PacifiCan-MMRI Accelerating Circular Economy (ACE) TechBrief Report

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Project title: Preliminary investigation into the use of biocomposites for a solar panel support truss system

Industry partner(s): Terrasol Geosolar Inc.

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Introduction & Background:

Growing concerns over climate change have accelerated the shift toward renewable materials and clean energy technologies. In 2020 alone, over $348 billion was invested globally in renewable energy [1]. Solar energy, in particular, offers a promising solution to reduce carbon emissions and fossil fuel dependence. However, traditional solar infrastructure often fails under extreme weather in hurricane-prone regions. Terrasol Geosolar Inc. has addressed this challenge by developing a hurricane-resistant solar canopy capable of withstanding Category 5 winds and remaining functional after storm surge submersion. Initially built with corrosion-resistant Carbon Fibre (CF), the structure meets ASCE standards and has a 20-year life expectancy. To improve sustainability, Terrasol is now exploring composites made of natural fibres and biobased resins in its designs. Despite their environmental benefits, natural fibres face challenges such as moisture absorption and weathering that needs to be further investigated [2]. This work explores the feasibility of Flax Fibre (FF)-reinforced biocomposites - using green polyethylene, bioepoxy, and Polyfurfuryl Alcohol (PFA) resins along with PFA reinforced CF - for resilient, eco-friendly solar panel structures. Mechanical and weathering performance are assessed alongside the structural behavior of a geometrically complex solar canopy using Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA). The integration of materials testing with fluid and mechanical simulations aims to lay the foundation for designing sustainable, disaster-resilient structures.

Relevance to Circular Economy:

Terrasol faces circularity challenges in designing hurricane-resistant solar panels from bio-based materials due to uncertainties surrounding the mechanical performance and weathering resistance of such emerging materials. This project characterizes flax fibre-reinforced biobased resins to assess their potential by incorporating mechanical data into CFD and FEA simulations to evaluate their ability to withstand Category 5 hurricane wind loads, supporting longer product lifecycles and reducing environmental impact.

Methodology:

This study investigates the weathering resistance and resilience of FF and CF reinforced bio-based polymer biocomposites as structural materials for a geometrically complex structure designed for Category 5 hurricane-resistant solar panel canopies. The study was conducted in two phases:

Phase I characterized the physical, mechanical, and thermal properties of flax fibre monofilament and its flax fibre reinforced green high-density polyethylene biocomposites. Flax and carbon fibre reinforced PFA resins were also fabricated and mechanically characterized. The impact of natural and accelerated weathering on biocomposites' mechanical and physical properties was investigated, as summarized in Figure 1. The PROMETHEE II method was used to determine the best biocomposite configuration based on mechanical, physical, weathering resistance performance, price, and sustainability factors.

	Accelerated ageing						Natural ageing		
	Control tests		Moisture (ASTM D5229)				Weathering station		
Test	No.	Dimension	No.	Condition	Dimension		No.	Time	Dimension
Tensile (ASTM D3039)	6	(250, 25)	6	Immersion in water at 70ºC for 7 days	(250, 25)		18	30- and 90-days exposure	(250, 25)
Impact (ASTM D7136)	3	(150, 100)	3		(150, 100)		9		(200, 150)
Damping	3	(150, 20)	3		(150, 20)		9		200, 20)
Density (ASTM D792)	3	(50,10)	3		(50,10)		9		(70,10)
Hardness (ASTM D785)	Samples will be taken from previous tests.								
Surface quality (LEXT)									
SEM									
Thermal stability (TGA/DSC)									

Figure 1: Methodology summary for biocomposite mechanical characterization under accelerated and natural ageing conditions.

Phase II used CFD with OpenFOAM and FEA with Abaqus to characterize shear stress, pressure loads, and structural response of a solar panel canopy made from the PFA/60%CF selected in Phase I under extreme hurricane conditions. The approaching storm directions examined include 0, 35, 45, 55, 90, 135, and 180 degrees, relative to the structure. After the direction of most severe loading was confirmed, wind simulations were performed with both direction. Final simulations from this direction were performed using Reynolds-Averaged Navier–Stokes (RANS) and Detached Eddy Simulation (DES) turbulence models.

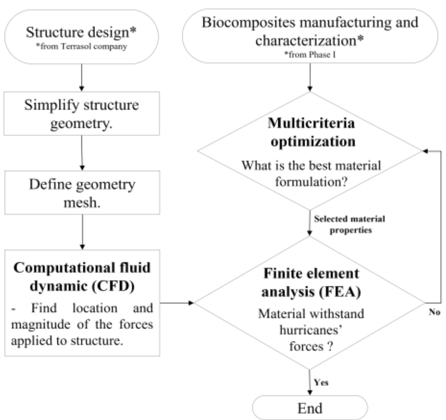

Figure 2: Phase II workflow.

Results & Discussion

Results from *Phase I* indicate that Bioepoxy with 35% FF and PFA with 60% FF exhibited similar density, tensile, and impact properties, while demonstrating at least 150% better damping performance than carbon fibre composites. Replacing just 15% of flax with carbon fibre in PFA/45%FF-15%CF led to a 130% increase in tensile strength and a 90% increase in modulus. Weathering exposure for 30 and 90 days had no significant impact on tensile or hardness properties. Data from 90-days weathering exposure (Figure 3) was utilized in a multicriteria decision-making analysis (PROMETHEE II) to rank the materials based on their performance. The ranking placed PFA/60%CF first, followed by PFA/45%FF-15%CF, PFA/60%FF, and Bioepoxy/35%FF. This analysis highlights the promising potential of hybrid biocomposites for outdoor structural applications, particularly for their durability and sustainability in weather-exposed environments.

Criteria	Bioepoxy/ 35%FF	PFA/ 60%FF	PFA/ 45%FF-15%CF	PFA/ 60%CF
↓ Material price (CAD/cm³)	0.066	0.077	0.105	0.19
↓ Process time (h)	3.00	1.50	1.75	2.25
↓ Density (g/cm³)	1.08	1.09	1.17	1.44
↑ Tensile strength (MPa)	76.9	91	189.5	730.3
↑ Young's modulus (GPa)	6.7	11.0	20.0	63.7
↓ Poisson's ratio (mm/mm)	0.16	0.11	0.08	0.06
↑ Tan (δ) (at 35 °C, 100 Hz)	0.048	0.041	0.039	0.062
↑ Thermal stability (°C)	209	230	241	357
↓ Specific absorbed energy (J cm3/g)	30.9	31.5	28.9	22.4
↑ Hardness (Shore D)	83.0	78.6	89.0	90.8
↑ Ecofriendly factor (1- Bad, 5- Good)	4	4	3	1

Figure 3: Decision matrix of biocomposites after 90-days natural ageing; arrows show the direction of preference sensitivity.

As per PROMETHEE II results, the biocomposite PFA/60%CF was selected to be used in the solar canopy simulations. Simplified wind simulations showed the most severe loading from the 45-degree direction, closely followed by 35 degrees. Detailed simulations using the actual geometry confirmed 35 degrees as the most critical direction. Final simulations from this direction were performed using RANS and DES turbulence modeling techniques, along with storm surge analysis. Structural response to wind loading was analyzed using the Abaqus finite element solver with simplified geometry and static load application (Figure 4). Results showed minimal deformation, with peak stress at only 0.054% of the material's tensile strength and deflection below the boundary layer thickness.

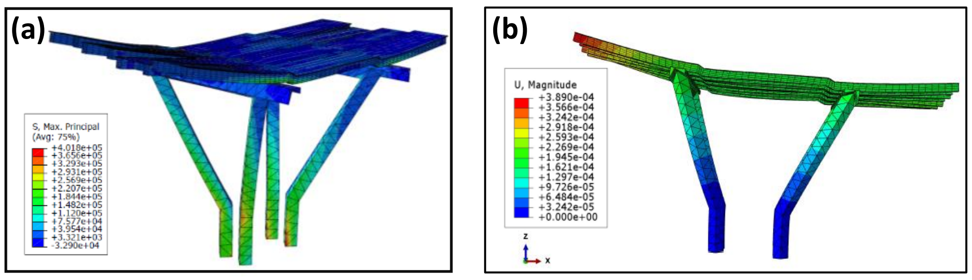

Figure 4: Structure (a) resultant principal stress and (b) deflection (scaled by 3000% and 3214.88%, respectively) under CAT 5 wind loading conditions.

Conclusion & Next Steps

The study demonstrates that carbon fibre-reinforced biobased resin, particularly PFA/60%, offers strong mechanical properties and weather resistance, while remaining 40% eco-friendly. Simulations show that these materials can withstand Category 5 hurricane conditions with minimal deformation. This research supports the development of sustainable, resilient solar canopies using bio-based materials for extreme weather resilience. Further FEA studies with PFA/FF composites are recommended as the next steps to enhance understanding of their performance and optimize their use in such applications.

References:

1. IRENA and CPI, "Global landscape of renewable energy finance, 2023," International Renewable Energy Agency, 2023.
2. Z. N. Azwa, B. F. Yousif, A. C. Manalo, and W. Karunasena, "A review on the degradability of polymeric composites based on natural fibres," Mater Des, vol. 47, pp. 424–442, 2013.

Further reading:

O. H. Margoto (2022). An experimental investigation and multicriteria decision making into flax and carbon fibres reinforced biopolymers for outdoor structural applications (T). University of British Columbia. Retrieved from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0422234

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