Optimization Protocol for Seshat's Bones: A High-Performance Hemp-Based Epoxy Composite

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Abstract

This document outlines a technical protocol to enhance the mechanical, thermal, and dielectric performance of *Seshat's Bones*, a novel fully hemp-based epoxy composite. The goal is to approach or surpass the mechanical efficiency of graphene-epoxy composites while preserving biodegradability, cost-effectiveness, and ecological safety. It includes material preparation, nanosheet exfoliation, dispersion strategies, interfacial bonding chemistry, and a complete test matrix.

1. Objective

To maximize the composite performance of Seshat's Bones by:

- Optimizing the exfoliation and dispersion of hemp-derived nanosheets
- Improving matrix-filler interface bonding
- Balancing reinforcement loading (biochar + nanosheets)
- Establishing a systematic experimental test matrix

2. Nanosheet Exfoliation Optimization

Parameters to Optimize

- **Precursor biomass:** Raw hemp bast vs. pyrolyzed hemp biochar
- **Sonication power:** 100W–750W
- **Sonication time:** 15–120 minutes

- **Solvent medium:** Water, ethanol, DMF, acetone
- **Centrifugation speed:** 5000–10,000 rpm

Characterization Methods

- Transmission Electron Microscopy (TEM)
- Dynamic Light Scattering (DLS)
- X-ray Diffraction (XRD)
- BET Surface Area Analysis

3. Dispersion Optimization into Epoxy-Lignin Matrix

Processing Variables

- **Nanosheet loading:** 0.5–5.0 wt%
- **Biochar loading:** 5–20 wt%
- **Mixing method:** Magnetic stirring vs. probe ultrasonication
- **Mix temperature:** Room temp – 60°C
- **Curing protocol:** Thermal step-cure (80°C to 150°C), vacuum-assisted

4. Interfacial Chemistry Enhancement

Strategies

- **Functionalize nanosheets:** Acid oxidation (e.g., HNO_3/H_2SO_4) to introduce carboxylic groups
- **Coupling agents:** Use silanes or maleic anhydride for improved matrix compatibility
- **Lignin modification:** Increase hydroxyl content via maleic anhydride esterification

Characterization Tools

- Fourier Transform Infrared Spectroscopy (FTIR)
- X-ray Photoelectron Spectroscopy (XPS)
- Scanning Electron Microscopy (SEM)

Sample ID	Nanosheet (wt%)	Biochar (wt%)	Tensile	Flexural	Tg (°C)	Dielectric
S-1	0.5	10				
S-2	1.0	10				
S-3	2.5	10				
S-4	2.5	15				
S-5	5.0	10				

Table 1: Composite test matrix for optimization of filler loading and performance

5. Experimental Test Matrix

6. Performance Goals

Target Property	Minimum Target	Ideal Benchmark
Tensile Strength	>100 MPa	200–300 MPa
Elastic Modulus	>10 GPa	30–50 GPa
Glass Transition Temperature (Tg)	>100°C	150°C
Dielectric Constant (1 MHz)	2–4	Tunable via nanosheet loading

Table 2: Performance goals for competitive hemp-based nanocomposite

7. Recommended Add-Ons

- **Hybrid Reinforcement:** Add hemp microfibers or bacterial cellulose
- **Co-curing Chemistry:** Bio-based amines, lignin-derived polyols
- **Precision Molding:** Use 3D-printed molds for ASTM-standard testing shapes

8. Conclusion

With the protocol outlined herein, *Seshat's Bones* can be systematically optimized to approach the performance levels of graphene-enhanced composites. Through controlled exfoliation, advanced dispersion, and strong interfacial engineering, this fully hemp-based material can serve as a breakthrough in sustainable, high-performance composites for aerospace, defense, electronics, and civil infrastructure.