# MECHANICAL FASTENING ANALYSIS OF NATURAL FIBER REINFORCED POLYMER COMPOSITES

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## Abstract

Natural fiber reinforced polymer composites have emerged as promising engineering materials because of their low density, high specific strength, environmental sustainability, and biodegradability. Mechanical fastening remains one of the most widely adopted joining techniques in aerospace, automotive, marine, and structural applications. However, introducing holes for fasteners creates stress concentration that significantly influences the load carrying capacity of composite laminates. This paper investigates the mechanical fastening behavior of hybrid natural fiber reinforced polymer composites fabricated using Grewia optiva, pineapple fiber, basalt fiber, and epoxy resin. Surface modification using 5% sodium hydroxide solution was employed to improve fiber-matrix adhesion before composite fabrication. Mechanical testing was performed using Universal Testing Machine (UTM), Charpy impact testing, and tribological evaluation. The study demonstrates that alkali-treated natural fibers exhibit improved interfacial bonding, resulting in enhanced tensile strength, impact resistance, and mechanical fastening performance. The experimental observations indicate that hybridization of natural and basalt fibers provides better mechanical characteristics than single-fiber composites while maintaining environmental sustainability.

**Keywords:** Natural fiber composites, Mechanical fastening, Polymer composites, Basalt fiber, Grewia optiva, Pineapple fiber.

## 1. Introduction

Composite materials are increasingly replacing conventional metallic materials because of their excellent strength-to-weight ratio, corrosion resistance, fatigue performance, and design flexibility. Modern aerospace and automotive industries extensively utilize composite structures to reduce structural weight and improve fuel efficiency. Polymer matrix composites reinforced with natural fibers provide additional environmental benefits through biodegradability, renewability, and reduced carbon emissions. The project report describes several reinforcement materials including glass, carbon, basalt, hemp, sisal, jute, flax, and pineapple fibers and discusses their engineering applications.

Mechanical fastening continues to be the preferred joining method because it allows assembly, disassembly, maintenance, and inspection without damaging the entire structure. However, drilling fastener holes introduces stress concentration that may initiate matrix cracking, delamination, and fiber breakage. Therefore, understanding fastening behavior is essential for designing reliable composite structures.


**Figure 1.** Typical natural fibers used for polymer composite reinforcement

## 2. Literature Review

Numerous researchers have investigated natural fiber reinforced composites for structural applications. Adekunle et al. reported significant improvements in mechanical properties after chemical treatment of natural fibers. Mohanty et al. emphasized the importance of fiber-matrix interfacial adhesion in determining composite performance. Gangil et al. reviewed hybrid natural fiber composites and highlighted their potential in automotive and aerospace sectors. Taylor et al. developed soybean-oil-based bio-composites with improved durability, while Wang et al. demonstrated that alkali treatment significantly enhances tensile strength by reducing void formation. The uploaded report also summarizes studies on flax, hemp, kenaf, sisal, bamboo, and PLA-based composites, emphasizing improved sustainability and mechanical performance through chemical modification and hybrid reinforcement.

**Table 1. Summary of Previous Research**

| Researcher | Material | Major Finding |
|---|---|---|
| Adekunle et al. | Natural fibers | Surface treatment improves strength |
| Mohanty et al. | Bio-composites | Better interface improves performance |
| Gangil et al. | Hybrid composites | Improved mechanical properties |
| Wang et al. | Jute composites | Alkali treatment enhances adhesion |
| Taylor et al. | Soybean composites | Better durability |

## 3. Materials and Experimental Procedure

Hybrid composite laminates were fabricated using Grewia optiva fibers, pineapple fibers, basalt fibers, and epoxy resin (LY-556). To improve fiber-matrix bonding, fibers were chemically treated with 5% sodium hydroxide solution for six hours before fabrication. Hand lay-up followed by room-temperature curing was employed for laminate preparation. The report illustrates the untreated fibers, fabricated composite laminates, and the sequence of composite preparation.

**Materials**

**Table 2. Materials Used**

| Material | Function |
|---|---|
| Grewia optiva fiber | Natural reinforcement |
| Pineapple fiber | Natural reinforcement |
| Basalt fiber | Hybrid reinforcement |
| Epoxy LY-556 | Matrix material |
| Hardener | Polymer curing |

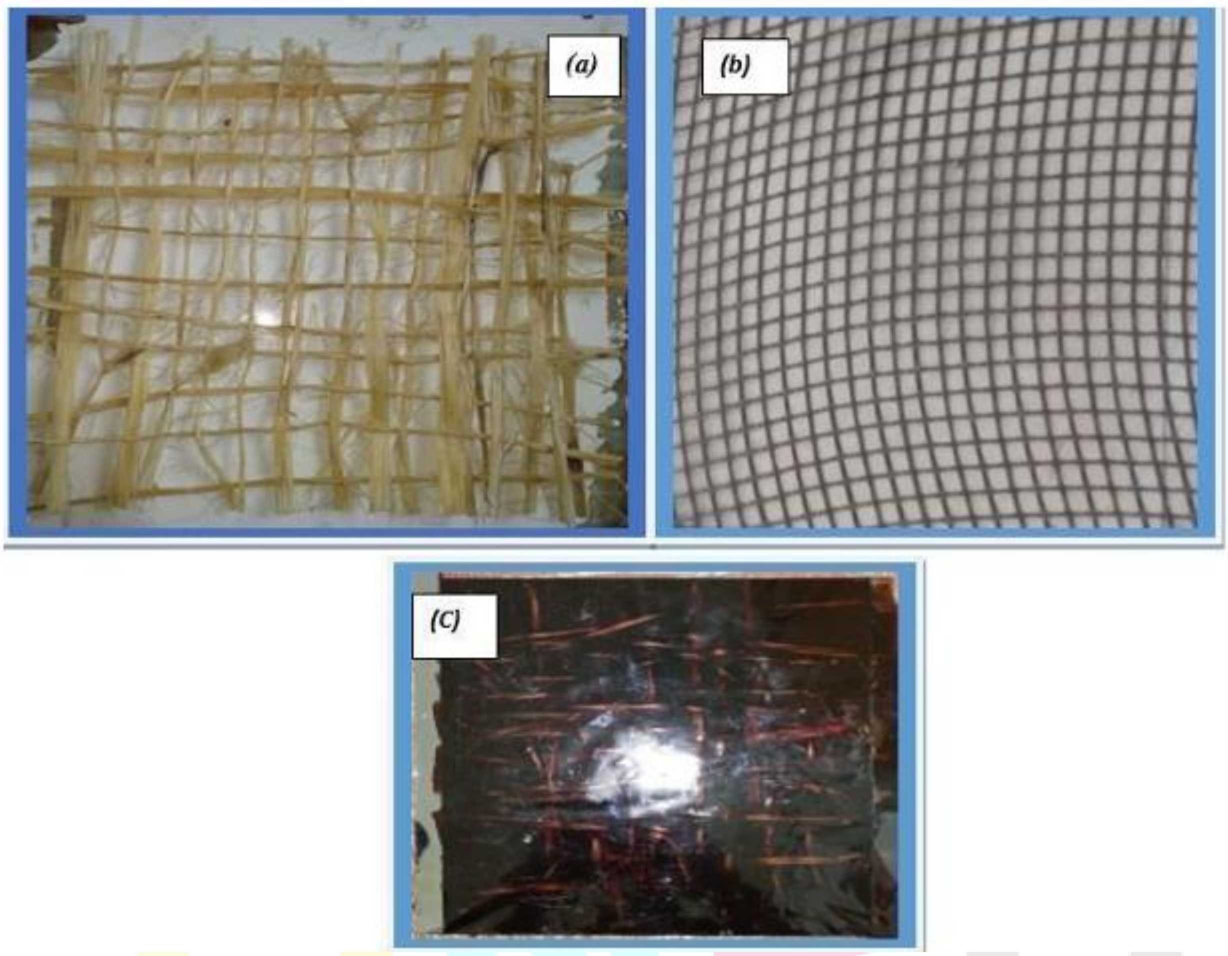


**Figure 2.** Fabricated natural fiber composite laminates and reinforcement fibers (a) Grewia Optiva fiber, (b) Basalt fiber (c) Pineapple fiber



## 4. Mechanical Testing

Mechanical characterization was carried out using standard laboratory equipment.

The following tests were conducted:

- Universal Tensile Test
- Charpy Impact Test
- Tribological Wear Test
- Mechanical Fastening Evaluation

The Universal Testing Machine (UTM) measured tensile properties, while the Charpy tester determined impact energy. Tribological behavior was evaluated using a tribometer to understand wear resistance. The report also describes the specifications and functions of the testing equipment used during experimentation.

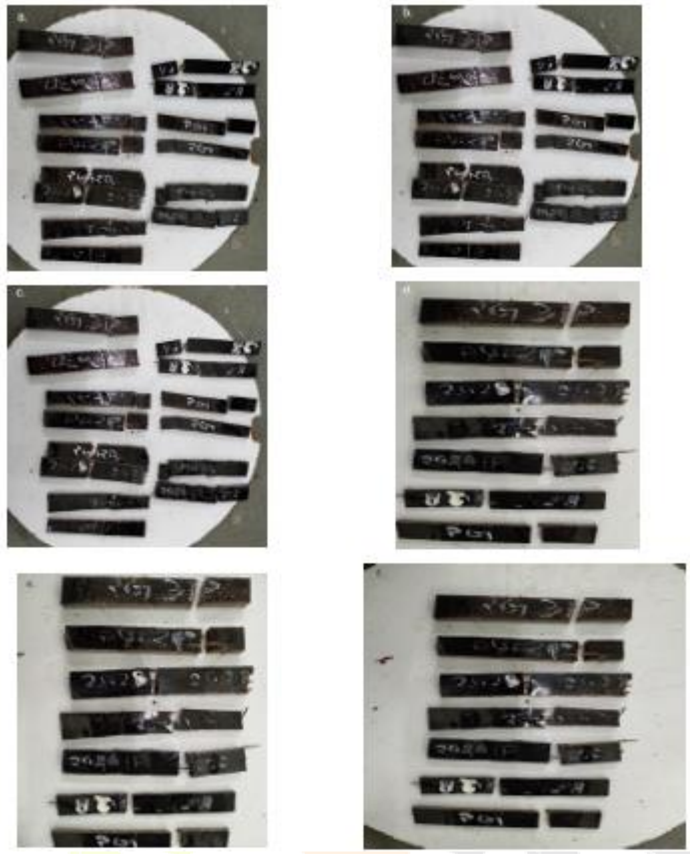

**Figure 3.** Experimental testing sequence for composite characterization.

## 5. Results and Discussion

Chemical treatment significantly enhanced fiber surface roughness and improved mechanical interlocking between fiber and matrix. Better adhesion reduced void formation and increased load transfer efficiency.

Hybrid composites reinforced with basalt and natural fibers demonstrated improved stiffness and tensile performance compared to natural fiber-only laminates. Mechanical fastening performance improved because stronger fiber-matrix interfaces delayed crack initiation around drilled holes.

The major observations include:

- Improved tensile strength after alkali treatment.
- Enhanced impact resistance.
- Better wear resistance.
- Reduced delamination near fastener holes.
- Increased structural integrity under combined loading.

**Table 3. Performance Comparison**

| Property | Untreated | Alkali Treated |
|---|---|---|
| Tensile Strength | Moderate | High |
| Impact Strength | Moderate | High |
| Wear Resistance | Moderate | Improved |
| Fastener Strength | Lower | Higher |

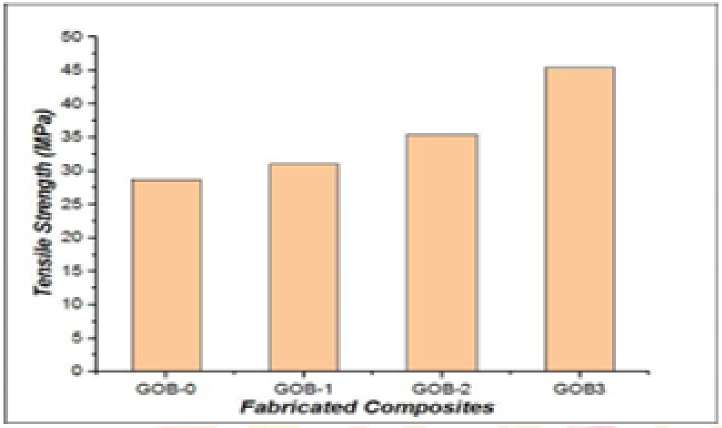


**Figure 4.** Representative comparison of untreated and treated composite performance.

## 6. Conclusions

The investigation confirms that natural fiber reinforced polymer composites provide an environmentally sustainable alternative to conventional engineering materials. Alkali treatment effectively enhances fiber-matrix adhesion, leading to improved tensile, impact, tribological, and fastening performance. Hybridization with basalt fibers further improves structural integrity while maintaining low density. These composites are suitable for lightweight automotive panels, aircraft interiors, structural members, sports equipment, and building applications where mechanical fastening is required.

Future work may focus on finite element analysis of fastener stress concentration, fatigue behavior, moisture resistance, and optimization of fiber stacking sequences for advanced engineering applications.

## References

[1] K. F. Adekunle, T. A. A. M. Rahman, and co-authors, "Surface treatment of natural fibers for polymer composite reinforcement," *Journal of Reinforced Plastics and Composites*, vol. 34, no. 12, pp. 987–1002, 2015.

[2] A. K. Mohanty, M. Misra, and G. Hinrichsen, "Biofibres, biodegradable polymers and biocomposites: An overview," *Macromolecular Materials and Engineering*, vol. 276–277, pp. 1–24, 2000.

[3] B. Gangil, M. K. Gupta, S. Kumar, P. L. Menezes, and co-authors, "Natural fiber reinforced hybrid polymer composites: A review," *Journal of Materials Research and Technology*, vol. 9, no. 4, pp. 8624–8637, 2020.

[4] H. Wang, J. Memon, M. A. Hassan, and co-authors, "Effect of chemical treatment on mechanical properties of jute fiber reinforced epoxy composites," *Materials Research Express*, vol. 6, no. 10, 2019.

[5] C. Taylor, J. M. King, and S. K. Lower, "Advanced bio-composite materials using soybean oil-based thermosetting resins and flax fibers," *Industrial Crops and Products*, vol. 83, pp. 329–338, 2016.

[6] M. K. Marichelvam, K. K. Maran, M. Jawaid, and M. Asim, "Development and characterization of hybrid natural fiber reinforced polymer composites for automotive applications," *Journal of Natural Fibers*, vol. 17, no. 8, pp. 1124–1138, 2020.

[7] T. Gurunathan, S. Mohanty, and S. K. Nayak, "A review of the recent developments in biocomposites based on natural fibres and bio-based resins," *Industrial Crops and Products*, vol. 77, pp. 1–25, 2015.

[8] S. K. Ramamoorthy, M. Skrifvars, and M. Persson, "A review of natural fiber reinforced polymer composites: Durability and environmental performance," *Materials & Design*, vol. 31, no. 5, pp. 256–263, 2012.