DEVELOPMENT OF HYBRIDIZED BAMBOO-COIR-RUBBER PANELS FOR SUSTAINABLE FORMWORK CONSTRUCTION

Project Reference No.: *48S_MTECH_0016*

College : Jyothy Institute of Technology, Bengaluru
Branch : Department of Structural Engineering
Guide(s) : Dr. Narendra Reddy
Mrs. C Bhargavi
Student(s): Mr. Naveen Dyava Naik

Keywords:

Bamboo fiber, Coir fiber, Natural rubber, Sustainable materials, Hybrid composites, Formwork, Green construction, Panel development, Compression moulding, Reusability.

Introduction:

With increasing concerns about environmental degradation and the need for sustainable alternatives in construction, the development of eco-friendly formwork materials has become a focus area. Conventional timber and steel formworks, though widely used, either deplete forest resources or have high embodied energy and cost (Asif et al., 2007; Cabeza et al., 2014). This study investigates the feasibility of using natural fibers—bamboo and coir—reinforced with natural rubber to fabricate hybridized panels for formwork applications.

Bamboo is a fast-growing, high-strength natural resource that exhibits excellent tensile properties and a favorable strength-to-weight ratio (Lakkad & Patel, 1981; Ghavami, 2005). Coir, a durable and resilient by-product of the coconut industry, is known for its good elongation, moisture resistance, and impact energy absorption (Ali et al., 2012). Natural rubber, with its elastomeric properties, enhances the flexibility and fatigue resistance of composites, making it suitable for dynamic construction environments (Thomas et al., 2009).

A critical aspect of formwork material performance is fracture toughness, especially under repeated loadings and harsh site conditions. Fracture toughness characterizes a material’s resistance to crack initiation and propagation, crucial for reusable systems subjected to mechanical and impact loads. Various studies (Mishra et al., 2001; Jawaid & Abdul Khalil, 2011) have demonstrated that hybrid natural fiber composites can be engineered to achieve improved toughness and damage tolerance, particularly when fracture behaviour is assessed using Mode I (opening) and Mode II (shear) loading conditions via SENB and ENF tests, respectively.

This work emphasizes local material sourcing, waste utilization, and energy-efficient processing through compression moulding. The outcome is a composite panel that is not only sustainable and cost-effective but also structurally efficient and fracture-resistant, offering a viable replacement for conventional plywood or steel formworks in green construction projects.

Objectives:

1. To fabricate hybrid panels using bamboo, coir, and natural rubber through compression moulding.
2. To evaluate the mechanical (flexural, tensile, impact) properties of the developed panels as per IS standards.
3. To assess fracture resistance under Mode I (opening) and Mode II (shearing) loadings.
4. To test thermal, moisture, and dimensional stability of panels.
5. To examine durability and reusability for multiple casting cycles in formwork applications.

Methodology:

1. **Material Selection**

- Bamboo (Dendrocalamus Strictus) strips
- Coir mats (natural coconut fiber)
- Natural rubber latex and rubber crumbs

2. Panel Design & Layup

- Bamboo and coir were arranged in alternating layers.

- Rubber crumbs served as the matrix, ensuring good bonding.
- Target thickness: ~10–15 mm for formwork panel simulations.

3. Fabrication Process

- Compression moulding at 180°C and 2000 psi for 15–20 minutes.
- Cooling under pressure to avoid thermal warping.

Figure 1: Fabrication Process of Hybrid Panels

4. Specimen Preparation

- As per **IS 2380 (Part 1 to 21)** for wood-based panels and relevant mechanical tests.

5. Mechanical Testing

- **Flexural Strength**: IS 1734 (Part 5):1983
- **Tensile Strength**: ASTM D3039
- **Impact Resistance**: IS 2380 (Part 17):1981
- **Hardness (Shore D)**: ASTM D2240
- **Nail-holding Capacity**: IS 2380 (Part 14):1981

6. Durability Testing

- **Water Absorption**: IS 2380 (Part 16):1981
- **Weather Resistance & Dimensional Stability**: IS 303:1989
- **Wet-Dry Cycles**: IS 4990:2011

7. Fracture Toughness Testing

- **Mode I**: Single Edge Notch Bending (SENB) as per ASTM D5045
- **Mode II**: End Notched Flexure (ENF) as per ASTM D7905

8. Rubber Content Variation Study

- Rubber volume fractions varied from 5% to 30% (in increments of 5%) to optimize fracture resistance and bonding.

9. Data Analysis & Optimization

- Stress-strain plots, load-deflection curves, fracture energy calculations, and damage pattern analysis will be performed.

Result and Conclusion:

Preliminary fabrications and tests have been done to optimise the suitable fiber: matrix ratios and fiber 1: fiber 2 ratio.

It has been found based on mechanical properties analysis that with Fiber: Matrix ratio of 80:20 and Bamboo: Coir ratio of 50:50, the panels have exhibited comparable mechanical strengths with that of plywood. Fig. 2 to 10 presents the results comparison considering plywood made of 10mm thickness as standard.

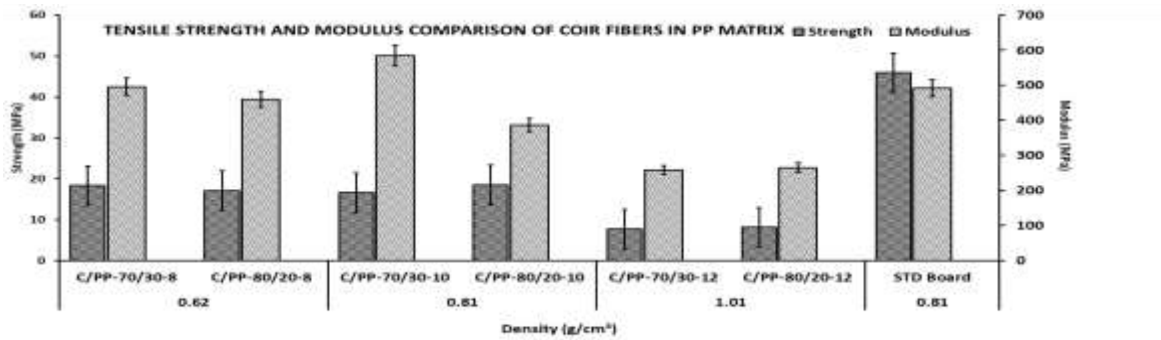

Figure 2 Comparison of Tensile Strength and Modulus of Individual Coir Panels

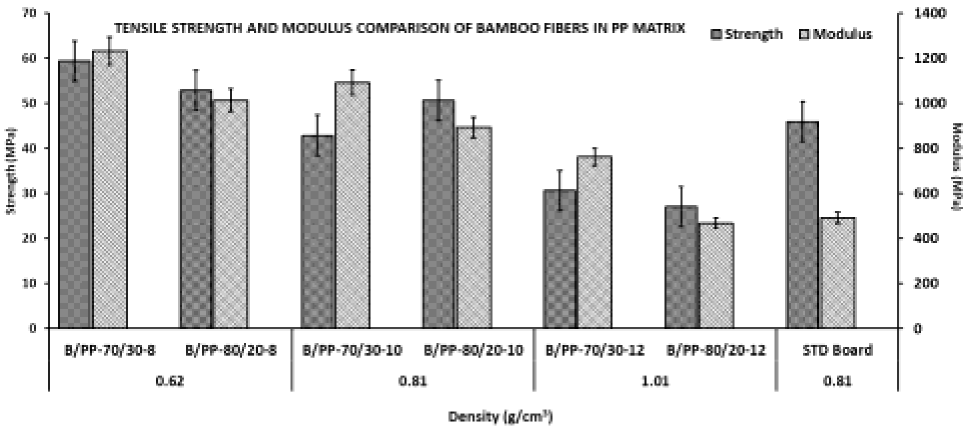

Figure 3 Comparison of Tensile Strength and Modulus of Individual Bamboo Panels

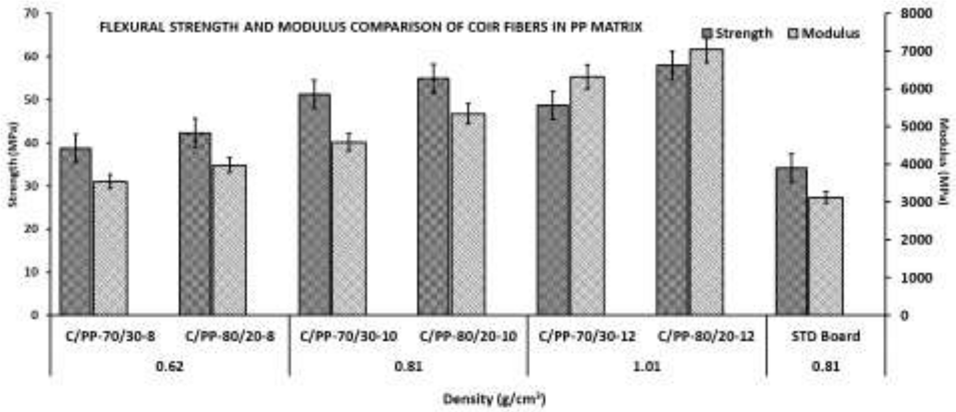

Figure 4 Comparison of Flexural Strength and Modulus of Individual Coir Panels

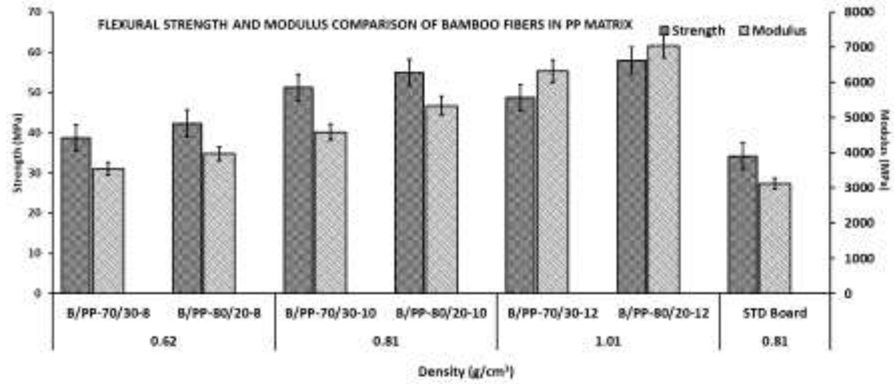

Figure 5 Comparison of Flexural Strength and Modulus of Individual Bamboo Panels

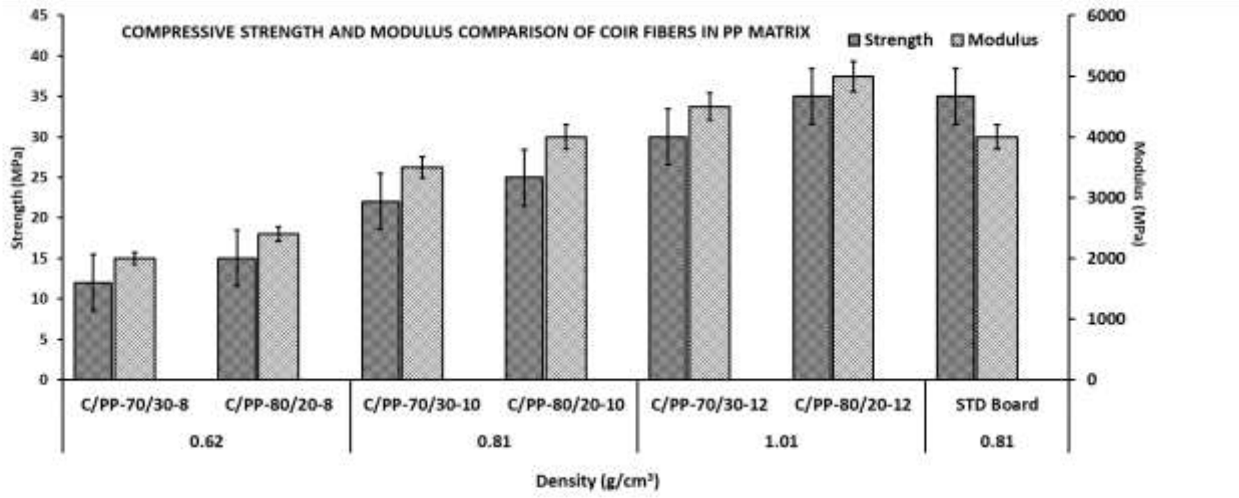

Figure 6 Comparison of Compressive Strength and Modulus of Individual Coir Panels

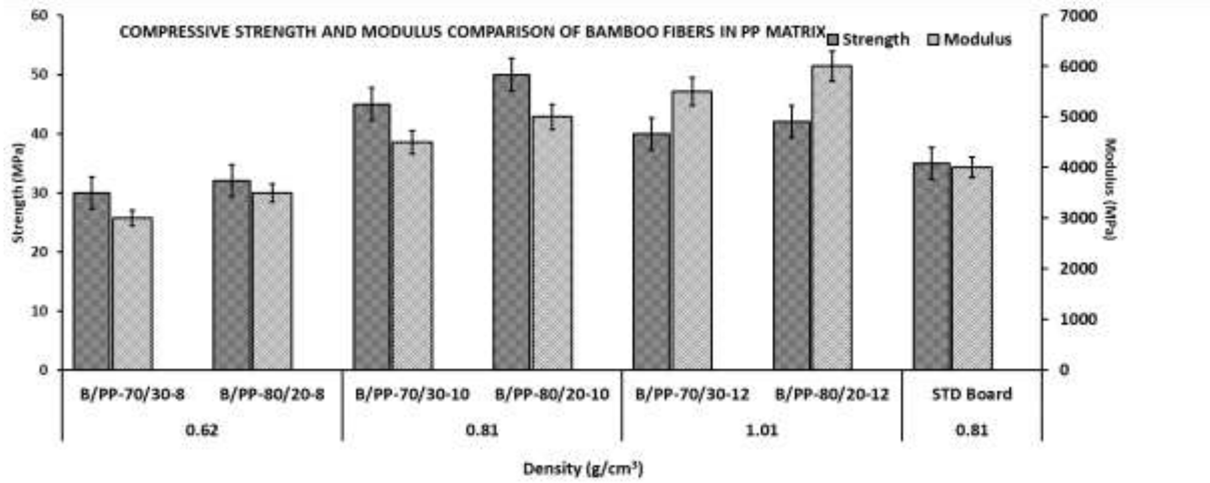

Figure 7 Comparison of Compressive Strength and Modulus of Individual Bamboo Panels

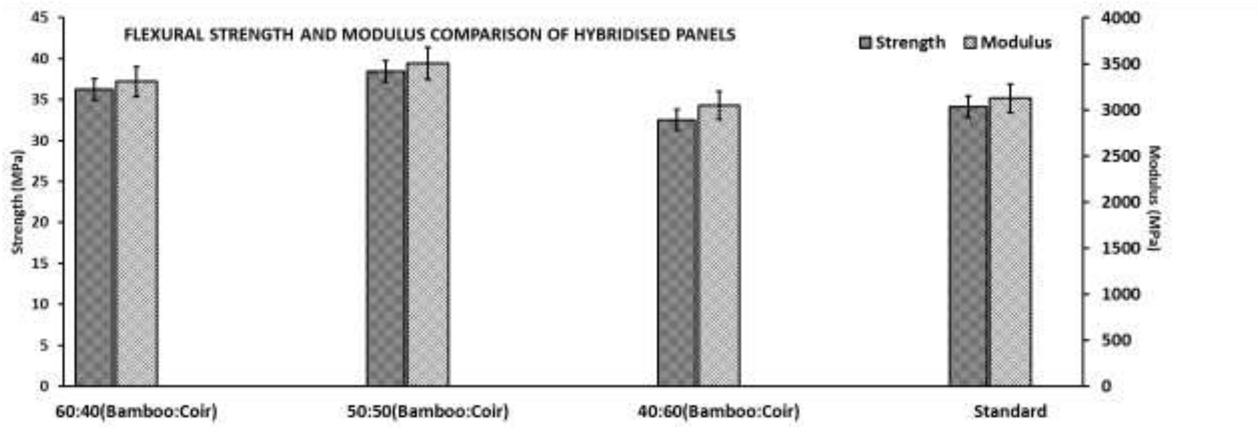

Figure 8 Comparison of Flexural Strength and Modulus of Hybridised Panels

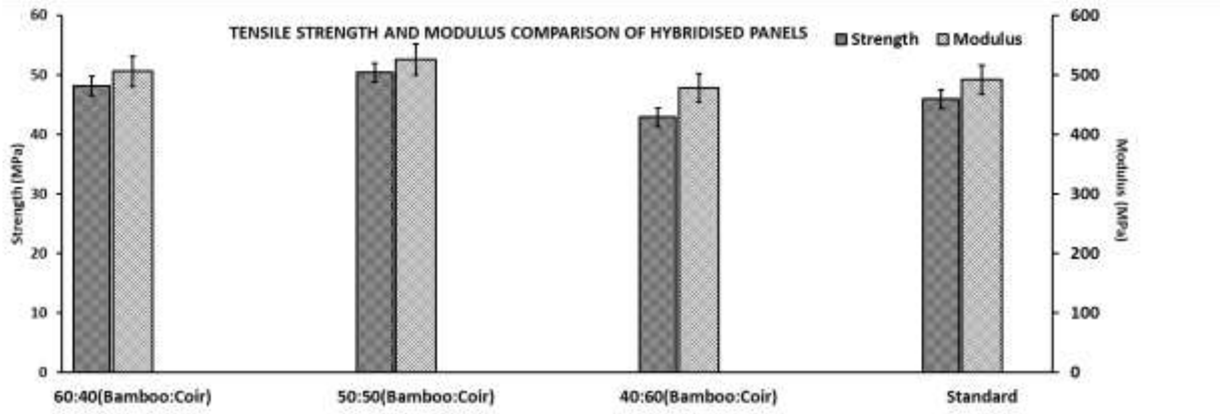

Figure 9 Comparison of Tensile Strength and Modulus of Hybridised Panels

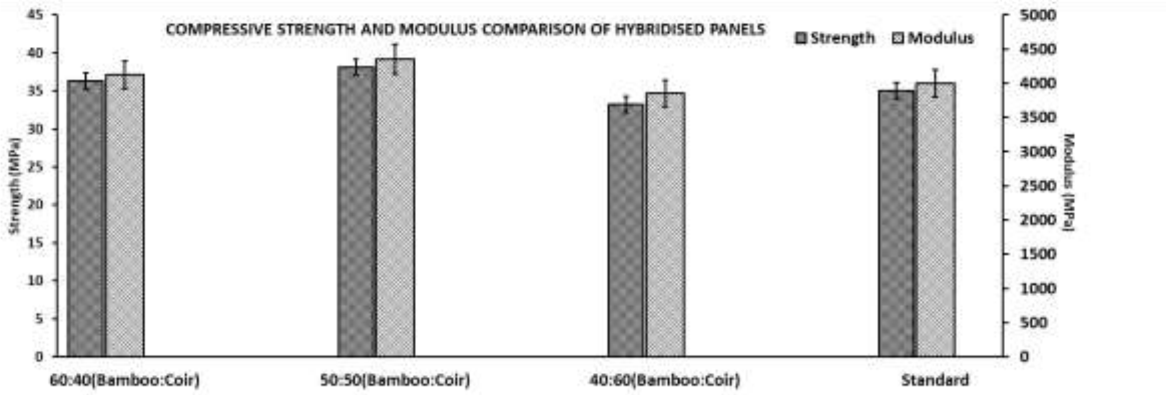

Figure 10 Comparison of Compressive Strength and Modulus of Hybridised Panels

Further, basic durability tests were also performed on the hybrid panels to check for their moisture absorption, swelling and alternate wetting and drying responses. Fig 11 & 12 presents the results of 15 days cyclic durability tests.

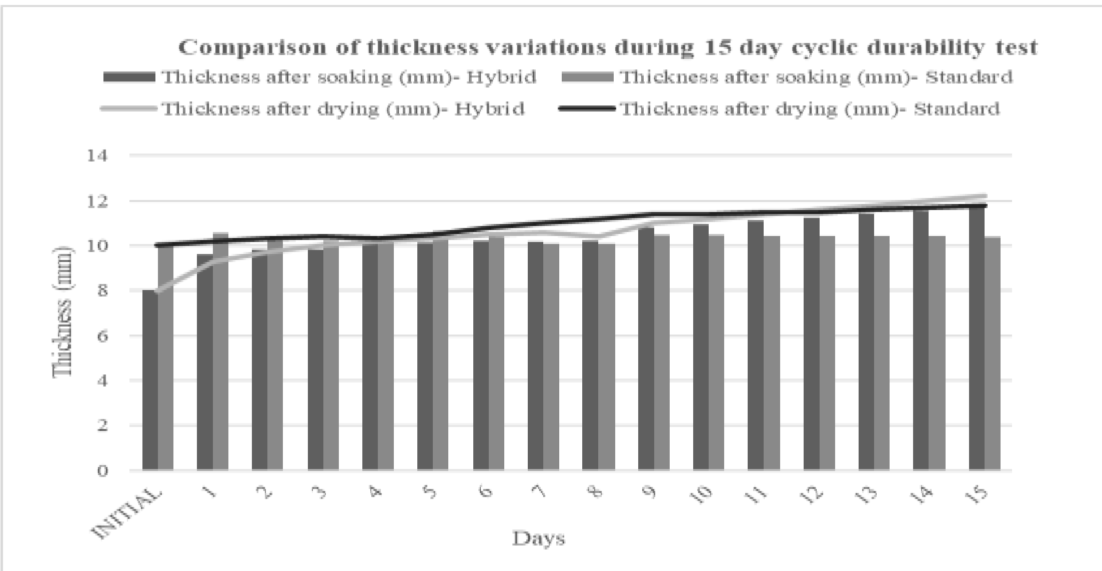

Figure 11 Comparison of thickness variations during 15-day cyclic durability test

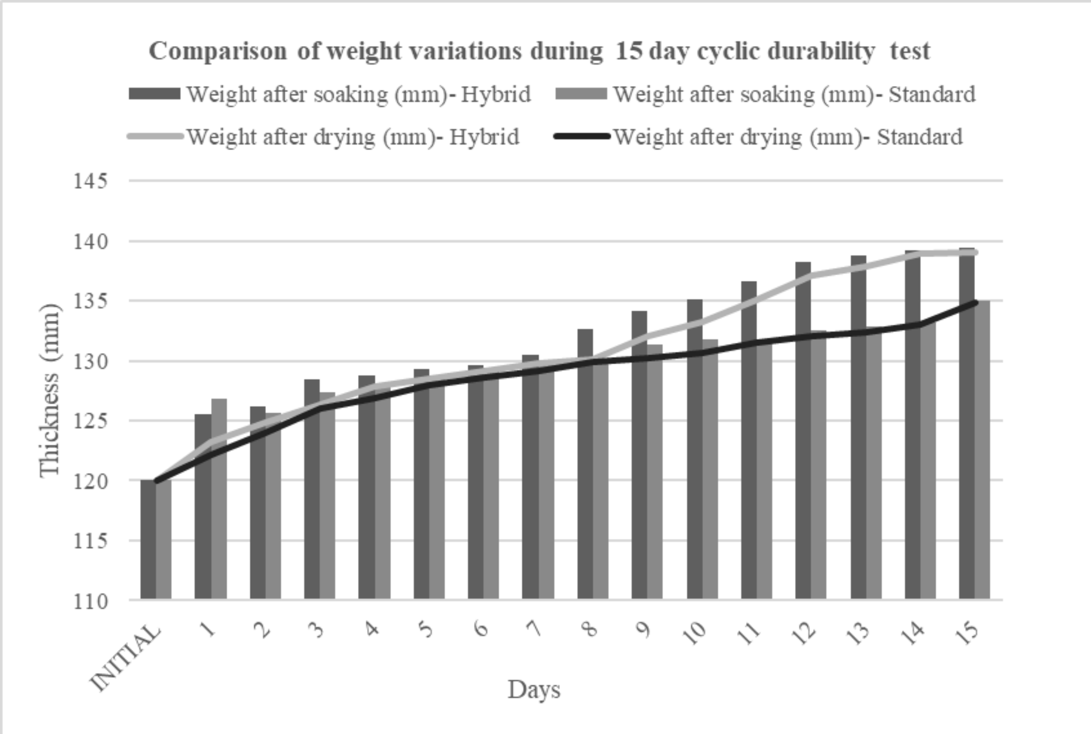

Figure 12 Comparison of weight variations during 15-day cyclic durability test

Currently, the rubber quantity is being varied from 5% to 30% in the increments of 5% to check for fracture resistance alongside the mechanical properties.

Project Outcome & Industry Relevance:

1. Developed an alternative to plywood and metal formworks using natural, renewable resources.
2. Demonstrated local value addition by utilizing regional agro-waste materials.
3. Industry relevance includes affordable housing, rural construction, and green building projects.
4. Potential for mass manufacturing using simple compression moulding techniques.
5. Could reduce timber dependency and carbon emissions in construction.

Project Outcomes and Learnings:

1. Hands-on experience in composite fabrication and testing.
2. Gained understanding of material compatibility and performance evaluation.

3. Learned sustainability principles in construction.

Future Scope:

The future scope of this project includes:

1. Scale-up fabrication using hydraulic presses and explore automation.
2. Evaluate long-term durability under site conditions (UV exposure, freeze-thaw, etc.).
3. Integrate waste rubber (e.g., crumb rubber from tires) to enhance cost-effectiveness.
4. Modify panel design to include interlocking or modular shapes for ease of assembly.
5. Study thermal insulation and fire resistance for broader application beyond formwork.
6. Collaborate with local industries or NGOs for pilot housing projects.
7. Explore life cycle assessment (LCA) to quantify environmental benefits.
8. Extend the concept to other applications like wall panels, temporary shelters, and flooring systems.