Development of a geotextile coated with latex and used as a protection element on heated surfaces

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Abstract. A lot has been researched today about new energy resources and sustainable materials aiming to decrease the impacts caused on the environment. Materials waste that were previously destined for the trash, are now seen in a different way. This present paper had as purpose the confection of a geotextile using banana tree leaves, in particular, fibers extracted from the stem of the banana tree leaves, which presently, are recognized as one of the strongest cellulosic fibers. As a natural geotextile matrix, latex was used and, subsequently, possible applications for the geotextile were analysed 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. Such results were obtained through tests, as: tensile properties, flammability, thermogravimetric analysis, water and humidity absorption, moisture resistance, friction, density, weight, biodegradation under environmental conditions, and thermal conductivity. Based on the obtained results, it was possible to conclude that geotextile can be used as surfaces coating, because beside 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, quality of an insulator. Also, it was conclude that the natural composite has combined properties from banana tree fibers (as thermal properties and mechanical strength) and from thermoplastic elastomer latex. Such 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 fulfil the coating function, as expected.

1. Introduction

A lot has been researched today about new energy resources and sustainable materials aiming to decrease the impacts caused on the environment.

Based on this new sustainable view, we aimed to change how natural geotextile are made, using materials from natural fibers and used in association with soil. These products are being manufactured using textile fibers or using a hybrid combination with synthetic fibers in its manufacture.

According to Raghavendra et al [1], sustainable materials made from natural fibers are renewable, have a low cost, they are partially or completely biodegradable materials, and also according to Ramesh et al [2], fibers are abrasive, they have a good net calorific value, excellent mechanical properties, low density and they are ecological materials. Fibers containing rich amounts of ligno-celluose such as banana, sisal, bamboo etc. are frequently used as a reinforcement in composites or geotextiles. The geotextile longevity is dependent upon the amount of cellulose and lignin on the fiber, therefore, its chemical composition is extremely important.

The possibility to utilize the waste disposed on plantations, emanating from banana fruit farming...
(banana trees leaves) to provide the basis to manufacture a natural geotextile has motivated this research.

A natural elastomer matrix, latex, was used. Derived from *Hevea Brasiliensis* tree, which brazilian production is approximately 90,000 ton/year and whose characteristics are low humidity absorption, high elasticity and biodegradability [3].

The geotextile manufacturing process using the reject from the banana tree as raw material, aim to recycle considering the social, economical and environmental aspects and, as a consequence, it contributes to an environmental preservation global policy.

2. Methodology

To create the geotextile, banana fibers from banana tree leaves were used as a reinforcement. And, to complete the biotextile, natural rubber latex pre vulcanized as an agglomerating agent. The fibers were peeled from the central Pseudopeciolo (stem) from the banana tree leaf (figure 1). The fibers presented from 1.0 to 4.0 meters length and an average diameter of 1.32 millimeters.

![Figure 1. Banana tree leaf divided in 1) Leaf; 2) Leaf central vein; 3) Petioles of the leaf. The natural rubber latex used was pre vulcanized. A is the length of the fiber after being cut from the tree.](image)

To manufacture the geotextile, banana tree leaves were cut from the trees, using a knife and, only cutting only the old leaves. The leaves had been cut on the Petioles to respect the length of the fiber, figure 1.

After the cut, the green surfaces of the leaf, both left and right (figure 1B), were removed, remaining only the central vein of the leaf, where all the fibers were manually extracted. Once the fibers had been removed from the leaf, all the fibers were placed on a marble table aiming to dry the plant’s sap. The drying process occurred in a climate-controlled environment that provided a room temperature of (25±3)°C and humidity 60%.

After a 12-hour period, the leaves had dried and they were cut. All fibers cut in 30 centimeters long for later characterization.

The analysis for fiber and geotextile fabric were conducted in University Federal do Rio Grande do Norte. First, banana fibers without a latex cover were analyzed and, subsequently, after the latex cover. The tests were also conducted with the geotextiles (with and without latex), the tests were: tensile tests of textiles and yarns (strength), Thermogravimetric analysis (TG) and used scanning electron microscopy (SEM).

Aiming to produce a fabric made from vegetable fibers, a manual weaver’s loom (25 centimeters x 25 centimeters) was used (figure 2). The yarns disposed as weft and warp, where the weft fibers were
stronger than the warp fibers that were more malleable, fitting better the weaving process.

Figure 2. Manual weaver's loom.

Manual weaving process lasted on average only five hours. After the process of manufacture of thread and fabric, we removed the tip waste and the base for the geotextile was now concluded (figure 3).

Figure 3. Steps of the process of manufacture of thread and fabric to create the geotextile. (a) Weft, (b) Weft and Warp, (c) Fabric, geotextile base.
The geotextile fabric consisted of a banana fiber fabric linked by a prevulcanized natural latex. Matrix and reinforcement combination took place in a glass container, figure 4, 18 cm wide x 6 cm deep. The recent weaved fabric on the bottom of the container, received a latex bath. The process also used a brush to facilitate its appliance. All curing process lasted average only four hours and, at the end of the process, a biotextile, 25 cm² and approx. 0.3 cm thick.

![Fabric in a latex bath](a) ![Geotextile](b)

**Figure 4.** (a) Fabric in a latex bath and (b) geotextile.

As the main goal of this project was an easy replication and a sustainable geotextile, the substrate received a simple and easy replication coating. For the same reason, in natural fibers have not undergone to any cleaning processes or even have received any chemical component. This also proved that without a special fiber treatment, fibers showed a good bond interaction with latex.

For characterization of the geotextile comparative tests have been made with fabrics, with latex and without latex, to have a better overview of the geotextile qualities and defaults. The tests also took place in University Federal do Rio Grande do Norte. The tests were also: tensile tests of textiles and yarns (strength), Thermogravimetric analysis (TG) and used scanning electron microscopy (SEM), flammability, the absorption of humidity, density (number of hairs per cm²), abrasion-resistant, environmental degradation, solar exposure, thermal conductivity.

2.1. **Tensile tests of textiles and yarns (strength)**
All tensile properties tests were performed in University Federal do Rio Grande do Norte at Textile Engineering Laboratory (LabCTex DET/UFRN) using a Tensolab 300 Mesdan. Analysis were carried out according to the technical standard ASTM D5034.

Four samples were cut in 15 centimeters length and 5 centimeters wide. All analysis were carried out under a 15 N/s.

2.2. **Thermogravimetric analysis (TG)**
All analysis were carried out in University Federal do Rio Grande do Norte at NUPEG (Oil and Gas Laboratory), using the equipment Netzsch STA 449F3. All the tests used the manufacturer-specific (proprietary) standard.

Samples (in natural and covered in latex) were cut in 1.5 centimeters length and tested as they were heated until 650°C.

2.3. **Scanning electron microscopy (SEM)**
Aiming a physical characterization of the banana leaf fiber, in natural samples and latex covered samples were cut in 1.2 centimeters length and enlarged from 50 to 100 times on the Hitachi TM3000 Microscope.
All tests were conducted in University Federal do Rio Grande do Norte at DEMAT (Materials Laboratory).

2.4. Flammability
As TG test, flammability analysis took place in NUPEG according to technical standard UL 94 (2013), item 7. Tests were conducted using 3 samples of geotextile and 3 samples of in natural fabric, both 15 centimeters length and 3 centimeters wide.

As the technical standard required, all samples burned for 30 seconds.

2.5. Humidity absorption
According to the manufacturer-specific (proprietary) standard, all samples were cut in a circular shape (in natural samples 1.0 grams and latex samples 3.9 grams) and then, heated until 110.5°C.

All tests were conducted in University Federal do Rio Grande do Norte at Laboratory of fluid mechanics using an ID-200.

2.6. Density
The test conducted in University Federal do Rio Grande do Norte at Textile Engineering Laboratory (LabCTex DET/UFRN) using a very simple thread counter. Analysis were carried out according to the technical standard ASTM D3801/ ISO 2060 (2015).

2.7. Abrasion-resistant
Also at Textile Engineering Laboratory (LabCTex DET/UFRN), analysis were carried out using a Crock Meter able to run 2000 cycles.

The samples used were geotextiles able to stand the endurance test.

2.8. Environmental degradation and solar exposure
According to technical standard EPA 9090A, all samples (in natural fabric and geotextile) were buried in a simulated ground for 2280 hours.

The simulated ground was divided in 23% clayey loam, 23% organic material (manure), 23% sand and 31% distilled water (mass).

2.9. Thermal conductivity
Using a conductive meter KD2 Pro at Laboratory of fluid mechanics, analysis were carried out.

Samples (in natural and covered in latex) were created in a cylindrical shape (50 millimeters thick x 190 millimeters high) and, using the KD2, all sides of the cylinder were tested.

3. Results
Each study followed the technical standard requirement which refers to every analysis, therefore, humidity, temperature and other parameters might vary according to the Standards specifications.

3.1. Fiber
The first test conducted on the fibers was scanning electron microscopy (SEM). SEM characterization of the fibers aimed to identify the physical characteristics of the fibers before and after receiving the latex bath and, subsequently, to support the analysis of the geotextile behavior based on its properties, figure 5.

It may be noticed, figure 5, that the banana tree leaf fiber presented a unique microstructure with high porosity due to its natural vegetable fiber characteristic. High amounts of cellulose linked to hemicellulose walls provided to the fiber a large quantity of fibrils. That explains the high level capacity of absorption of humidity and liquids in general, or high hygroscopicity. When covered in latex, it is not evident such characteristic, figure 6.
Figure 5. SEM from a banana tree leaf recently removed from the central vein of the leaf. View from the top and lateral view.

Figure 6. Banana tree leaf fiber covered by latex. View from the top and lateral view.

Figure 7. TGA graphs for fibers a) without latex, b) covered by latex.

Next test made looked for establish the relation between mass loss and heat. That relation could be obtained from continuous measurements of weight in function of temperature along time using thermogravimetric analysis (TGA).

The fibers behavior (with latex and no latex) showed differences between each of them, even though they have the same composition underneath. That is explained by the fact that latex covered up
all the small fibrils which covered the fiber. Having no elastic, coating, a considerable mass loss happened due to a higher amount of short fibers and fibers on the fiber surface.

Because of the coating on fibers surface, latex filled up all the empty spaces previously filled by air, therefore, there was less mass loss, figure 7(b).

It could be concluded that latex provided to the natural fiber, a higher stability and resistance to mass variation during the heating.

3.2. Geotextile

The tests were conducted for both fabrics, with and with no latex. As mentioned, all analyzes had the same purpose, which was test the resistance to heat, tearing and traction (tensile strength).

The first test aimed to verify the tensile strength. Geotextiles showed a better and longer resistance, such as more elongation at break and a higher tensile strength than the fabric without the latex coat, since, they received a latex cover as a matrix, they also were weaved as a warp and weft combination as a reinforcement, figure 8.

![Figure 8. Graph showing 4 samples of Geotextile coated by latex.](image)

In regards to Flammability, it became evident that the behavior observed during previously thermogravimetric analysis (TGA) was attested, which means, latex substrates burned faster than the substrates with in natural fibers. This is due to latex highly flammable characteristics.

With respect to the textiles properties, it became apparent that the geotextile presented a high resistance to abrasion since the material resisted to 380 of the 2000 cycles by the Taber Abraser. The test stopped only because the test tissue tear. In terms of density, the measurement, made by a thread counter, was considered high, being 4 thread/cm². As for a conventional fabric, this density is considered high because of natural porosity of fabrics, but as a geotextile material, it was considered acceptable and an important characteristic which permits heat exchange with the environment.

The procedure related to humidity absorption was conducted using a Moisture Test ID-200, in accordance with the manufacturer's technical specifications. As they were introduced in ID-200, all samples were exposed to high temperatures rising until 110°C and, after the analyzes, they showed different results. It was possible to identify that, after all the heating process, the natural fibers samples presented a capacity of absorbing humidity equal to 12.8%. While latex samples did not show the same capacity, absorbing only a 3.5% of humidity. It occurs due to latex treatment. Receiving latex bath as a plastic matrix, reduces the capacity of absorb air humidity, becoming less hygroscopic. Latex
filled all of the empty pores, cellulosic fibers characteristics (SEM), upon the fibers, that prevented fibers fibrils to absorb the right amount of moisture without buildup.

In a similar way, water absorption test showed that in natural fabric absorbed more distilled water prior than the geotextile fabric, table 1.

| Table 1. Values for water absorption for in natura fabric and geotextile. |
|--------------------------|-------------------|-------------------|-------------------|
| In Natura Fabric         | Dry Weight        | Humid Weight      | Weight Gain %     |
| Sample 1                 | 0.21g             | 1.53g             | 628.57%           |
| Sample 2                 | 0.23g             | 1.58g             | 586.96%           |
| Sample 3                 | 0.24g             | 1.49g             | 520.83%           |
| Geotextile               | Dry Weight        | Humid Weight      | Weight Gain %     |
| Sample 1                 | 1.48g             | 3.26g             | 120.27%           |
| Sample 2                 | 1.46g             | 2.64g             | 80.82%            |
| Sample 3                 | 1.45g             | 2.61g             | 80%               |

There was a large increase in weight when considering both samples, however a larger increase value could be observed on in natural samples, table 1. This happened due to the fact that in natural fabric had no alterations to its physical or chemical composition. The same is not true about the geotextile which absorbed 93% of its original weight. Even having changes in characteristic of the fiber, the geotextile as still considered a hygroscopic material.

In accordance to what has been already proved, the geotextile absorbed a large amount of water. This fact propitiated a higher interaction with the soil and the environment where the sample was exposed. It was evidenced by the fact that those samples, in natural fabric and geotextile, were completely buried in the ground for 120 days.

The samples were completely degraded in the natural environment. Similarly, latex composites presented a partial decomposition, figure 9.

![Figure 9. Latex specimen partially degraded after 120 days buried.](image)

Something similar happened when the specimens were degraded by the surrounding environment. The samples interacted very slowly in the environment and accumulated in their bodies: insects, leaves, sand, etc. Once more, latex has proved to increase samples useful life. Thermoplastic elastomer provided resistance to the environment’s degradation, increasing the geotextile quality.

Finally, thermal properties analysis were conducted aiming to check samples measurements for: conductivity, specific heat and thermal diffusivity. Analysis were performed on superior, inferior and lateral sides of both cylindrical specimens, in natural and reinforced by latex.

According to Wang [4] a composite is a thermal insulator when $K < 0.25$ W/mK. As seen in table 2, it can be evidenced that in natural sample is an insulating substrate. After being covered by latex, the
substrate loses its insulating capability, however, $K$ remains lower than 0.25 W/mK.

Table 2. Average Measurements of both cylindrical specimens, in natural and reinforced by latex.

| Average Measure | $K$ Thermal Condutivity (W/mK) | $C_p$ Specific Heat (J/m³K) | $\alpha$ Thermal Diffusivity (mm²/s) |
|-----------------|--------------------------------|-----------------------------|-------------------------------------|
| No Latex        | 0.146                          | 7816.67                     | 0.188                               |
| Latex           | 0.214                          | 1379.2                      | 0.154                               |

Inserting latex to fill empty pores on the fabric surface, has led to an increase over thermal conductivity measurement values. It can be said that lower than 0.25 W/mK is acceptable for an insulating composite, therefore, geotextile showed lower values, that proves it can be used as an insulating material.

As regards the specific heat, according to Callister, 2005, specific heat of polymers can vary between 1300 and 2000 J/m³K, which relates to the results obtained.

Knowing that, as latex filled the pores on the fibers, what increases density because all the air of empty pores and spaces were fulfilled by a heavy material. Although, this procedure has not changed significantly the thermal difusivity values. This can all be seen in table 2 ($\alpha$ 0.154 mm²/s), in other words, insulating materials characteristics [5].

References

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