Experimental Investigation on the effect of water ingress on the flexural and interlaminar properties of glass/vinyl-ester composite for marine applications

Mr Alex Portela

Dr Niamh Nash

Mr Carlos Bachour

Dr Ioannis Manolakis (former Co-PI – now Sligo IT)

Dr Anthony Comer (PI)

Irish Composites Centre (IComp)

School of Engineering

Bernal Institute

University of Limerick

IComp
Irish Composites Centre

FIBRESHIP
INTEGRAL COMPOSITE SHIP

Bernal Institute

Marine Aging of Polymers, Brest
28-29 August 2019

University of Limerick
Ollscoil Luimnigh

Contents

- Overview of FIBRESHIP H2020 project
- Background
- Objective of this study
- Experimental Details
- Results & Discussion
- Conclusions
- Acknowledgements

Ship Block Demonstrator
(iXblue Shipyard, La Ciotat, France)

Overview

- Composites dominate construction of small-to-medium length vessels (< 50 m)
- Restriction on use of composites on ships longer than 50 m !
- Main Reason: Lack of **design guidelines** from certification bodies
- Main issues: Safety - particularly **Fire**
- The trend in aviation (e.g. B787, A350) demonstrates that adoption of composite technology in primary and secondary structures is feasible

Courtesy of Tuco Marine (FIBRESHIP partner) – ProZero range of offshore/patrol/service FRP vessels (8-18 m)

PROMARINE, OUEST composites SEMI RIGID Boat (JEC 2019)

Challenge

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- Enhance acceptance of composites in primary structures of ships > 50 m
- Recommend relevant changes in rules and regulations to the responsible bodies
- Create a niche market opportunity for the manufacture of large marine vessels in the EU

Light Commercial Vessels

Representative Container Vessel

Passengers transportation & Leisure

Representative ROPAX

Special Services

Representative Fishing Research Vessel

Engineering, production and life-cycle management for the complete construction of large-length FIBRE-based SHIPs

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Partners

- 18 partners, 11 countries
- European shipyards: 3
- Naval architect/design/engineering companies: 4
- Ship owners & operators: 4
- R&D organisations: 4
- Classification/certification bodies: 3

Technical Impact

- Feasibility of the concept of a composite large-length ship
- Reduce fuel consumption
- Lower greenhouse gas emissions
- Increase of payload cargo capacity
- Underwater noise reduction
- Reduce maintenance and life cycle costs
- Corrosion-free

Safehaven marine 11-18 m

Swedish Navy Visby > 70 m

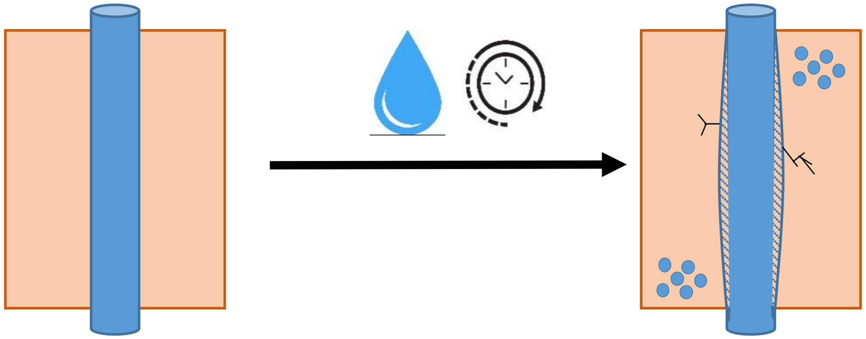
Context

Ships are exposed to under a wide range of environmental conditions

Durability of composites may be compromised

Service life of marine composites (typically 20-25 years)

The mechanical and thermal properties degrade accordingly, and the service life is shortened



Background

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- Recent publication in Composite Part B (Available online August 10) https://doi.org/10.1016/j.compositesb.2019.107271

- **Objective:** Evaluate and compare ILS, flexural properties and failure modes of four different material systems under short term immersion in water and diesel

ELSEVIER
Composites Part B: Engineering
Available online 10 August 2019, 107271
In Press, Journal Pre-proof

Effect of environmental conditioning on the properties of thermosetting- and thermoplastic-matrix composite materials by resin infusion for marine applications

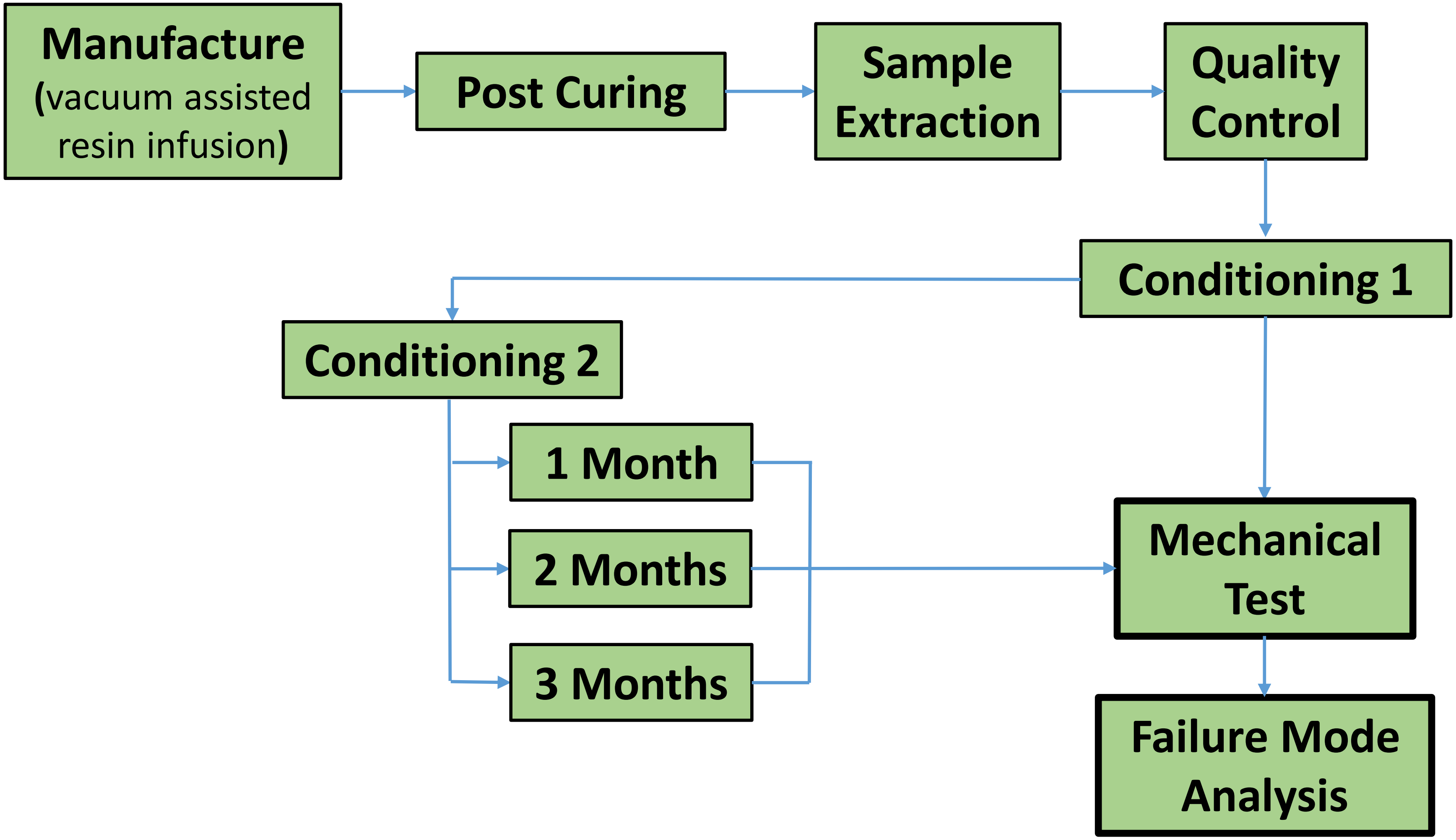
N.H. Nash [a], A. Portela [a], C. Bachour [a], I. Manolakis [a] [1], A.J. Comer [a, b]

- Current study focuses on one material system for a longer duration (3 mths)

Objective

Evaluate the flexural, interlaminar shear properties and failure modes of a glass/vinyl-ester laminate under dry and wet conditions.

Experimental Details



Experimental Details

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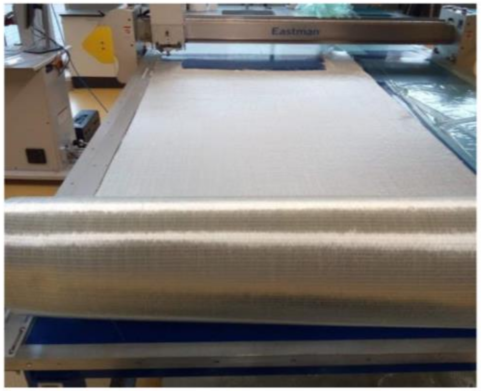
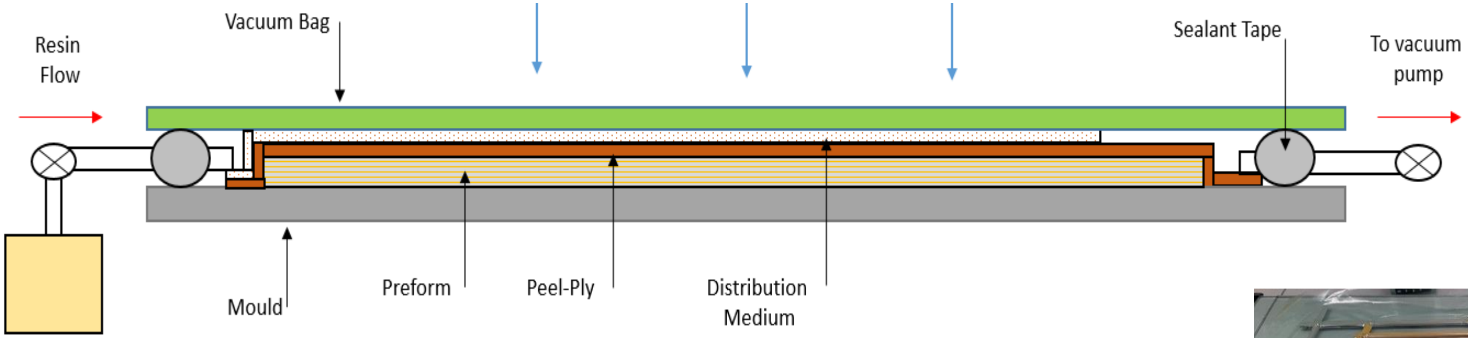
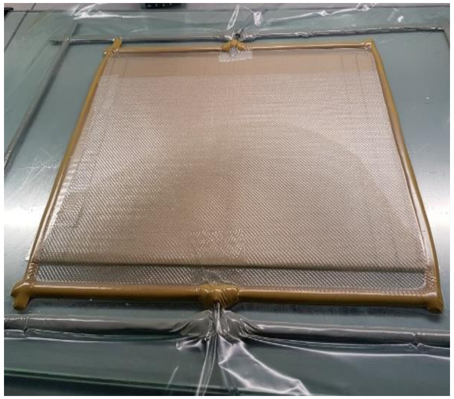


Manufacturing of composite laminate





- Lay-up: 0_{2S} (4 layers of NCF)
- SAERTEX U-E-940 g/m²-LEO UD
- LEO Injection Resin 8500 from BÜFA

Quality Control

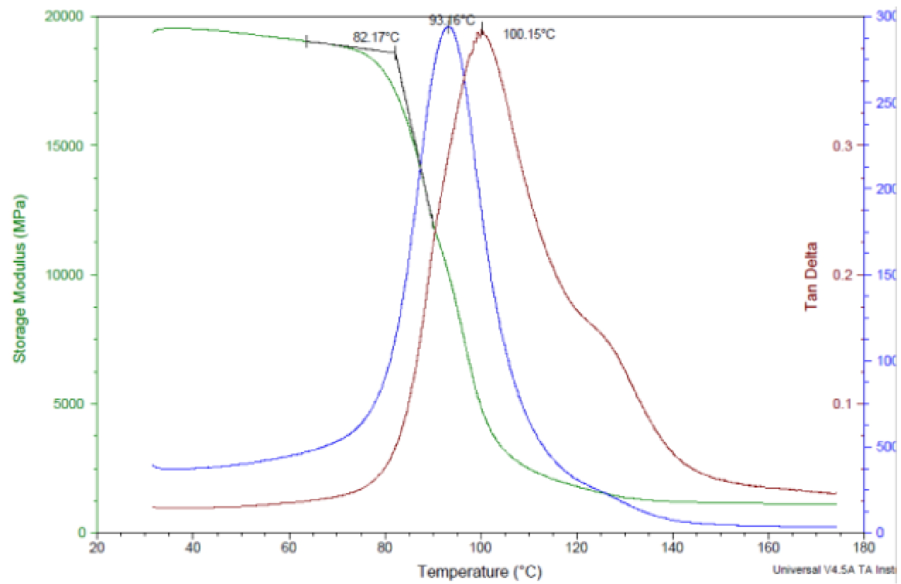
- **Cured ply thickness**

Laminate	Cured Ply Thickness
Range	0.64 ~ 0.66

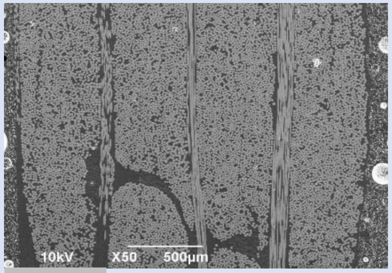
- **Fibre Volume Fraction**

Laminate	ISO 14127:2008	ASTM 3171
Fibre Volume %	55.3%	54.5%

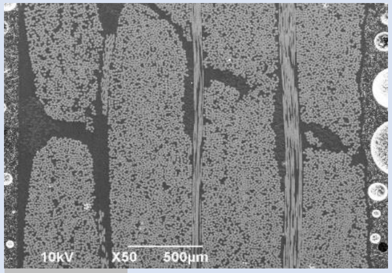
- **T_g and degree of cure**



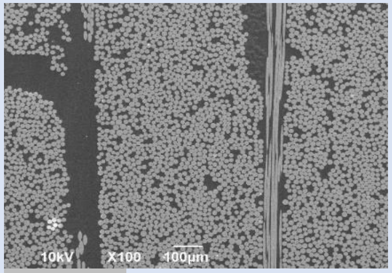
- **Void Analysis (MS 0051)**



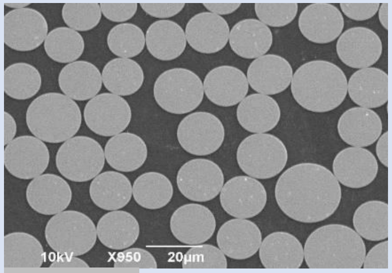
x50



x50



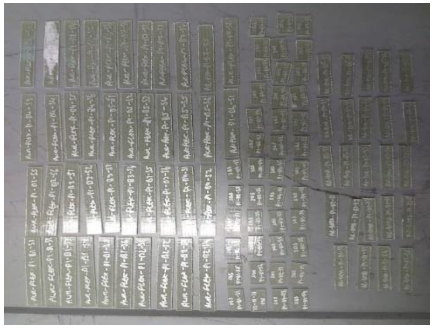
x100

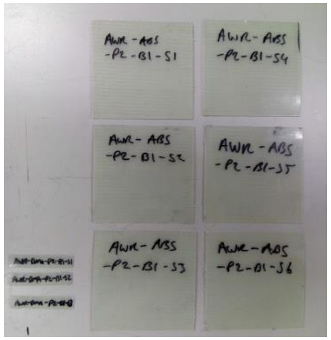


x950

Conditioning 1 and 2

✓ Procedure 1





↓

Oven for 5 hours at 45°C

↓

Record the Mass

✓ Procedure 2

Immersion Bath (Deionised water @ 35 °C)

↓

Record water uptake (ASTM D5228)

Experimental Details

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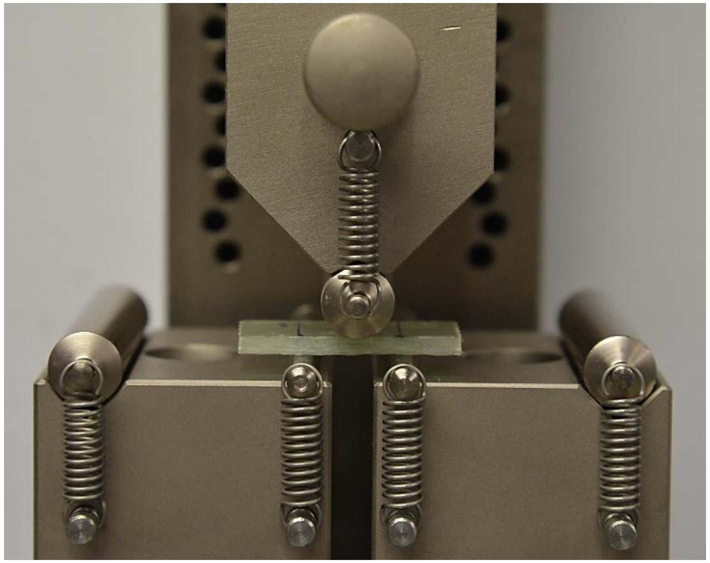
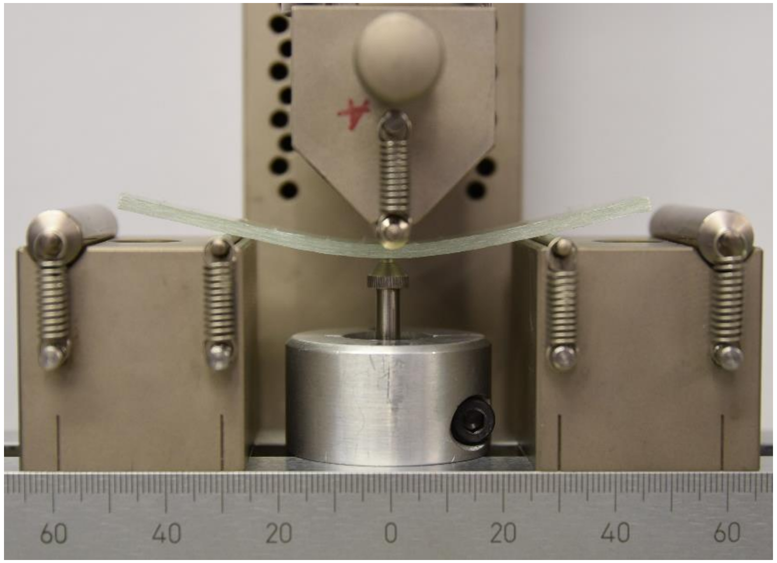
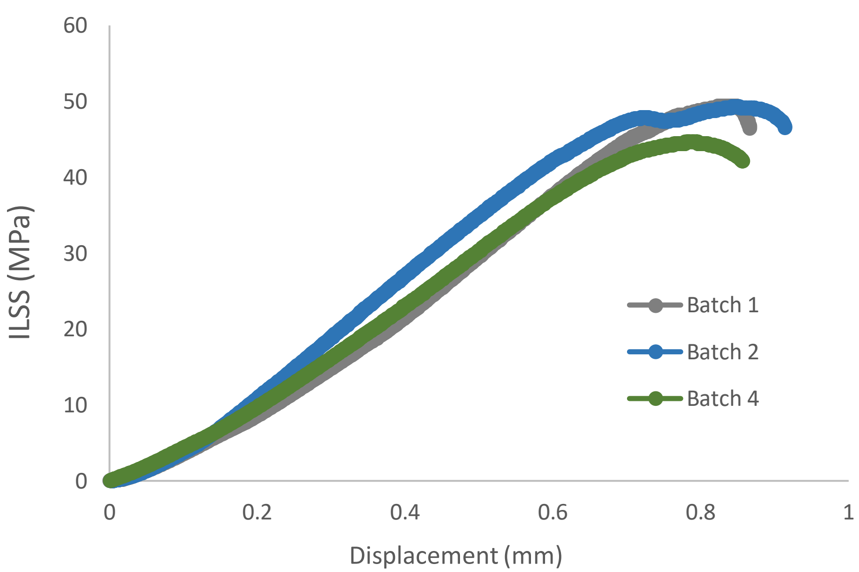
Test	Standard	Properties	Nominal Sample Dimensions	Number of Samples
INTERLAMINAR SHEAR (ILS)	ISO 14130	APPARENT INTERLAMINAR SHEAR STRENGTH	30 mm X 15 mm X 3 mm	5 No immersion 5 after 1 mth immersion 5 after 2 mth immersion 5 after 3 mth immersion
FLEXURE – 3 POINT BEND	ISO 14125	FLEXURAL STRENGTH FLEXURAL MODULUS	100 mm X 15 mm X 3 mm	



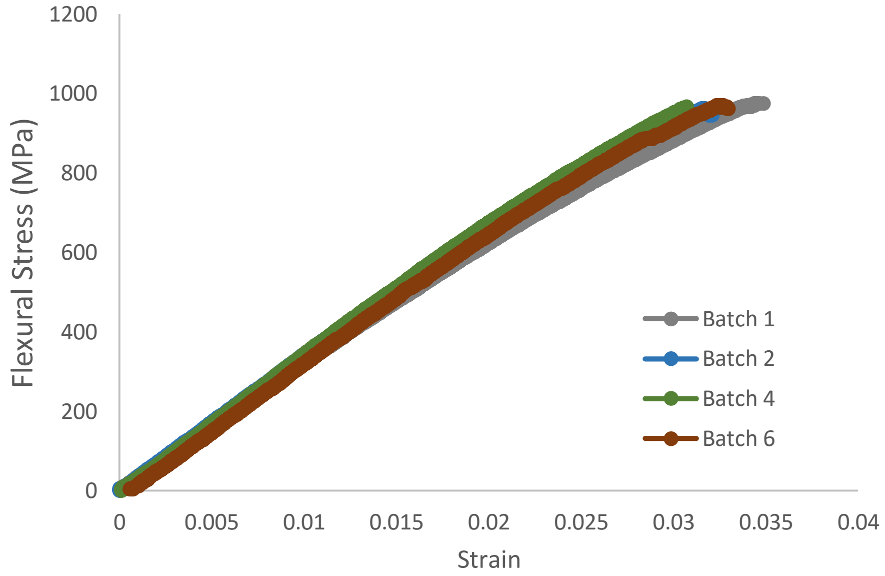


30:1

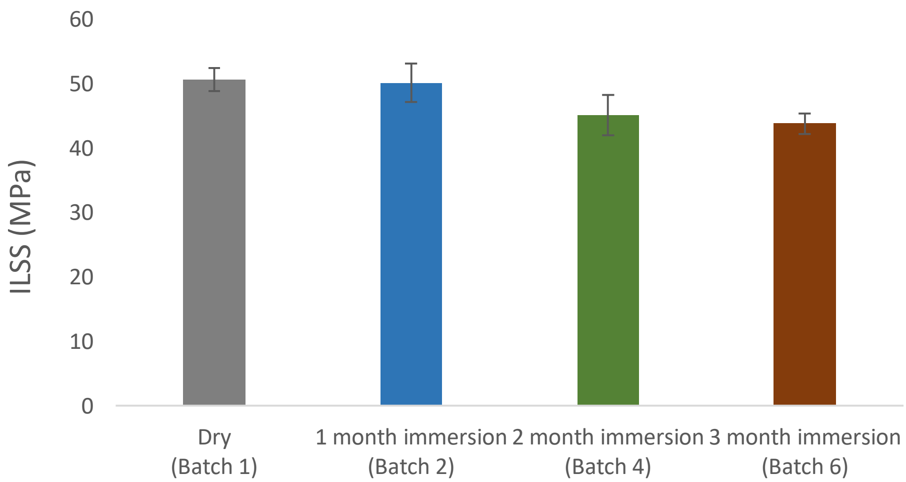
Results



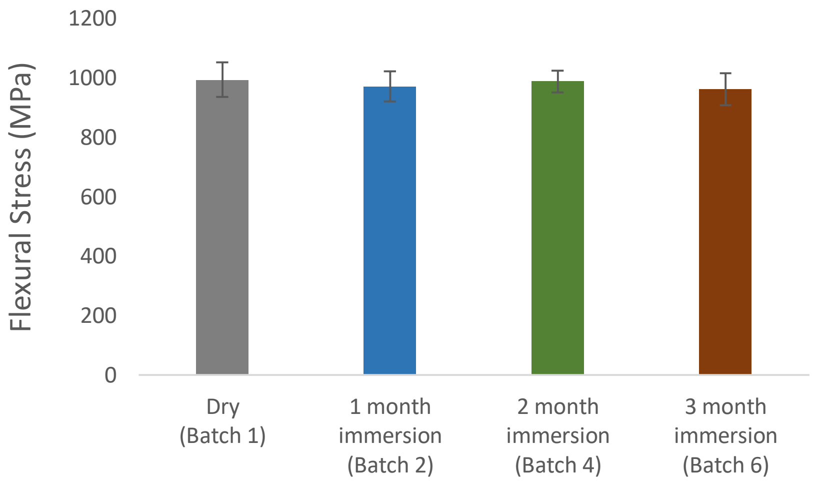
ILSS (MPa)
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
Displacement (mm)
Batch 1
Batch 2
Batch 4



Flexural Stress (MPa)
1200
1000
800
600
400
200
0
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
Strain
Batch 1
Batch 2
Batch 4
Batch 6



ILSS (MPa)
60
50
40
30
20
10
0
Dry (Batch 1)
1 month immersion (Batch 2)
2 month immersion (Batch 4)
3 month immersion (Batch 6)



Flexural Stress (MPa)
1200
1000
800
600
400
200
0
Dry (Batch 1)
1 month immersion (Batch 2)
2 month immersion (Batch 4)
3 month immersion (Batch 6)

Failure Mode: ILS

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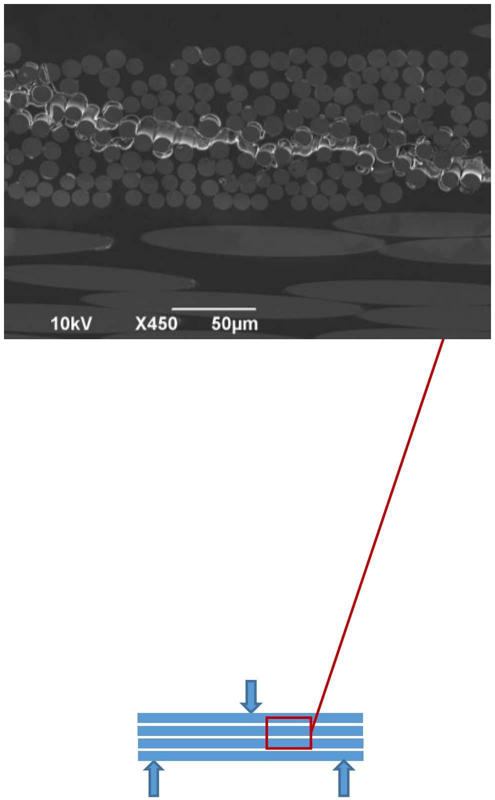
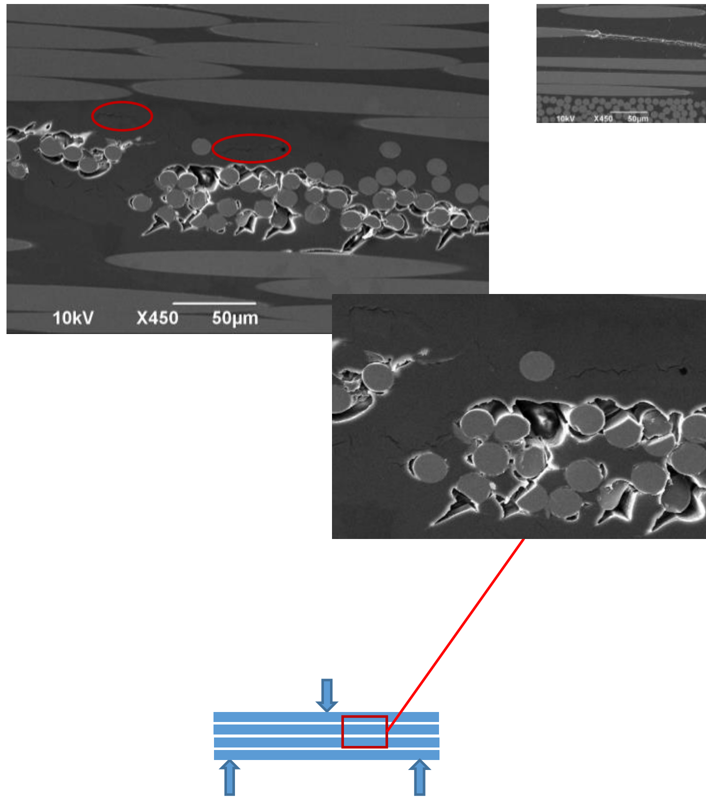
1 mth immersion (98% retention)



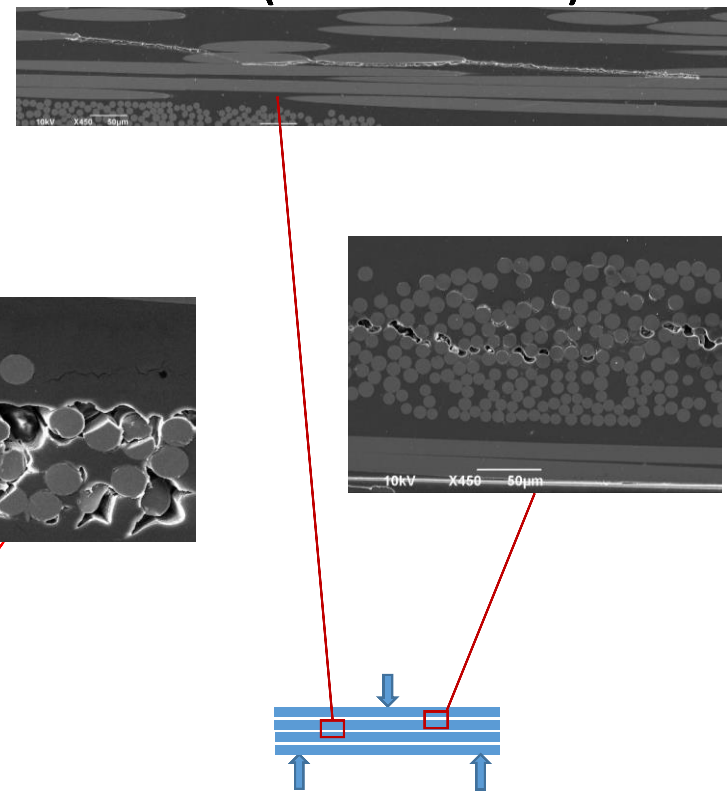
Shear crack formation at fibre-matrix interface in 90° tows

2 mths immersion (89 % retention)



Micro-crack formation in the matrix plus shear crack formation at fibre-matrix interface in 90° tows

3 mths immersion (86 % retention)



Crack formation at 0° fibre-matrix interface plus shear crack formation at fibre-matrix interface in 90° tows

Failure Mode: Flexure

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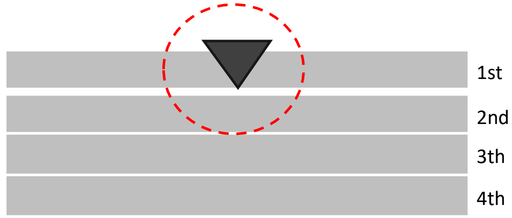
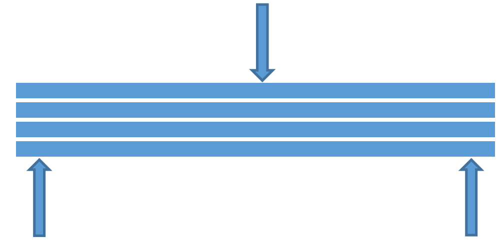
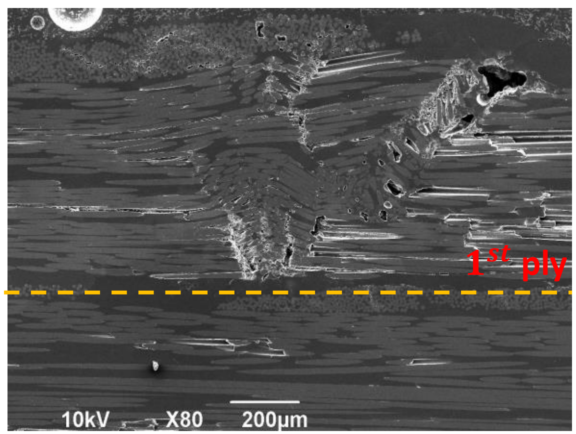
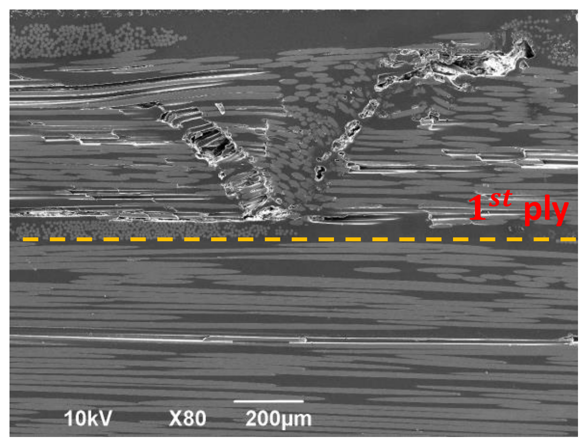




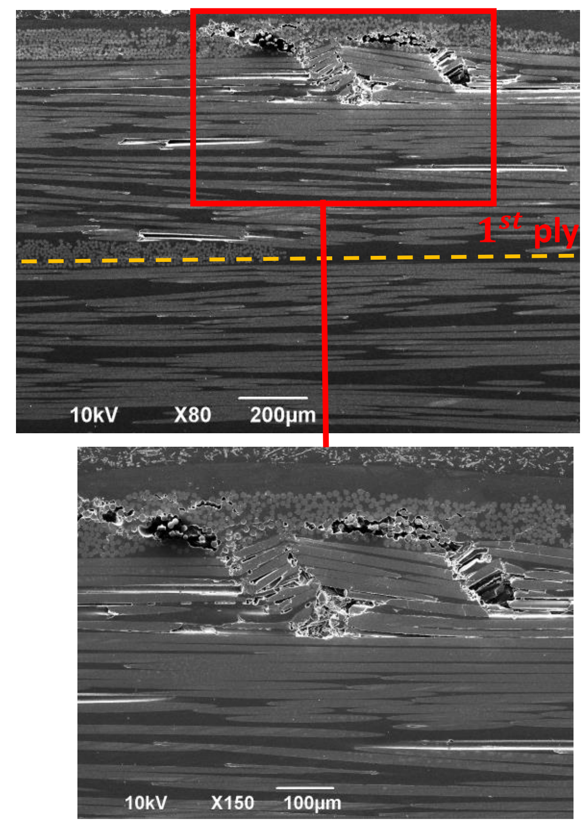
1 Month (97% retention)



2 Months (99% retention)



3 Months (96% retention)



Conclusions

Effect of hydrothermal aging on a glass/vinylester laminate were studied. The following observations and conclusion were drawn based on the results and analysis.

- Interlaminar shear strength appeared to decrease as the immersion time increased.
- A negligible change in flexural strength was observed.

Further analysis is currently underway to investigate these observations.

Acknowledgements

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Thank you for your attention

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