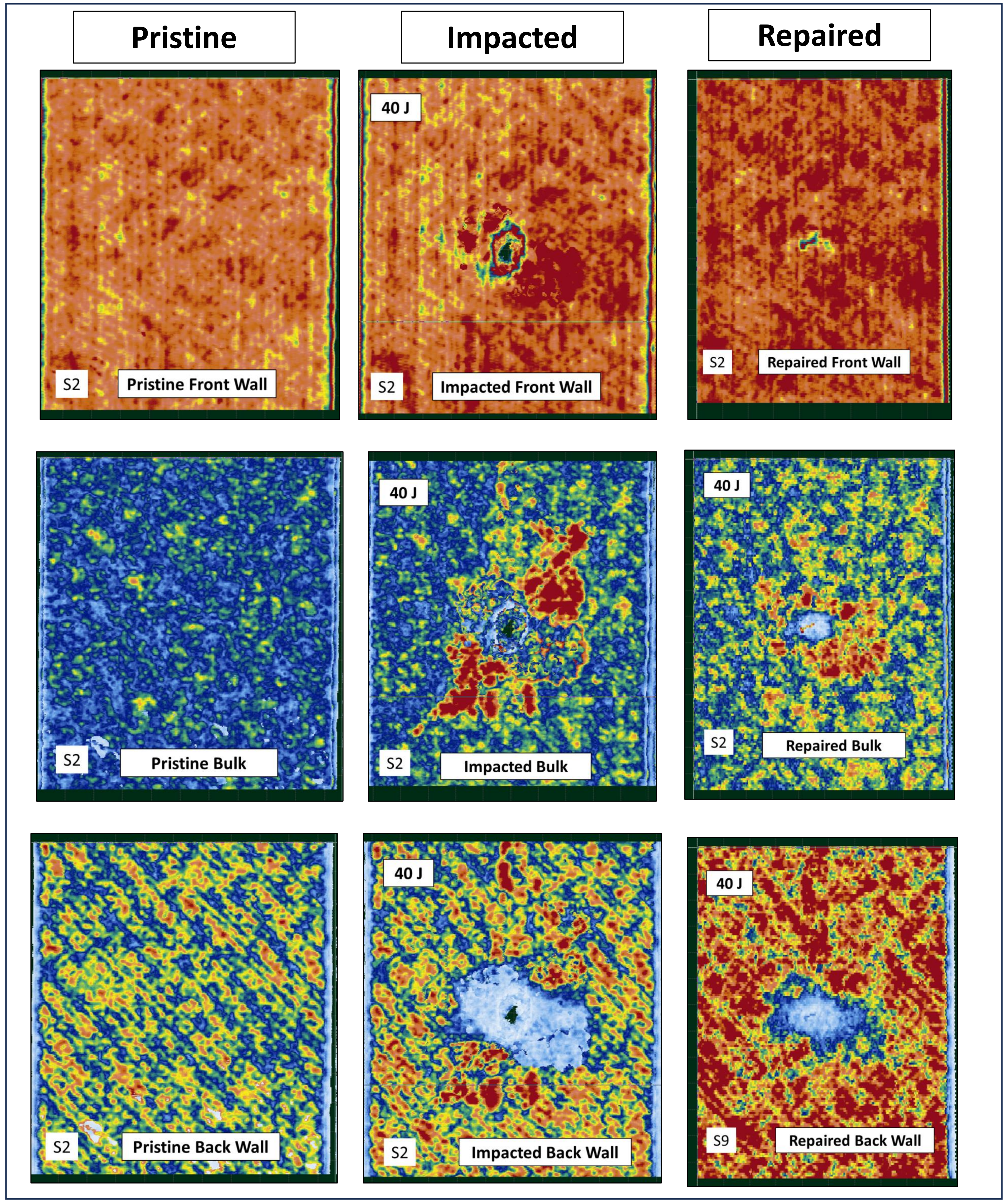
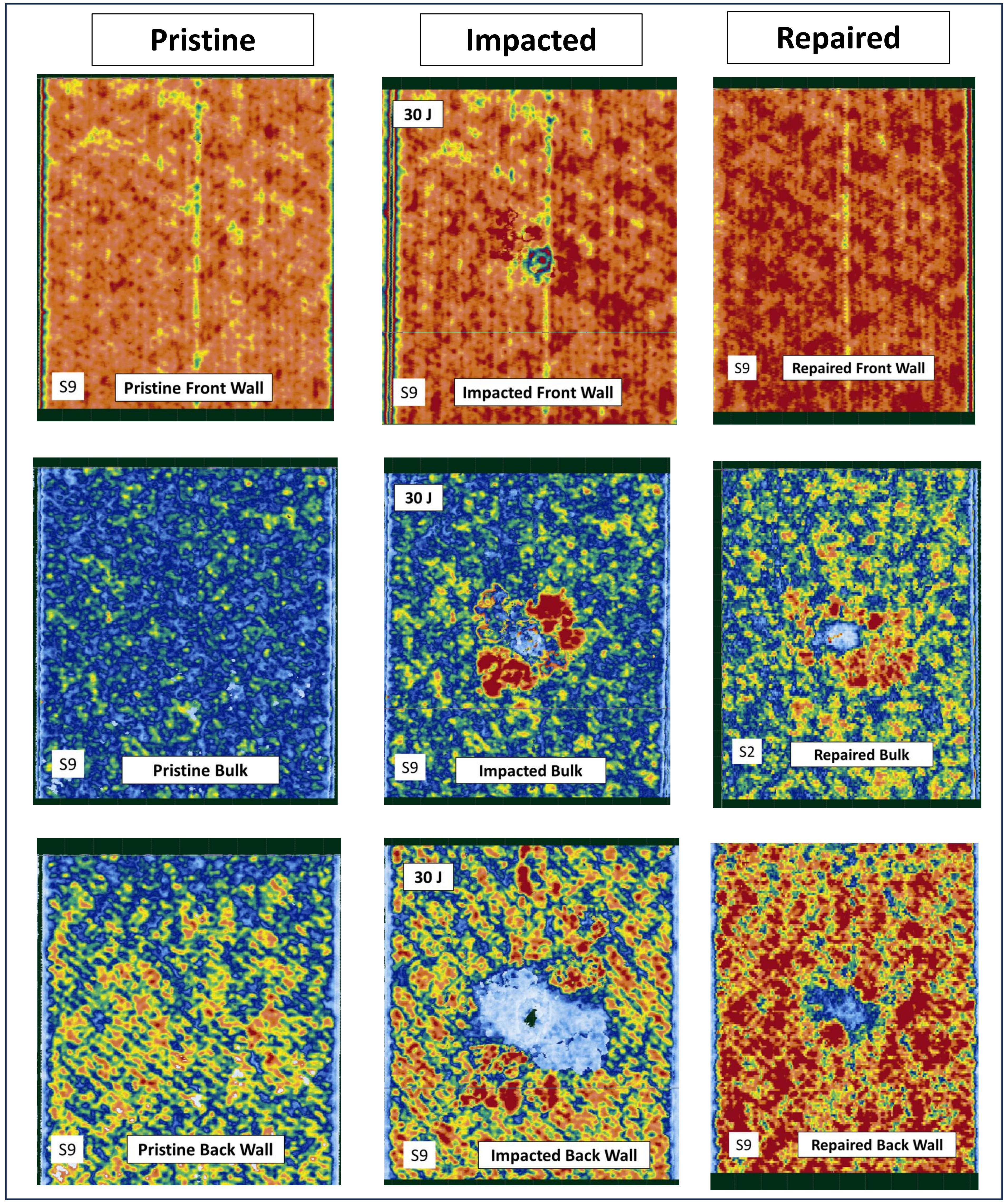
Repair Procedure

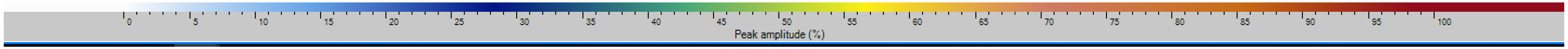


Assessment of Repair





Healing of the impact damage is observed.



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Summary:

- Good compression properties were observed for Elium based GFRP & CFRP laminates.
- Fractography revealed plastic matrix characteristics.
- Thermal consolidation under vacuum showed evidence of healing of the impact damage Elium based laminates.

Future/Ongoing Work:

- Post Impact- post repair compressive (CAI) behaviour of Elium based laminates is being studied.

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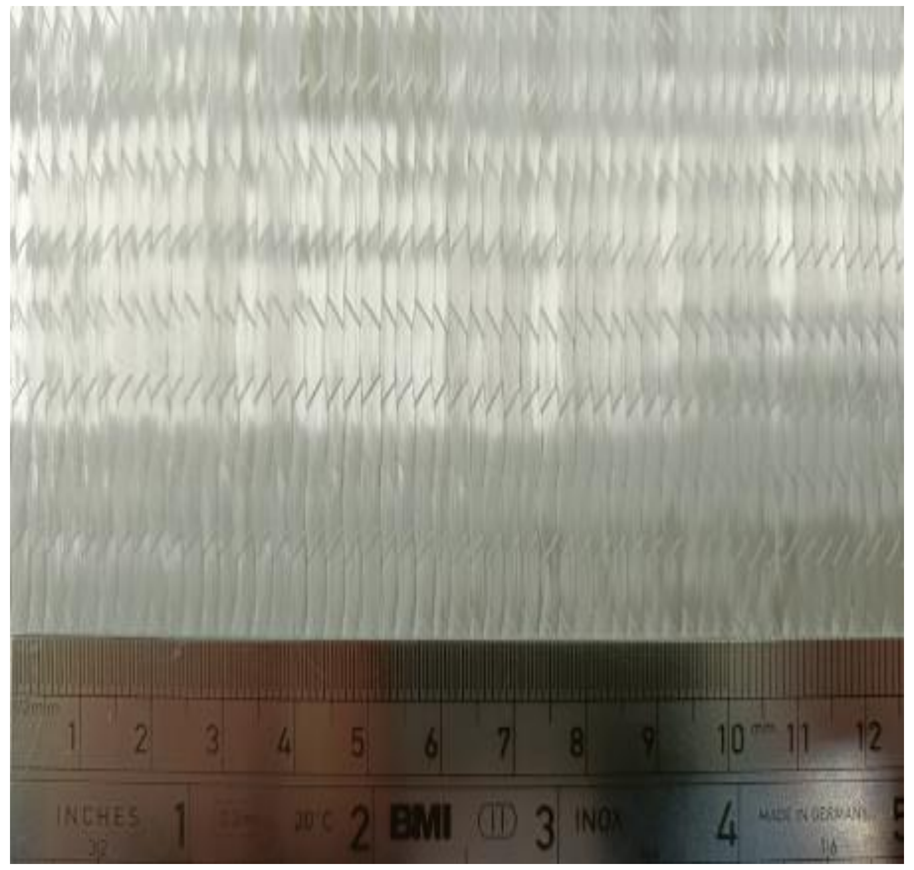
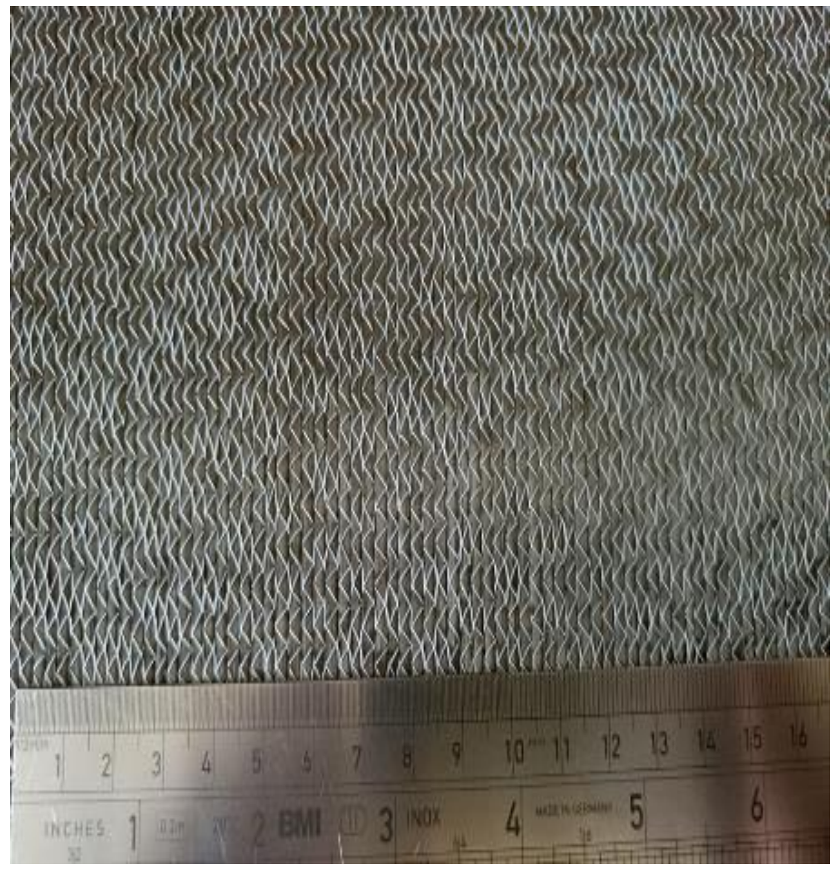
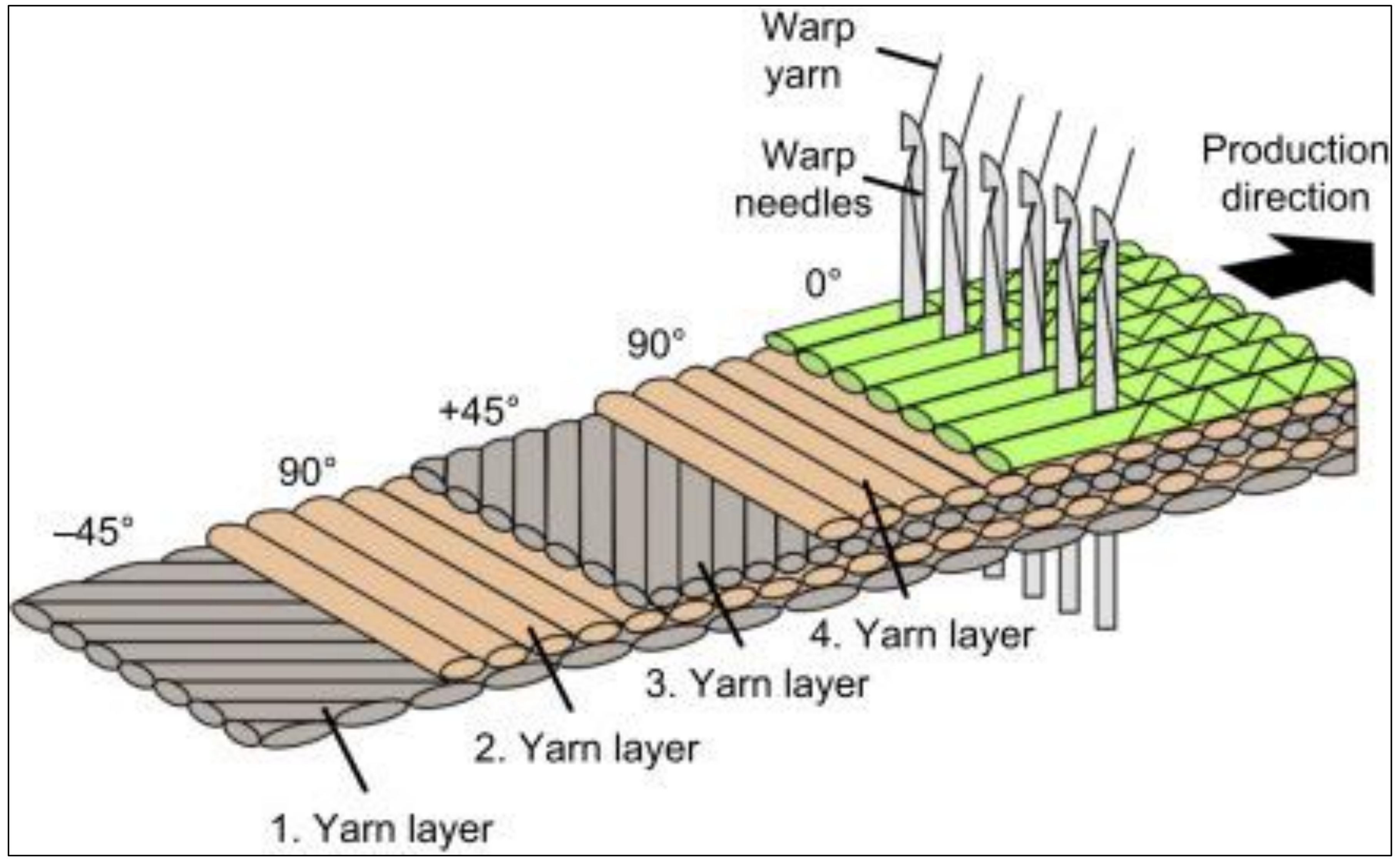
Thank you all for your attention

Gursahib Singh Bhatia
Postdoctoral Researcher
Bernal Institute, University of Limerick
Email: gursahib.s.bhatia@ul.ie

Appendix-1: Why Carbon and glass ?







- ✓ Both are **non-hygroscopic** and have low susceptibility to the environmental degradation
- ✓ Carbon has the **highest stiffness** – important to minimize deformation of long slender structures and helps to avoid excessively thick laminates
- ✓ Carbon is relatively expensive (10 times the price of glass fibre), so glass is a much more **cost-effective option** where the higher stiffness of carbon is not required
- ✓ In both cases the **fiber size/coating** is compatible with elium resin systems – this is important to ensure a fair comparison of the mechanical properties of the laminates

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Appendix 2-Selected Materials

	Thermoplastic Acrylic (Arkema)	
Resin Name	Elium 188O	Elium 188XO
Curing Agent	Perkadox GB-50X	Perkadox GB-50X
Fabric	Saertex U-C 438 g/m^2 Carbon fibre	Saertex U-E 1182 g/m^2 Glass fibre

Fabric Type	Construction	Sub Layer	Fibre	Areal Weight (gsm)	Total Areal Weight (gsm)
Glass Fibre	90°	1	NEG Hybon 2026	36	1182
	0°	2	NEG Hybon 2026	1134	
			Synthetic stitching	12	
Carbon Fibre	-60°	1	E-glass	8	438
	60°	2	E-glass	8	
	0°	3	Mitsubishi TR50S 1,2k 12k	410	
			Synthetic stitching	12	