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EFFECT OF CHEMICAL TREATMENT ON PHYSICAL, MECHANICAL, AND HYDRAULIC PROPERTIES OF JUTE GEOTEXTILES: A LABORATORY STUDY

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ABSTRACT

Jute Geotextiles (JGT) are increasingly utilized in geotechnical engineering projects such as soil erosion control, slope stabilization, subgrade reinforcement, and drainage. It offers a biodegradable and sustainable alternative to synthetic geotextiles. This study provides a detailed investigation into enhancing these properties through a specific chemical treatment. The primary objective was to evaluate the effect of a 1:9 polyester resin-acetone mixture coating on the performance of JGTs.The methodology involved treating three different types of woven JGTs with varying mass per unit area (237, 310, and 425 GSM). The treatment process included pre-soaking the fabrics in a 1% NaOH solution. It was followed by immersion in the resin-acetone mixture, air-drying, and a final curing process in an oven at 100°C. Standard laboratory tests were then conducted on both untreated and treated samples to compare their characteristics. These tests included mass per unit area, nominal thickness, wide-width tensile strength, CBR puncture resistance, permittivity, transmissivity, and apparent opening size (AOS). The results demonstrate that the chemical treatment successfully impregnated the jute fibers. It resulted in a significant increase in mass per unit area (ranging from 40% to 62%) while only minimally affecting the nominal thickness. This coating led to a notable enhancement in mechanical properties. For instance, the wide-width tensile strength of the 425 GSM fabric increased from 18.91 KN/m to 21.32 KN/m in the machine direction, and CBR puncture resistance increased across all samples, with gains ranging from 6.9% to 26.7%. Conversely, the hydraulic properties showed a slight reduction. For the 425 GSM sample, permittivity decreased by 6.7% (from 1.5 to 1.4 s^{-1}) and transmissivity also slightly decreased, which is attributed to partial clogging of the fabric's pores by the resin. Despite the slight reduction in hydraulic properties, the treated JGT samples maintained sufficient permeability and transmissivity for geotechnical application. However, the apparent opening size (AOS) was not significantly altered.The principal conclusion is that the 1:9 resin-acetone treatment is an effective method for significantly improving the mechanical strength and durability of Jute Geotextiles. This study suggests that this chemical modification provides a viable, long-term, and environmentally responsible pathway to make JGTs more robust for a wide range of geotechnical applications.

Keywords: *Geosynthetics, Sustainability, Jute Geotextiles (JGT), Chemical Treatment*

1. INTRODUCTION

Geotextiles are commonly used in geotechnical and civil engineering for purposes such as separation, filtration, drainage, reinforcement, and erosion mitigation. They are generally divided into synthetic and natural types. Jute geotextiles (JGTs) have become of increasing interest as a natural alternative owing to their environmental sustainability. Synthetic geotextiles, generally composed of polymers like polypropylene, polyethylene, and polyester, have physical and uniform mechanical properties; however, they pose environmental issues due to their non-biodegradable characteristics, especially in temporary uses. JGTs, derived from natural jute fibres, offer a biodegradable and environmentally beneficial solution, positioning them as a sustainable substitute for synthetic geotextiles.

Jute geotextiles (JGTs) have been successfully used in low-impact engineering projects, such as rural road construction, slope stabilization, and riverbank erosion mitigation, especially in developing countries like Bangladesh, where jute is abundant and economical. Field investigations in rural road construction under various soil conditions in Bangladesh have evidenced the reinforcement capability of JGTs. At six locations, the incorporation of JGTs as subgrade reinforcement markedly enhanced bearing capacity. Field CBR experiments documented strength enhancements ranging from 3.0% to 19.3% in Keraniganj and from 2.4% to 10.4% in Brahmanbaria during a 16-month duration. Subgrade strength increased by 50% to 543%, suggesting that JGTs may allow for a reduction in pavement thickness in rural road design (Khan et al., 2014).

In addition to constructing roads, open-mesh JGTs have shown efficiency in slope stabilization, especially in hilly areas susceptible to erosion. Slope erosion is primarily induced by raindrop impact, which releases soil particles afterward carried downhill by surface runoff. In April of 2013, field research along the Alikadam–Thanchi road in Bandarban involved the installation of 700 GSM open-mesh JGTs on three silty clay hill slopes, subsequently followed by the sowing of local 'Gyama' seeds before the monsoon. The JGTs effectively mitigated erosion during the initial wet season. Within one year, a dense vegetative cover emerged, with root depths attaining 2.43 m and plant heights reaching 3.96 m. The integration of root reinforcement and canopy coverage offered temporary stabilization, illustrating the efficacy of JGTs in hillside management until vegetation was completely established (Islam et al., 2014).

Jute fibres consist mainly of cellulose (65.2%), hemicellulose (22.2%), and lignin (12.5%) (Mishra, 2000). The cellulose fraction contains anhydro-glucose units with hydroxyl (-OH) groups that establish intermolecular and intramolecular hydrogen bonds, affecting the fibre's physical and mechanical properties

These fundamental characteristics influence water interaction and fibre strength, which are essential variables in the engineering performance of JGTs. Various chemical modification approaches have been investigated to improve the physical and mechanical properties of natural fibres. Treatments such as acetylation (Zini et al., 2004), alkali combined with aloe vera, and polyester resin coating (Khan et al., 2025) have been investigated to improve fibre–matrix interactions and surface characteristics. Various surface modification techniques, including dewaxing, alkali treatment, cyanoethylation, and grafting, have also been applied to jute fabrics (Lakshmanan et al., 2018).These treatments resulted in significant improvements in mechanical properties, with tensile strength increasing by about 50%, bending strength by 30%, and impact strength by nearly 90%. Additionally, jute fiber composites have been successfully produced using soy protein and water as binders, without the use of chemical plasticizers (Reddy & Yang, 2011).

It may be noted that these studies were focused on different types of natural and jute fibers. Whereas, in this novel study, a chemical treatment method has been used on jute geotextiles, which are jute fiber-based finished products specially designed for use above or below the earth surface for obtaining civil engineering benefits. Although made of jute fibers, the effect of a chemical treatment on the JGTs is not known. The geotextiles were subjected to a diluted solution of polyester resin and acetone, resulting in a thin surface coating on the fibres. The treated and untreated JGTs were evaluated via laboratory testing to identify modifications in physical, mechanical, and hydraulic properties. The objective was to evaluate the effectiveness of this surface treatment to enhance the performance of JGTs for geotechnical applications.

2. METHODOLOGY

2.1 Materials

Jute geotextiles (237 GSM, 310 GSM, and 425 GSM) were collected from the Jute Diversified Promotion Centre (JDPC) in Dhaka, Bangladesh. The acetone monomer and unsaturated polyester resin were obtained from the Bangladesh Council for Scientific and Industrial Research (BCSIR), Dhaka.

2.2 Chemical Treatment of JGT

Initially, untreated jute fibres were soaked in a 1% (v/v) NaOH solution until they were fully saturated. Then, they were washed thoroughly with water. This process was done only to remove surface impurities like hemicellulose, lignin, waxes, and pectin, and the NaOH soaking slightly improves tensile strength, bonding, and durability (Flores et al., 2024). The fibres were then soaked in a mixture of resin and acetone made at a 1:9 ratio to make sure the solvent got into the fabric evenly. After treatment, the samples were air-dried so that the acetone could fully evaporate. This was safer than drying them directly in the oven because acetone is flammable. After that, the samples were put in an explosion-proof oven and dried at 100 °c for four hours. The samples were cured at 100 ± 4 °c for four more hours to finish the process and ensure complete curing of the polyester resin and strong bonding with the jute geotextile.

2.3 Summary of the Test

A series of tests was performed on both treated and untreated JGT samples with GSM values of 237, 310, and 425 to evaluate their physical and mechanical properties under laboratory conditions as well as after soil burial. The details of these tests are summarized in Table 1.

Table 1: Summary of Test

Properties	Name of the Tests	Test Standards	237 GSM		310 GSM		425 GSM	
			Untreated	Treated	Untreated	Treated	Untreated	Treated
Physical Properties	Mass per Unit Area	ASTM D5261	✓	✓	✓	✓	✓	✓
	Nominal Thickness	ASTM D5199	✓	✓	✓	✓	✓	✓
Mechanical Properties	Wide-Width Tensile Strength	ASTM D4595	✓	✓	✓	✓	✓	✓
	CBR Puncture Resistance	ASTM D6241	✓	✓	✓	✓	✓	✓
Hydraulic Properties	Permittivity	ASTM D 4491	×	×	×	×	✓	✓
	Transmissivity	ASTM D4716	×	×	×	×	✓	✓
	Apparent Opening Size(AOS)	ASTM D4751	✓	✓	✓	✓	✓	✓

3. RESULTS AND DISCUSSION

3.1 Physical Properties of Untreated and Treated JGT Samples

3.1.1 Mass Per Unit Area

The mass per unit area of the untreated JGT samples was measured as 238 g/m², 310 g/m², and 424 g/m² for the 237 GSM, 310 GSM, and 425 GSM fabrics, respectively. After treatment, these values increased to 386 g/m², 466 g/m², and 596 g/m² for the 237 GSM, 310 GSM, and 425 GSM fabrics. It corresponds to increases of 62%, 51%, and 40%, respectively. The consistent rise in mass per unit area across all fabric types confirms the successful impregnation of resin within the jute yarn structure and inter-fibre spaces. This indicates that the resin-acetone mixture was effectively absorbed and retained by the jute fibres, forming a thin polymeric coating on the fabric surface.

3.1.2 Nominal Thickness

The nominal thicknesses of the untreated JGT samples were measured as 1.03 mm, 1.13 mm, and 1.32 mm for 237 GSM, 310 GSM, and 425 GSM, respectively. After resin treatment, the corresponding thicknesses slightly increased to 1.04 mm, 1.16 mm, and 1.36 mm. This minimal change in thickness indicates that the treatment primarily increased the mass of the JGT without significantly altering its structural dimensions, suggesting that the treated samples gain durability while retaining their original form. The physical properties of untreated and treated JGTs are given in Table 2.

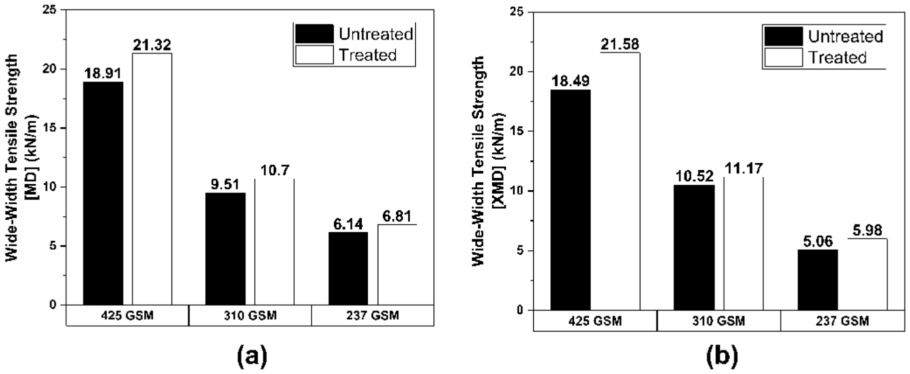
Table 2: Physical properties of JGT (237 GSM, 310 GSM, 425 GSM)

Physical Properties	Untreated 237 GSM	Treated 237 GSM	Untreated 310 GSM	Treated 310 GSM	Untreated 425 GSM	Treated 425 GSM
Mass per Unit Area (gm/m^2)	238	386	310	466	424	596
Nominal Thickness (mm)	1.03	1.04	1.13	1.16	1.32	1.36

3.2 Mechanical Properties of Untreated and Treated JGT samples in Laboratory Conditions

3.2.1 Wide-width Tensile Strength

The tensile strength of all treated JGT samples exceeds that of untreated samples in both the machine direction (MD) and cross-machine direction (XMD). As shown in Figure 1, for the 237 GSM, 310 GSM, and 425 GSM fabrics. In the MD, the tensile strength of the 425 GSM specimen rose from 18.91 KN/m to 21.32 KN/m, the 310 GSM specimen from 9.51 KN/m to 10.70 KN/m, and the 237 GSM specimen from 6.14 KN/m to 6.81 KN/m after treatment. In the XMD, the 425 GSM sample increased from 18.49 KN/m to 21.58 KN/m, the 310 GSM sample from 10.52 KN/m to 11.17 KN/m, and the 237 GSM sample from 5.06 KN/m to 5.98 KN/m. The results indicate that the resin–acetone chemical treatment improves the tensile performance of JGT, with a more notable improvement noted in the heavier (425 GSM) samples. This improvement is due to the existence of a thin resin layer on the jute fibre surface, which improves inter-fibre adhesion.



(a) (b)

Figure 1: Wide-width tensile strength of treated and untreated JGTs : (a) machine direction (MD), (b) cross-machine direction (XMD)

3.2.2 CBR Puncture Resistance

Figure 2 illustrates the variation in CBR puncture resistance of untreated and resin-acetone-treated Jute Geotextiles (JGT) across varied mass per unit areas (237, 310, and 425 GSM). All treated samples exhibited greater puncture resistance compared to the untreated ones. The resistance for the 425 GSM JGT increased from 2223.6 N to 2377.29 N, indicating a 6.9% rise. For 310 GSM, the resistance increased from 1366.86 N to 1572.87 N, and 15.1% increase for the treatment. For 237 GSM, it increased from 918.87 N to 1164.12 N, indicating a 26.7% increase. The results indicate that the resin–acetone modification improves the mechanical integrity of JGT.

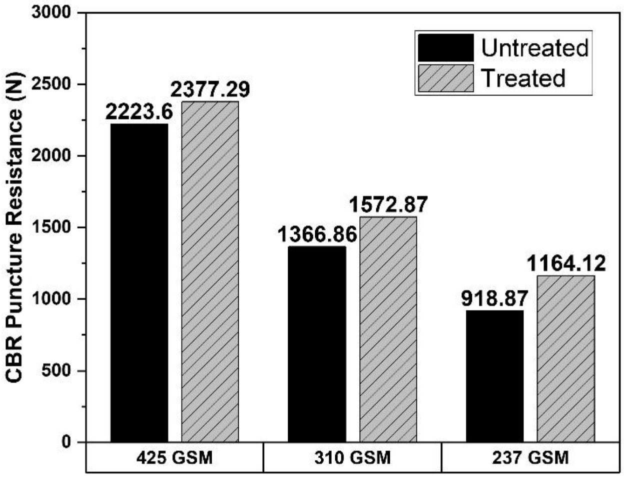


Figure 2: CBR Puncture Resistance (N) both untreated and treated JGT samples

3.3 Hydraulic Properties of Untreated and Treated JGT samples

The 237 GSM and 310 GSM jute geotextile samples, both untreated and treated, are unsuitable for hydraulic property tests (permittivity and transmissivity) due to their fragile condition.

3.3.1 Permittivity

Figure 3 (a) illustrates the permittivity measurements for untreated and resin-acetone treated jute geotextiles (JGT) for the 425 GSM specimen. The untreated JGT showed a permittivity of 1.5 s^{-1}, which slightly reduced to 1.4 s^{-1} post-treatment. This small drop, about 6.7% signifies that the resin coating partially clogged the surface pores and inter-yarn spaces, resulting in a slight decrease in the fabric's water permeability perpendicular to its plane. Despite this reduction, the treated JGT maintained sufficient permeability for drainage applications, indicating that the chemical change did not substantially impair its hydraulic performance.

3.3.2 Transmissivity

Figure 3 (b) shows the transmissivity values of untreated and resin-acetone treated Jute Geotextiles (JGT) for the 425 GSM sample. The untreated 425 GSM jute geotextile sample showed a transmissivity of 41.69 mm^2/s, while the treated 425 GSM sample showed a decreased transmissivity of 38.95 mm^2/s. This is a minor reduction in transmissivity, and the treated JGT still maintains sufficient transmissivity for its application.

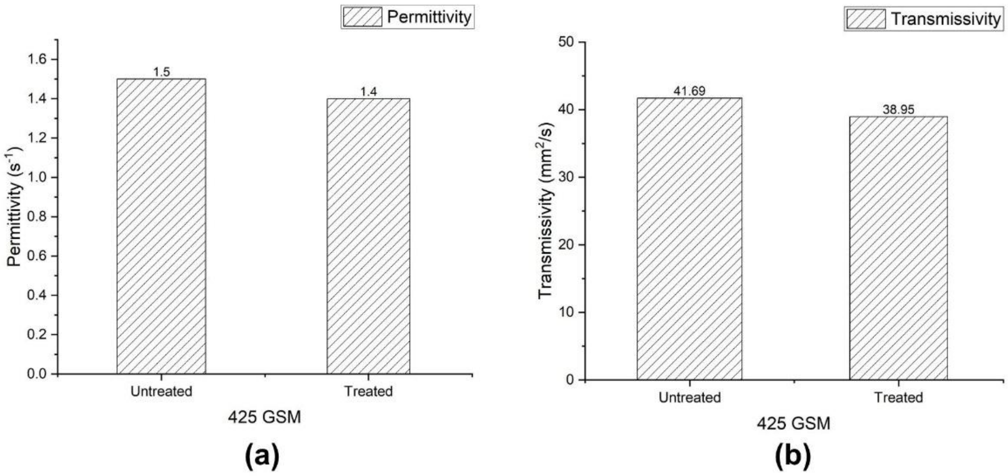


Figure 3: Permittivity and Transmissivity of Both Untreated and Treated JGT Samples

3.3.3 Apparent Opening Size (AOS)

Table 3: Apparent Opening Size (AOS) both untreated and treated JGT samples

Hydraulic Properties	Untreated 237 GSM	Treated 237 GSM	Untreated 310 GSM	Treated 310 GSM	Untreated 425 GSM	Treated 425 GSM
Apparent Opening Size (AOS) (mm)	> 1.19-0.6	> 1.19-0.6	> 1.19-0.6	> 1.19-0.6	1.19-0.6	1.19-0.6

Table 3 illustrates that the apparent opening size (AOS) for the 237 GSM and 310 GSM samples, both untreated and treated, had an AOS greater than 1.19-0.6 mm range. Similarly, the 425 GSM samples, regardless of treatment, demonstrated an AOS within the range of 0.6–1.19 mm. This uniformity suggests that the chemical treatment did not significantly alter the pore size distribution of the jute geotextiles.

4. CONCLUSIONS

This study investigated the influence of chemical treatment on the physical, mechanical, and hydraulic properties of jute geotextiles (JGT) with varying mass per unit area. The results demonstrate that the applied resin-acetone treatment slightly enhanced the mechanical strength and durability of JGT without significantly compromising its permittivity and transmissivity. Additionally, minor variations in permittivity and transmissivity suggest that the treatment preserved the material's drainage and filtration capability. This serves as an essential requirement for geotechnical applications.

The findings confirm that suitable chemical modification can improve the performance of jute geotextiles. This makes them more competitive with synthetic geotextiles in terms of strength and durability while maintaining eco-sustainability. This approach provides an environmentally responsible pathway to enhance the long-term field applicability of JGT in soil reinforcement, erosion control, and drainage-related projects. Further research focusing on field validation and long-term biodegradation under varying environmental conditions is recommended to optimize treatment parameters for large-scale geotechnical applications.

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AI DECLARATION

The authors declare that artificial intelligence (AI) tools were used only for language refinement, grammar correction, and improvement of clarity during the preparation of this manuscript. The AI assistance did not influence the research design, data collection, data analysis, interpretation of results, or scientific conclusions. All technical content, data, analyses, and interpretations are entirely the responsibility of the authors. The authors confirm that the manuscript is original, and all cited references were selected, verified, and included by the authors.

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