

## REVIEW OF HYBRID COMPOSITE MATERIALS FOR ENHANCING CONCRETE CYLINDER COLUMNS: A FOCUS ON JUTE AND E-GLASS LAMINATES

A.J. Zulfikar<sup>1,2</sup>, M.Y. Yuhazri<sup>1\*</sup>, D.A.A. Ritonga<sup>3</sup>, W. Weriono<sup>4</sup>, and N. Fitriadi<sup>5</sup>

<sup>1</sup>Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan,  
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian  
Tunggal, Melaka, Malaysia.

<sup>2</sup>Program Studi Teknik Mesin, Fakultas Teknik,  
Universitas Medan Area, Jl. Kolam No. 1 Medan Estate, 20223, Medan, Indonesia.

<sup>3</sup>Program Studi Teknik Mesin, Fakultas Teknik dan Komputer,  
Universitas Harapan Medan, Jl. HM Joni No 70 C, 20216, Medan, Indonesia.

<sup>4</sup>Program Studi Teknik Mesin, Sekolah Tinggi Teknologi Pekanbaru,  
Jl. Dirgantara No.4, Sidomulyo Tim., Marpoyan Damai, 28125, Pekanbaru, Indonesia.

<sup>5</sup>Program Studi Teknik Mesin, Politeknik Aceh Selatan,  
Jl. Merdeka Komplek Reklamasi Pantai Tapaktuan, 23711, Aceh Selatan, Indonesia.

\*Corresponding Author's Email: [yuhazri@utem.edu.my](mailto:yuhazri@utem.edu.my)

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**ABSTRACT:** This literature review investigates the potential of hybrid jute and E-glass fiber laminates in enhancing the mechanical properties of concrete cylinder columns. The study comprehensively examines existing research on the tensile, compressive, and flexural strength improvements offered by these composite materials. As a sustainable alternative, fiber-reinforced composites, particularly those incorporating natural fibers such as jute, have garnered attention. This review highlights significant improvements in the performance of concrete structures when reinforced with jute and E-glass laminates, emphasizing their potential in concrete rehabilitation. These hybrid composites offer a balanced solution to the limitations of traditional methods, providing enhanced structural integrity without significantly increasing weight. The findings advocate for further research to optimize these materials for sustainable and effective application in modern construction.

**KEYWORDS:** *Hybrid Composite Materials; Jute Fiber Reinforcement; E-Glass Laminates; Concrete Cylinder Columns; Structural Rehabilitation*

### 1.0 INTRODUCTION

Concrete has long been the predominant construction material due to its exceptional compressive strength and durability, making it indispensable in various architectural domains, including residential homes, commercial buildings, transportation infrastructure, and hydraulic structures[1]. However, despite its advantages, concrete exhibits significant deficiencies in tensile and flexural strength, which often lead to structural failures such as delamination and cracking at bonded interfaces under bending and tensile stresses[2]. To address these shortcomings, reinforcement techniques have evolved, with steel reinforced concrete (SRC) and steel fiber reinforced concrete (SFRC) being notable innovations that enhance tensile capacity and mitigate weaknesses[3]. However, these methods increase the dimensions and weight of the concrete structures, posing limitations in space-constrained or weight-sensitive applications. The need for more efficient and sustainable reinforcement techniques has led to the exploration of fiber-reinforced composite materials, particularly natural fibers like jute, which offer an eco-friendly alternative with promising mechanical properties[4]. Studies have shown that integrating fiber-reinforced plastics (FRP) into

concrete significantly enhances its mechanical properties. For instance, the use of hybrid carbon fiber-reinforced plastic (CFRP) and high-performance mortar (HPM) has been demonstrated to improve the performance of reinforced concrete (RC) beam/column joints by 1.34 times compared to unreinforced specimens[5]. Similarly, glass fiber-reinforced plastic (GFRP) jackets have been used to increase the flexural strength of damaged RC beams by up to 114%[6]. Additionally, natural fibers such as jute have been explored for their potential in concrete reinforcement due to their high tensile strength and biodegradability. Studies on jute fiber-reinforced composites (JFRC) have shown significant improvements in resistance to shear forces and overall structural strength[7]. The hybridization of jute with other fibers, such as E-glass, has been investigated to leverage the strengths of both materials, offering enhanced mechanical properties and sustainability[8].

The primary objective of this research is to investigate the potential of hybrid jute and E-glass fiber laminates in enhancing the mechanical properties of concrete cylinder columns. Specifically, the study aims to evaluate the tensile, compressive, and flexural strength improvements offered by these composites and to assess their effectiveness in concrete rehabilitation. By addressing the current gaps in research, this study seeks to provide a sustainable and efficient solution for concrete reinforcement, contributing to the development of more durable and environmentally friendly construction materials.

## 2.0 WOVEN JUTE FABRIC

Jute, scientifically known as *Corchorus* spp., is a long, soft and shiny vegetable fiber that can be spun into coarse and strong thread. This plant has been cultivated primarily in the Bengal Delta in India and Bangladesh for centuries, with historical significance dating back to the Mughal era under Emperor Akbar, where it was widely used by villagers to make clothes and other textile products[9]. Jute fiber is traditionally used in making ropes, sacks, and rough cloth because of its strength and durability. Figure 1(a) shows the shape of woven jute cloth which is commonly used as sack material[10]. Over time, the use of Jute expanded to more industrial applications, including the automotive industry and packaging materials, reflecting its versatility and economic value[11]. Historical records emphasize the utility and benefits of Jute for the environment, demonstrating its potential as a key material in sustainable development[9].

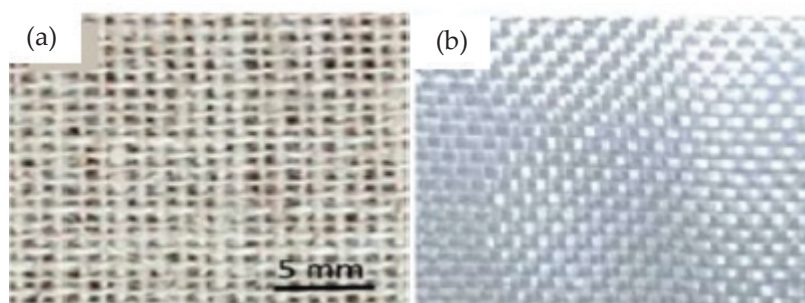


Figure 1: Plain woven fabrics (a) jute [10], (b) E-glass [12]

Jute fibers are characterized by their high tensile strength, low extensibility, and biodegradability, making them suitable for various industrial applications. Mechanically, jute exhibits impressive tensile strength, which ranges between 400-800 MPa, and a modulus of elasticity between 20-55 GPa, depending on the processing and treatment methods used[10]. These properties make jute a strong candidate for reinforcement in composite materials, providing both strength and sustainability. The biodegradability of jute also ensures minimal environmental impact, making it an attractive material for industries looking to reduce their carbon footprint [11]. The potential of jute as a reinforcing material in composite applications is immense, given its favorable physical and mechanical properties. Research over the past decade has explored the hybridization of jute with other fibers, such as glass and carbon,

to enhance the mechanical performance of composite materials. This hybridization process involves combining jute fibers with synthetic fibers to leverage the strengths of both materials, resulting in composites with improved tensile, flexural, and impact properties [4]. The development of woven jute fabric composites has shown promise in various engineering applications, including automotive components, construction materials, and packaging solutions. These composites offer a balance of strength, durability, and environmental benefits, making them suitable for a wide range of industrial uses [12].

Furthermore, ongoing research focuses on optimizing the processing techniques for jute composites, such as chemical treatments and surface modifications, to enhance their bonding with matrix materials and improve their overall performance [8]. The incorporation of nanomaterials and advanced fabrication methods can further expand the applications of jute composites, providing opportunities for innovation in lightweight and high-strength materials. The environmental advantages of using jute, coupled with its economic feasibility, make it a compelling choice for industries aiming to develop sustainable products. As the demand for eco-friendly materials grows, the exploration and development of jute-based composites are expected to play a significant role in advancing sustainable manufacturing practices and reducing environmental impact [10].

### **3.0 WOVEN E-GLASS FABRIC**

E-Glass, or electrical grade glass, is a type of fiberglass known for its high electrical resistance and favorable mechanical properties. The scientific name for E-glass is derived from its composition, primarily consisting of silica ( $\text{SiO}_2$ ), alumina ( $\text{Al}_2\text{O}_3$ ), calcium oxide ( $\text{CaO}$ ), and boron oxide ( $\text{B}_2\text{O}_3$ ). Their high strength-to-weight ratio and resistance to corrosion and temperature fluctuations quickly found utility in other sectors, such as automotive, aerospace, and marine industries[13]. Over the decades, advancements in manufacturing processes have enhanced the properties of E-glass fibers, making them an integral component in the production of composite materials. These composites are widely used in various structural applications, where they contribute to reduced weight, improved durability, and enhanced performance under mechanical loads[14]. Figure 1(b) shows the shape of woven e-glass fiber sheets which are commonly used as coatings or walls[12].

E-glass fibers are known for their high tensile strength, typically ranging from 2,000 to 3,500 MPa, and their modulus of elasticity, which is around 70-80 GPa[15]. They also exhibit excellent thermal stability, maintaining their properties at temperatures up to 600°C, and have good resistance to chemical corrosion. These characteristics make E-glass fibers ideal for applications requiring high mechanical performance and durability in harsh environments[16]. In the automotive industry, E-glass fiber composites are used to manufacture lightweight and high-strength components, contributing to improved fuel efficiency and reduced emissions [17]. The aerospace sector also benefits from E-glass composites, where they are used to produce components that require high strength and durability while minimizing weight [18]. The ongoing advancements in the manufacturing and application of E-glass composites underscore their critical role in modern engineering and construction, providing solutions that meet the demanding requirements of contemporary infrastructure and industrial applications[12].

### **4.0 LAMINATE COMPOSITE**

Figure 2 shows the terminology of composite laminates. Recent studies have demonstrated the efficacy of using jute and E-glass laminate composites in reinforcing and wrapping concrete structures. The combination of natural fibers like jute with synthetic fibers such as E-glass has shown promising results in enhancing the mechanical properties of concrete.

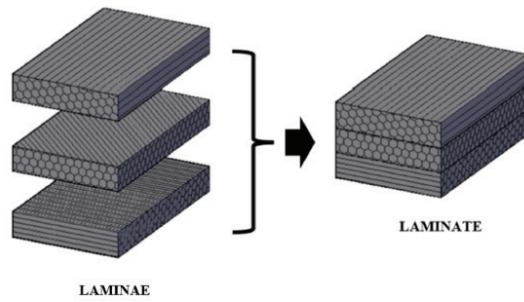


Figure 2: Terminology of laminate structures[20]

This study highlighted the potential of jute laminates in improving the load-bearing capacity and overall durability of concrete structures, especially when used as external wraps[7]. Similarly, Khalid et al. [19] focused on the hybridization of jute and E-glass fibers, demonstrating that such composites could be effectively used for structural applications. The study found that the strategic orientation and layering of these fibers in laminate form resulted in enhanced mechanical properties, making them suitable for use in high-stress environments[19] owing to their low weight, high strength, and outstanding performance at elevated temperatures. However, the utilization of natural reinforcements for functional polymer composites is still in infancy. In this study, the tensile properties of natural and synthetic fiber-reinforced hybrid composites are reported. Glass-jute hybrid composites, prepared through hand layup technique, were used with different glass and jute fiber stacking sequences. The experimental results stipulate that the tensile properties of glass fiber reinforced polymer (GFRP). Furthermore, the research conducted by Sanjay and Yogesha [27] indicated that hybrid composites of jute and E-glass provided a balanced combination of strength, flexibility, and environmental sustainability. The mechanical properties of jute and E-glass laminate composites are influenced by the individual characteristics of each fiber type and their interaction within the laminate structure. E-glass fibers contribute high tensile strength and durability, with tensile strengths typically ranging from 2,000 to 3,500 MPa and a modulus of elasticity around 70-80 GPa. These properties are crucial for applications requiring high load-bearing capacity and resistance to mechanical stresses[12]. Jute fibers, on the other hand, offer moderate tensile strength but excel in terms of biodegradability and low density, making them an attractive option for sustainable composite materials. The hybridization of jute and E-glass fibers results in a composite that benefits from the high strength of E-glass while maintaining the eco-friendly and lightweight nature of jute. Studies have shown that these hybrid composites exhibit improved flexural strength, impact resistance, and dimensional stability compared to composites made solely from synthetic fibers[4].

The potential of jute and E-glass laminate composites as structural reinforcement materials for concrete is significant, particularly in the context of sustainable construction practices. These composites can be used to wrap concrete columns and beams, enhancing their tensile and flexural strength, and thereby extending the service life of concrete structures. The application of such composites in rehabilitation projects is especially promising, as they provide a cost-effective and environmentally friendly solution for repairing damaged concrete structures[6]. Moreover, the use of laminate composites can mitigate common issues associated with traditional concrete reinforcement methods, such as increased structural dimensions and weight. The lightweight nature of jute and the high strength of E-glass fibers offer a balanced solution, making these composites ideal for applications where weight reduction and high mechanical performance are critical[14]. The integration of these materials into concrete reinforcement strategies aligns with the growing emphasis on sustainability in construction, offering a pathway to more durable, resilient, and eco-friendly building practices.

## 5.0 CONCRETE REHABILITATION

Concrete rehabilitation has emerged as a critical field of study aimed at extending the service life and maintaining the structural integrity of aging infrastructure. Traditional methods of concrete rehabilitation, such as steel jacketing and concrete overlays, have proven effective but often come with drawbacks like increased weight and dimensions of the repaired structures. Recent advancements in the use of fiber-reinforced polymer (FRP) composites, particularly those incorporating natural fibers like jute and synthetic fibers like E-glass, offer promising alternatives. Figure 3 shows the concrete repair technique using FRP. These materials provide high tensile strength and flexibility, which are essential for repairing and reinforcing concrete structures without significantly altering their weight or dimensions. The integration of hybrid composites, combining the eco-friendly properties of jute with the mechanical robustness of E-glass, has demonstrated significant improvements in structural performance and sustainability. Studies have shown that using composite materials based on natural fibers for structural reinforcement can increase load-bearing capacity significantly[21]. The use of jute and E-glass in polymer composites has been found to enhance tensile and flexural strength, making these materials suitable for various industrial applications[22]. Research also indicates that hybrid fiber composites, such as those combining jute and polyester, can improve strength and ductility of confined concrete structures[23]. Moreover, incorporating nanoclay fillers in jute/E-glass fiber composites further enhances their mechanical properties, making them highly effective for structural applications[24]. Overall, glass-jute fiber reinforced polymer composites have been found to significantly improve the mechanical properties of concrete, offering a cost-effective and sustainable alternative to traditional materials[25].

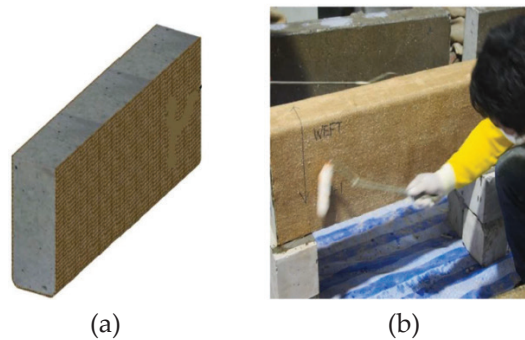


Figure 3: Concrete repairing (a) U-shaped wrapping, (b) wet hand lay-up method[7]

Studies have shown that the application of jute and E-glass laminate composites can substantially enhance the durability and load-bearing capacity of rehabilitated concrete structures. Additionally, the use of woven jute fiber reinforced composites (JFRC) has been effective in increasing the resistance to shear forces in damaged concrete beams, thereby improving their overall structural integrity[26]. The hybridization of jute with E-glass fibers in laminate composites not only leverages the high tensile strength and corrosion resistance of E-glass but also incorporates the sustainability and biodegradability of jute, resulting in a composite material that is both strong and environmentally friendly[27]. This dual benefit underscores the potential of these materials in advancing concrete rehabilitation practices, aligning with contemporary goals of sustainability and efficient resource utilization[28], [29].

## 7.0 CONCLUSION

The primary objective of the review is to investigate the potential of hybrid jute and E-glass fiber laminates in enhancing the mechanical properties of concrete cylinder columns, particularly focusing on improvements in tensile, compressive, and flexural strength. Through an extensive synthesis of recent research, the review reveals that hybrid jute and E-glass laminates significantly enhance these mechanical properties. Jute fibers, known for their biodegradability and tensile strength, provide a sustainable reinforcement option, while E-glass fibers contribute high mechanical strength and durability. The combination of these

fibers in laminate form results in a composite material that leverages the strengths of both components, offering improved compressive, tensile, and flexural properties. Moreover, the hybrid composites demonstrate significant potential in concrete rehabilitation, enhancing structural integrity and resistance to environmental stressors. The findings underscore the efficacy of these materials in addressing the inherent weaknesses of concrete, such as low tensile and flexural strength, and extending the service life of concrete structures. The review concludes by emphasizing the environmental benefits and mechanical enhancements provided by jute and E-glass laminates, advocating for further research to optimize their design and application in various structural contexts to maximize their potential in sustainable construction practices.

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