Physical and Mechanical Properties: Latex-coated Banaca Geotextile Net

Jonathan Bueno[1], Andrie Gonzales[1], Carl Edmund Nuñez[1], Noli Santos[1], Roselle Gonzales[2], Cristy Malasan[2]

[1]BSCE, NEUST, Cabanatuan City, Philippines

[2]Faculty, NEUST, Cabanatuan City, Philippines

***Abstract*: Banaca net has been proven to be an effective alternative geotextile blanket that mitigates soil erosion. This paper encompasses the properties and the significant influence of administering the ratio of 50% Banana fibers & 50% Abaca fibers in the production of Banaca geotextile. The Banaca nets were constructed manually. Laboratory tests were conducted to determine the corresponding tensile strength for single-twined and wide-width tensile strength of the constructed net. To assert how these ratios, influence the Banaca net. The results showed that the Banaca net with the same percentage of banana fiber and abaca fiber is stronger in terms of the average tensile strength per twine of 920N and an average lengthwise tensile strength of 15.6KN/m plus the average crosswise tensile strength of 16.4KN/m for wide width tensile strength is the best for slope protection reinforcement. The result also conveys that the Banaca net had an average water absorption of 212% which can reduce the soil saturation the most. This study proved that altering the ratios of the fiber percentage of Banaca fiber geotextile net is effective at targeting the desired performance of geotextile. The mass per unit area computation shows the three (3) results of geotextile nets with the dimension of 200mm by 200mm and a mass of 28.15g, 26.30g, and 27.5g that although the banaca fiber net possesses higher mass per unit area value, it is closely like coconet, making it possible to be made into geotextile. This means that the banaca fiber net conforms and passes the standard specifications ASTM D5261-10. Latex coating contributes to the performance of the geotextile since the banaca fiber rope and the net are coated with latex, the output becomes compact and can lessen the probability of its outer strand being damaged.**

***Keywords*: Abaca Fiber, Alkaline Treatment, Banana Fiber, Latex Paint. Natural Geotextiles.**

1. Introduction

The study was conducted to introduce improved natural fibers to develop geotextile nets with the use of latex coating material. Banana fiber has the potential to be used in the production of handicrafts, home decoration, home furnishings, and paper because banana fiber is used to make a wide range of products. Geotextiles with natural fibers are emerging as an alternative to polymeric geotextiles for temporary or non-critical structures where a shorter life cycle may be sufficient. Banana or musa fiber is a natural fiber from banana trunks that is considered as a major waste material because of problems in disposal (Saraiva et al. 2012). It is a lignocellulosic fiber, obtained from the pseudostem of a banana plant (Musa sepientum) with relatively good mechanical properties (Kiron, 2021). This kind of fiber possesses properties suited for soil erosion control when turned into a geotextile mat (Hernandez et al. 2018). Banana and abaca fiber will be the main components of the geotextile that the researchers will use. The benefits of this geotextiles are biodegradability, the ability to protect soil from splash erosion, to retain water, and to reduce water loss by evaporation. These are signs that natural geotextiles have an advantage over synthetic geotextiles for the application of slope stability. In this context, the investigation of the other possible natural fiber resources, such as banana fiber, may be carried out to minimize agro-waste left on the field, which may significantly reduce soil erosion when converted adequately to a geotextile net. Latex has the properties to sustain the rubber-like behavior with large elongation to break and low stiffness as well as tear resistance and overall resilience.

Banana is a fruit grown mainly in tropical countries of the world. After harvest, almost 60% of banana biomass is left as waste. Worldwide, about 114.08 million metric tons of banana waste-loss are produced, leading to environmental problems such as the excessive emission of greenhouse gases. These wastes contain a high content of paramount industrial importance, such as cellulose, hemicellulose and natural fibers that various processes can modify, such as bacterial fermentation and anaerobic degradation, to obtain bioplastics, organic fertilizers and biofuels such as ethanol, biogas, hydrogen and biodiesel. In addition, they can be used in wastewater treatment methods by producing low-cost biofilters and obtaining activated carbon from rachis and banana peel (Acevedo et. al., 2021).

According to C.S. Souza et. al (2019), As a natural geotextile matrix, latex was used, and, subsequently, possible applications for the geotextile were analyzed through previous material characterization based on literature. The samples were weaved and covered by latex, thereafter, analysis and verification were conducted on the main physical-chemical properties and also mechanical and thermal properties. Results were obtained through tests, such as tensile properties, flammability, thermogravimetric analysis, water and humidity absorption, moisture resistance, friction, density, weight, and biodegradation under environmental conditions. and thermal conductivity. Based on the obtained results, it was possible to conclude that geotextile can be used as a surface coating because besides its high tensile strength, even when heated, the geotextile presents a low thermal conductivity (0.214 W/mK). That fact means that the material has good thermal characteristics, the quality of an insulator. Also, it was concluded that the natural composite has combined properties from banana tree fibers (as thermal properties and mechanical strength) and from thermoplastic elastomer latex. Such a result did not compromise the hygroscopicity of the banana fiber. Finally, it could be concluded that the material is sustainable, does not damage the environment, and fulfills the coating function, as expected.

Abaca fiber, also known as Manila hemp, is a natural fiber derived from the leaf sheath of the abaca plant (Musa textilis), native to the Philippines and other regions of Southeast Asia. Abaca fiber is renowned for its exceptional strength, durability, and versatility, making it a valuable material with a wide range of applications. Abaca fiber is extracted from the leaf sheath of the abaca plant, which belongs to the banana family Musaceae. The abaca plant is primarily cultivated in the Philippines, Ecuador, Costa Rica, and other tropical regions with suitable climatic conditions. Abaca fibers have high tensile strength, which is nearly four times that of cotton fibers. (Koronis et al., 2013). Abaca fiber can be used for a variety of applications, including cordage, textiles, and specialty papers." (Espiritu et al., 2015). Abaca fiber exhibits natural water resistance and has good resistance to rot and mildew. Additionally, it is biodegradable, making it an environmentally friendly choice. (Yap, 2019).

According to Desai, A. N., & Kan, R. (2016), the concept of geotextiles as ground improvement methods is to enhance the engineering properties of soil originating from the age-old use of natural fibers. Currently, the geotextile market is dominated by synthetic polymer-based products produced by petrochemicals because they are durable and can be customized for specific applications. Unlike synthetics, natural fibers are biodegradable, annually renewable, noncarcinogenic, and therefore health friendly. The biodegradability of natural fibers has led to their use in geotechnical applications such as erosion control, soil stabilization, and soil reinforcement.

Desai, A. N. & Kant, R. said, that blending natural fibers with synthetics or using some chemical treatments or some protective coating techniques can ensure the designed biodegradability of these natural geotextile materials for use in short to medium-term applications. Government and private industry have been working to revive the once-booming demand for natural fibers. Marginal farmers earn a living from natural fibers and the natural fiber industry employs a large number of individuals throughout the world, especially in developing countries. By choosing natural fibers, we can contribute to the economies of developing countries and help fight hunger and rural poverty.

According to Wu, H., Yao, C., Li, C., Miao, M., Zhong, Y., Lu, Y., & Liu, T. (2020), geotextiles are the most widely use geosynthetics. They are products made of synthetic or natural polymeric materials, which are used in contact with soil or rock and/or other geotechnical materials and mainly include geotextile, geogrid, geocell, geonet, geomembrane, erosion control mat, geosynthetic clay liner, and geo-composite. The first reported employment of geotextiles can be considered to be the nylon bags filled with sand used in the Dutch Delta Works in 1956. In the last 60 years, geotextiles have been widely used in geotechnical engineering which can be used for at least one of the following functions in geotechnical engineering: Separation, filtration, drainage, reinforcement, stabilization, barrier, and erosion protection.

At present, 1.4 billion square meters of geotextiles are used every year, and the trend is on the rise. About 98% of geotextiles consist of non-degradable polymers from the polyolefin, polyester, or polyamide family. The long-term use of geotextiles, because of quite a few environmental factors, such as wind, moisture, friction, and ultraviolet radiation, may cause the disintegration of synthetic polymer, resulting in the accumulation of microplastics in the surrounding environment. In addition, the application of geotextiles in geotechnical engineering may encounter complex environmental conditions, such as complex acid-base conditions, but then the performance requirements of geotextiles will be higher (Wu, et.al. 2020).

A complete characterization of the mechanical properties of acrylic-based latex blend coatings comprising hard ($T_g = 45°C$) and soft ($T_g = -5°C$) phases is presented. Although clear and transparent in appearance, these blends remain phase-separated through the entire range of compositions based on their hard phase content. Blends with less than 50% hard phase (soft blends) show a typical rubber-like behavior with large elongation to break and low stiffness, whereas those with more than 50% hard phase (hard blends) exhibit a progressively glassy behavior. The values of effective Young's moduli and Poisson's ratios lie within the bounds calculated from Hashin-Shtrikman models and exhibit a sigmoidal-shaped profile as a function of composition, in close agreement with the solutions of Hill-Budiansky equations. These results, along with interpretations based on a percolation theory, indicate that a phase inversion to a continuous hard matrix from the soft one occurs around 30%–40% hard phase content, a conclusion further supported by scanning electron micrographs of the fracture surfaces (Agarwal, N., & Farris, R. J.).

According to Raghavendra, S. et.al., Natural fibers reinforced bio-degradable composites are a good alternative to conventional materials. Natural fibers are cheaper, environmentally friendly, and biodegradable. In the present work, composites are made using short Banana fibers and natural rubber. Composites obtained were determined for mechanical properties like tensile strength, and tear strength were studied. The effect of different lengths of fiber content with natural rubber was determined and the matrix fiber interface was studied using SEM.

2. Guidelines

A. Research Design

In this study on the performance of banaca fiber as a geotextile, the researcher will use experimental design in gathering the data needed. This study entitled “Physical and Mechanical Properties: Latex-Coated Banaca Geotextile Nets” is quantitative. The chosen research design will be administered as it is seen as most suitable for acquiring needed data to complete the study. Additionally, this type of research design ensures a more accurate result.

Experimental research is a type of study that strictly adheres to a scientific research design. It revolves around a variable or group of variables that can be manipulated, measured, calculated, and compared by the researcher. It also includes a hypothesis and is completed in a controlled environment. In this type of research, the researcher collects data and the results that come out of these data will either support or reject the hypothesis. On the other hand, quantitative research is a type of data-gathering technique that deals with numerical data and an objective stance.

B. Locale of the Study

Banana fiber extraction, alkali treatment, and liquid latex application took place at Jaen, Nueva Ecija. This location was chosen by the researchers because it has enough supply of bananas, to extract the required amount of fiber for the study.

The geotextile nets and rope will be woven at Jaen, Nueva Ecija, and will be sent to the DOST-Philippine Textile Research Institute (DOST-PTRI) for laboratory testing. The textile samples from the beginning of the experimentation will be brought to the DOST-Philippine Textile Research Institute (DOST-PTRI) in Taguig, Metro Manila for laboratory testing.

C. Research Instrument

In this study, the collection of data is based on laboratory tests. Laboratory tests will be sufficient in identifying the properties of banaca fiber as geotextile nets. The geotextile samples will be tested and observed based on their water absorption, mass per unit area, and wide-width tensile strength. Laboratory tests will conform to the ASTM standards.

D. Data Gathering

The collection of data needed is gathered through laboratory tests. In this study, the researcher will assess the properties of banaca fiber (latex coated and not coated) based on their water absorption, mass per unit area, and tensile strength for its single strand, twined, and geotextile nets form. The researcher will follow a step-by-step procedure to collect the needed data.

E. Preparation of Materials

Banana trees will be collected from Jaen, Nueva Ecija. The banana fiber will be extracted and made into a rope fiber having 5mm to10mm diameter conforming to Item 518 of the DPWH standard specifications to be made into a 1 x 2-meter woven geotextile. On the other hand, abaca fiber will be acquired through online stores. Twined specimens and a 1 x 2-meter geotextile mat will be sent to DOST-PTRI for laboratory testing. Detailed steps are listed below:

- Banana Fiber Extraction Process
- Purchasing of Abaca Fibers
- Geotextile making
- Laboratory Testing

F. Data Analysis and Technique

The data collected will be tabulated and will adopt simple statistical analyses using Mean, Standard Deviation, and Coefficient of Variation. Based on the ASTM Standard Test Methods, the average of the majority of test results will give the corresponding properties needed to assess the performance of the net samples- banaca fiber net.

Additionally, the following are the test procedures that will be used based on ASTM.

1. Mass per Unit Area (ASTM D5261-10)
2. Determination of Water Absorption Capacity
3. Tensile Strength (Twine) ASTM D2256
4. Tensile Test by Wide-Width Strip Method (ASTM D4595)

Table 1
Standard specifications for coco-net

Properties		**Coconet 400**	**Coconet 700**	**Coconet 900**
Thickness, mm			10.0 Min.	
Width, m			1.0 Min.	
Length, m			25.0 Min.	
Unit Weight, 1 g/m^2		400±25	700±35	900±45
Diameter of Twined, mm Hand Spun			5.00 mm + 0.50 mm	
No. of Twines/m	Crosswise Direction	40 Min.	40 Min.	70 Min.
	Lengthwise Direction	40 Min.	70 Min.	70 Min.
Material		Woven Netting made from High Strength 100% Coconut fiber twine		
Color		Natural Earth Tone		
Tensile Strength, N/twine		150 Min.		
Elongation	(Machine Direction) %	26 Min.	34 Min.	42 Min.
	(Cross-Machine Direction) %	32 Min.	38 Min.	32 Min.
“C” Factor		0.002		
Water Velocity, m/sec		2.7 Min.	3.35 Min.	4.26 Min.
Water Absorption, %		163 Min.	146 Min.	132 Min.
Slope Inclination, H : V		≤ 1:1	1:1 to 60^o	75^o

3. Experimental Results

Table 2
Latex coated banaca net mass per unit result

Sample No.	Unit Area (m^2)	Mass (g)	Mass per Unit Area g/m^2
1	0.04	28.15	703.75
2	0.04	26.30	657.5
3	0.04	27.5	687.5

Table 3
Banaca net mass per unit result

Sample No.	Unit Area (m^2)	Mass (g)	Mass per Unit Area g/m^2
1	0.04	22.13	489.74
2	0.04	23.72	562.64
3	0.04	22.86	687.5

Table 4
Latex coated banaca fiber net water absorption result

Sample No.	Area (m^2)	(a) W_{dry} (g)	(b) Wpan+Wscreen (g)	(c) WT (g)	Weight of absorbed water $W_w = c - \sum a+b$	Absorption Capacity W_w/W_{dry}
1	0.0225	10	160	190	20	2
2	0.0225	10	160	192	22	2.2
3	0.0225	13	160	201	28	2.15

Table 4
Uncoated banaca fiber net water absorption result

Sample No.	Area (m^2)	(a) W_{dry} (g)	(b) Wpan+Wscreen (g)	(c) WT (g)	Weight of absorbed water $W_w = c - \sum a+b$	Absorption Capacity W_w/W_{dry}
1	0.0225	7	160	187	20	2.86
2	0.0225	8	160	191	23	2.875
3	0.0225	13	160	210	37	2.85

Table 5
Twined latex coated banaca fiber test results

Sample No.	F_H	ε_H	F_β	ε_β	t_{Test}
	N	%	N	%	s
1	434	7.8	291	8.0	25.54
2	713	9.6	622	9.8	19.91
3	618	11.8	610	11.8	24.16
4	932	12.6	642	12.8	25.92
5	1050	15.0	713	15.2	23.28
6	785	14.6	629	14.8	22.69
7	920	12.0	830	12.2	18.75
8	941	13.2	770	13.2	20.44
9	705	12.8	487	12.8	19.78
10	912	13.0	721	13.0	19.94
11	673	10.6	467	10.8	16.66
12	931	10.6	891	10.8	16.75
13	1230	11.6	1180	11.6	17.95
14	1640	11.8	1310	11.8	18.39
15	1310	14.4	882	14.6	22.29

Table 6
Uncoated twined banaca fiber test results

Sample No.	F_H	ε_H	F_β	ε_β
	N	%	N	%
1	358.55	14.8	277.86	15.0
2	596.49	18.4	484.92	19.0
3	423.65	11.8	287.08	12.2
4	477.50	12.6	426.78	12.8
5	696.17	18.2	662.40	18.4
6	606.51	17.4	520.03	17.4
7	749.29	15.4	517.25	15.8
8	720.48	15.0	597.15	16.2
9	388.08	13.2	373.88	13.2
10	336.74	8.4	263.85	8.4
11	800.05	12.6	556.31	12.8
12	373.06	9.6	328.92	10.2
13	516.96	10.8	476.98	10.8
14	521.08	13.0	354.71	13.2
15	355.46	7.2	336.50	7.2

Table 7
Latex coated banaca fiber Wide-Width test result

	F_f lengthwise	F_f crosswise	Tensile Strength, MD	Tensile Strength, CMD	Elongation @max force, MD	Elongation @max force, CMD
N_r	N	N	kN/m	kN/m	%	%
1	4881.99	-	24.4	-	13.2	-
2	2794.15	-	14.0	-	13.1	-
3	2625.45	-	13.1	-	12.1	-
4	2293.01	-	11.5	-	13.1	-
5	1580.61	-	12.9	-	13.0	-
6	3552.25	-	17.8	-	12.0	-
7	-	2813.27	-	14.1	-	11.6
8	-	2981.76	-	14.9	-	9.9
9	-	3329.18	-	16.6	-	10.0
10	-	3947.97	-	19.7	-	15.0
11	-	3612.88	-	18.1	-	12.6
12	-	2967.01	-	14.8	-	12.5

Table 8
Statistics of latex coated banaca fiber net test result

Series	F_f lengthwise	F_f crosswise	Tensile Strength, MD	Tensile Strength, CMD	Elongation @max force, MD	Elongation @max force, CMD
N=12	N	N	kN/m	kN/m	%	%
x̄	3121.25	3275.34	15.6	16.4	12.6	11.9
s	960.94	439.10	4.8	2.2	0.9	1.9
v	30.79	13.41	30.79	13.41	6.87	15.85

Table 9
Uncoated banaca fiber test results

	F_f lengthwise	Tensile Strength, MD	Elongation @max force, MD
N_r	N	N	kN/m
1	1467.5077	7.34	13.73
2	1160.7186	5.80	24.91
3	1683.0249	8.42	19.18
4	1527.8700	7.64	17.75
5	2172.6213	10.86	22.83
6	1646.6354	8.23	12.08
7	2644.7625	13.22	24.67
8	952.0781	4.76	16.24
9	1495.0109	7.48	21.24
10	1738.8846	8.69	17.66
11	1091.6863	5.46	18.15
12	1469.9703	7.35	18.46

Table 10
Statistics of uncoated banaca fiber test result

Series	F_f lengthwise	Tensile Strength, MD	Elongation @max force, MD
N=12	N	N	kN/m
x̄	1587.5642	7.94	18.91
s	463.9520	2.32	3.98
v	29.22	29.22	21.05

Fig. 1. The preparation to extract the fiber from the banana trunk

Fig. 2. Banana fiber extraction process

Fig. 3. Geotextile making

Fig. 4. Finished product latex-coated banaca geotextile rope

Fig. 5. Finished product latex-coated banaca geotextile net

Fig. 6. Twined fiber tensile strength test (ASTM D2256)

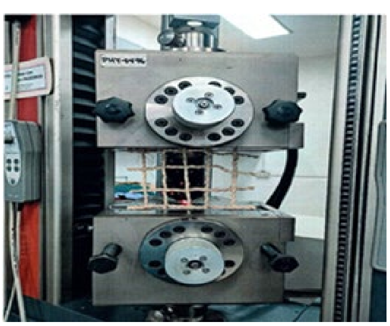

Fig. 7. Wide-Width method tensile strength test (ASTM D 4595)

4. Conclusion

The findings of this study confirm that the Banaca net, composed of equal parts banana and abaca fibers, is a promising geotextile material for erosion control and slope protection. The manually fabricated net demonstrated excellent mechanical properties, including high single-twined and wide-width tensile strengths, meeting and even surpassing typical geotextile performance benchmarks. Its impressive water absorption capacity further supports its function in reducing soil saturation, a key factor in preventing erosion. The mass per unit area values are comparable to established products like coconet, suggesting that Banaca nets can be a practical and sustainable alternative. Moreover, the application of latex coating notably improved the net's structural integrity and resistance to damage. This study highlights the effectiveness of optimizing fiber ratios to achieve desirable geotextile characteristics and provides a foundation for further development of natural fiber-based erosion control solutions. The use of abundant agricultural by-products like banana and abaca fibers not only offers an environmentally friendly option but also adds value to local resources. Overall, Banaca net presents itself as a durable, efficient, and sustainable geotextile solution suitable for various environmental engineering applications.

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