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MECHANICAL PERFORMANCE OF FLAX FIBER COMPOSITES WITH DOUBLE-DOUBLE LAYUPS: INFLUENCE OF AREAL WEIGHT

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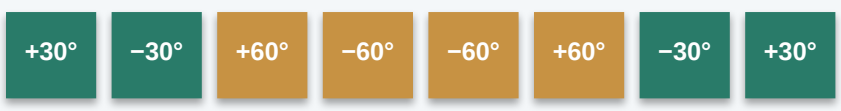
DD 200 g/m²: +19.5% tensile strength and +47.5% compressive strength vs. DD 50 g/m²

INTRODUCTION & OBJECTIVE

Natural flax fiber composites are attractive for lightweight applications but unidirectional (UD) laminates exhibit strong anisotropy. Double-double (DD) stacking combines two angle pairs to promote multi-directional load sharing. This work investigates how flax areal weight (50 vs. 200 g/m²) affects strength and failure mechanisms.

MATERIALS & METHODS

Epoxy: Araldite LY 5052 / Aradur 5052 (100:38 by mass). UD reference: 110 g/m², vacuum infused. DD: 8 plies, [±30°/±60°]s, compression molded at 80 °C and 1.5–2.0 MPa.



8-ply symmetric DD architecture (schematic; not to scale)

Tests: tensile (ASTM D3039), compression (ASTM D6641), and SEM fractography. Values shown as mean ± standard deviation.

UD REFERENCE: ANISOTROPY

Tension: 145.86 ± 42.32 MPa (0°) → 12.23 ± 2.16 MPa (90°). Compression: 83.87 ± 10.39 MPa (0°) → 70.63 ± 11.51 MPa (90°).

SEM FRACTOGRAPHY

Higher areal weight showed increased fiber participation, with fiber breakage and delamination; lower areal weight exhibited more pull-out and matrix-controlled damage.

INSERT ORIGINAL SEM MICROGRAPH

DD 50 g/m²

Matrix cracking / fiber pull-out

INSERT ORIGINAL SEM MICROGRAPH

DD 200 g/m²

Fiber breakage / delamination

MECHANICAL PERFORMANCE

Comparison of DD laminates (MPa)

TENSILE STRENGTH



Error (SD): ±6.54 / ±9.44 MPa for 50 / 200 g/m²

COMPRESSIVE STRENGTH



Error (SD): ±7.69 / ±4.70 MPa for 50 / 200 g/m²

RESULTS & DISCUSSION

The 200 g/m² DD laminate reached 112.80 ± 9.44 MPa in tension and 90.18 ± 4.70 MPa in compression. Compared with the 50 g/m² DD laminate, strength increased by 19.5% and 47.5%, respectively. The higher-areal-weight laminate also exhibited lower relative dispersion in compression.

KEY INTERPRETATION

Higher areal weight increases fiber participation and is consistent with improved load transfer. Measured fiber volume fraction is needed to clarify this effect.

CONCLUSIONS

- The DD layup reduced reliance on a single load-bearing direction compared with UD laminates.
- DD 200 g/m² exhibited superior tensile and compressive strengths relative to DD 50 g/m².
- SEM suggests a shift from matrix-controlled toward fiber-controlled failure with higher areal weight.

REFERENCES & ACKNOWLEDGMENTS

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ASTM INTERNATIONAL. ASTM D3039/D3039M — Tensile Properties of Polymer Matrix Composite Materials.

ASTM INTERNATIONAL. ASTM D6641/D6641M — Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture.

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SEM image areas are placeholders; insert original annotated micrographs with scale bars before presentation.