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Elaboration of a Composite Material Based on Fabrics Waste and Polystyrenes: Effect of Polystyrene Resin on the Strengths of the Composite

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Abstract This study consists in proposing a recycling method for sewing fabrics and polystyrene waste. One way of valorization such waste is through its use as a new raw material resource in materials. The objective of this work is the development of new materials based on sewing fabrics waste and expanded polystyrene. For the elaboration of the samples, two types of fabrics, LFNF (loincloth fabrics based on natural fibers) and LFSF (loincloth fabrics based on synthetic fiber) were selected because they are the most accessible. The samples were made by varying the rate of fabric and expanded polystyrene (EPS). Tests were made on these samples to determine their physical (density and absorption) and mechanical (wear resistance and three-point bending strength) properties. The results obtained showed that the density of two types of composites decrease with increasing rate of EPS. Water absorption also decreases from 5.12% to 1.15% for MLFSF (materials with loincloth fabrics based synthetic fiber) and from 15.02% to 2.68% for MLFNF (materials with loincloth fabrics based natural fiber) with an increase in the PSE resin content. Finally, the bending strength increases from 3.23 MPa to 4.53 MPa for the MLTSF and from 3.01 MPa to 4.32 MPa for the MLTNF with a variation in the rate of the EPS resin ranging from 60 to 80%. Wear strength also decreases with increasing resin. The use of EPS as a binder in composites gives it encouraging physical and mechanical properties. The use of EPS and fabrics waste as a new raw material resource in manufacturing of new materials is therefore a way of recovering this waste.

Keywords Sewing fabrics, Waste, Expanded polystyrene, Valorization, Composite

1. Introduction

The proliferation of industrial waste such as sewing and polystyrene waste contributes enormously to environmental pollution. It is therefore necessary to recover this waste by considering it as a new raw material resource in manufacturing of new materials in order to reduce the use of natural raw material. The valorization of this waste could constitute an interesting environmental and economic alternative, by eliminating it from cumbersome and polluting landfills. The literature mentions that there are several ways of recovering polystyrene waste through several production methods [1-4]. Similarly, the recycling of fabrics waste is the subject of several studies [5-7]. It is with this in mind that a recycling method including these two types of waste was initiated.

The general objective of this work is then to develop new materials using expanded polystyrene (EPS) in the form of resin as a binder and sewing fabric waste as reinforcement.

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2. Materials and Method

2.1. Raw Materials

2.1.1. Expanded Polystyrene

Figure 1. Expanded polystyrene waste

The polymer used for the development of the matrix is recycled expanded polystyrene shows in Figure 1. It comes from the recovery of packaging material and other plastic products collected throughout the city of Abidjan. It represents a significant quantity left behind in our environment.

2.1.2. Sewing Fabrics Waste

Sewing tissue waste is generally leftover fabric discarded after being used by different fashion designer. This tissue waste is mainly made up of natural and synthetic fibers.

Among these fabrics the choice fell on loincloths because they are the most used and the most rejected in our environment. The fabrics waste shows in Figure 2a used for this study comes from the various sewing workshops in the city of Abidjan. This waste is sorted, classified by constituent, and then shredded into small pieces (Figure 2b and 2c) in order to facilitate the homogeneity of the fabrics-resin mixture.

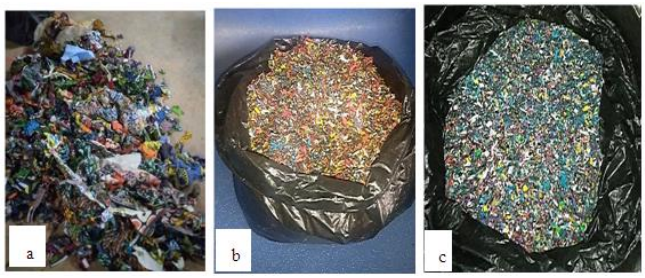

Figure 2. Sewing fabrics waste; (a) fabrics bulk, (b) synthetic fiber fabrics shredded; (c) natural fiber fabrics shredded

2.2. Experimental Method

2.2.1. Polystyrene Resin Production Method

Expanded polystyrene at the end of its life is recycled and used as a binder for making composites. For this study, a solvent (acetone) was used to melt the expanded polystyrene. During the elaboration of this resin (Figure 3) one liter (1l) of acetone was used to melt 0.7 kg of polystyrene.

Figure 3. Expanded polystyrene (EPS) resin

2.2.2. Formulation and Elaboration

For manufacturing of the materials, the pieces of fabrics and the polystyrene resin were mixed according to the variable mass proportions. The quantity of EPS used for the elaboration of the materials varies between 60% and 80% with an increment of 10. It should be noted that it is from 60% PSE resin that consolidated samples are obtained. After mixing (EPS resin and fabrics) in a container, the assembly is introduced into an extruder for mixing for 3 minutes.

For the shaping of the samples, the mixture obtained is introduced into the mold of a static manual press and then compressed. After compaction, the samples are removed from the mold and then dried. After drying, the samples are then subjected to thermoforming. Thermoforming is a process that consists of softening the sample by put it in an electric oven at a temperature of 230°C for 30 min. The sample, once flexible and malleable, is introduced into the mold of the static manual press and then compressed. After compression, the final material is obtained. The methodology adopted for the elaboration of materials is summarized on the Figure 4.

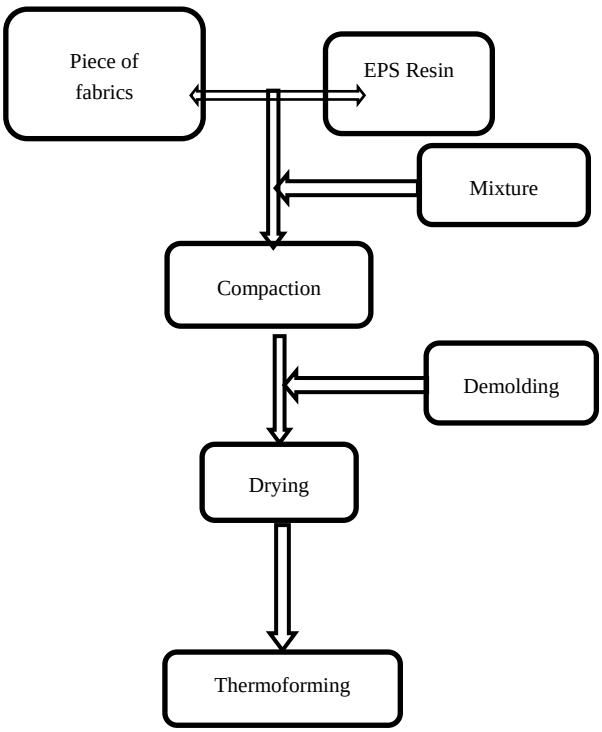

Figure 4. Diagram of sample development procedure

The samples obtained are shown in Figure 5.

Figure 5. Picture of samples obtained

2.3. Characterizations of the Samples Produced

2.3.1. Physical Characterizations

2.3.1.1. Density

After thermoforming, the samples are weighed. The different dimensions (length, width and thickness) are measured. From the dimensions, the volume of the samples is calculated, then the density is obtained by the Equation (1).

$$\rho = \frac{M}{V} \quad (1)$$

Where $\boldsymbol{\rho}$ is the density in (g/cm^3); M is the mass of the sample in (g); V its volume (cm^3).

2.3.1.2. Water Absorption Test

The penetration of water into a material is done by absorption. This absorption influences the durability of the material and is responsible for several damages. There are several types of absorption test. The immersion absorption test carried out during this study is determined according to the directives of standard NBN B 15-215:1989 [8]. After thermoforming the samples are weighed (ms). Then the samples are immersed in water for 24 hours and then weighed again (mh). The water absorption by immersion expressed as a percentage is obtained by the Equation (2).

$$Abs = \frac{mh-ms}{ms} \times 100 \quad (2)$$

Where: Abs is the absorption (%), mh is the wet mass after immersion (g), ms is the dry mass (g).

2.3.2. Mechanical Characterization of Samples

2.3.2.1. Bending Strength

The mechanical strength of building materials is one of the most important properties for their use. The bending test was carried out according to standard NF B 51-008 [9] on samples measuring 150 x 100.8 x 10.5 mm^3. The three (3) point bending strength is expressed in MPa or N/mm^2 and is given by the Equation (3).

$$Rf = \frac{3FL}{2be^2} \quad (3)$$

Where F: the load measured at break (N), L: the distance between the two support points (mm), b: the width of the specimen (mm), e: thickness of the specimen (mm).

2.3.2.2. Wear Test

The hardness of an object is its ability to scratch another object or to be scratched by it. Surface hardness makes it possible to know the durability of a material, to estimate the importance of some types of alteration and to appreciate the ability of materials to resist surface abrasion. The wear test characterizes the abrasion resistance of the faces of the samples. For this, samples with different contents of tissue residue and EPS resin are subjected to mechanical erosion applied by friction using a metal brush. To measure wear, we used the device shows on Figure 6, produced by the Geomaterials team [10].

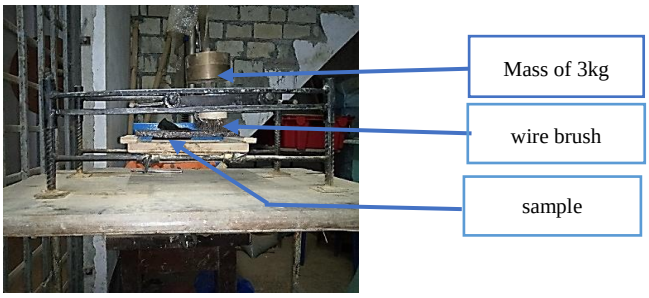

Figure 6. Wear measuring device

The device consists of a small trolley resting on four wheels, below which is fixed a wire brush. The carriage is mounted on two rails which fit together at both ends. The device is fixed to the support through the metal rods. The wheels have a translation movement along the metal rods. The trolley is loaded with a mass of 3 kg. A wrist is used to pull the trolley which moves on the wheels.

The wear of the sample is characterized by the loss of mass after 25 application cycles on one of the faces. The wear is given by the Equation (4).

$$U = \frac{m1-m2}{S} \times 100 \quad (4)$$

Where: m1 is the mass before brushing in (g); m2 is the mass after brushing in (g) and S is the brushed area (cm^2).

3. Results and Discussion

3.1. Influence of Polystyrene Resin on Density

Figure 7 shows the density variation as a function of EPS resin content.

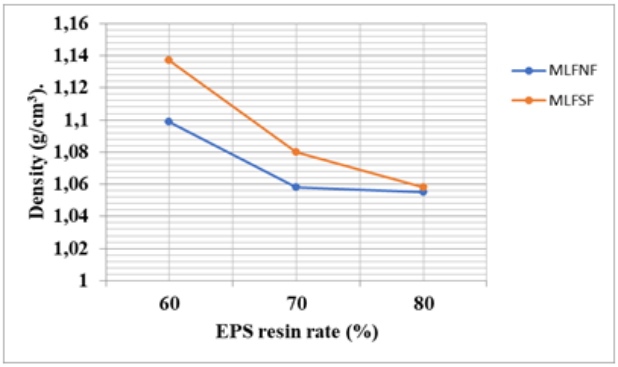

Figure 7. Density variation function resin content of EPS.

This figure shows that the density of the samples decreases with the increase in the content of EPS resin (from 60 to 80%). Densities decrease from 1.137 to 1.058 g/cm^3 for MLFSF and from 1.099 to 1.055 g/cm^3 for MLFNF. This decrease of the materials density is due to an increase in the content of EPS resin in the mixture. Indeed, the density of the materials will tend towards that of the binder (EPS) which has a low density (0.77 g/cm^3). Similar results were obtained by Benoit [11] during these studies on composite materials based on hemp fibers and LDPE. He showed that the density of the samples decreases with the increase of the binder

(HDPE) in the mixture.

It is also observed that the density curve of MLTSF is above that of MLFNF. This is explained by the fact that during thermoforming, in the MLFSF material in addition to the PSE binder, the synthetic fiber-based fabric pieces soften and become an addition to strengthen the bonds between the unsoftened fabric pieces. On the other hand, for the MLFNF material, only the EPS alone softens. The MLFSF materials are then more compact compared to the MLFNF materials, thus coating their high density. These results are also similar to those of Vilaseca et al. [12], who showed in their work that composites based on chemical fibers have a higher density than those of composites based on natural fibers. The same goes for Sagnaba [1], in his research on the development of eco-materials based on polystyrene from cotton hulls.

3.2. Influence of the Polystyrene Rate on Water Absorption by Total Immersion

Figure 8 shows the variation of the absorption rate as a function of the EPS resin content

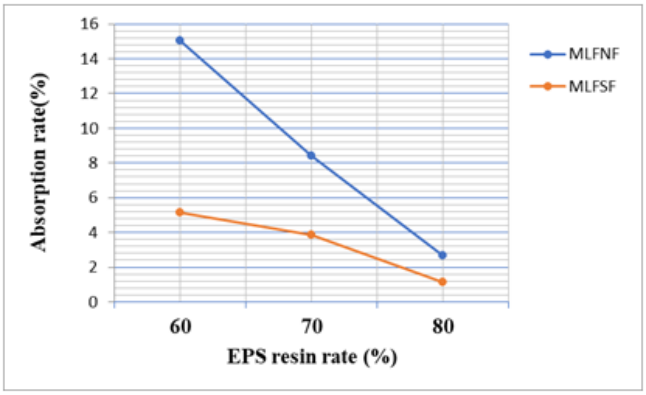

Figure 8. Variation of the absorption rate as a function of the EPS resin content

The figure shows that the absorption rate drops from 15.022 to 2.683% for the material (MLFNF) while that of the material (MLFSF) drops from 5.125 to 1.155% when the resin content increases from 60 to 80%. This result partially confirms that of the density showing that materials with low densities with more voids between the pieces of tissue absorb more water. On the other hand, the absorption curve of the material (MLFSF) is below that of the material (MLFNF).

This is due to the fact that the MLFSF material is based on synthetic fiber, therefore hydrophilic, absorbs less water, compared to MLFNF materials which is based on natural fiber, therefore hydrophilic, thus absorbing more water. The fact that the pieces of fabrics (LFNF) being hydrophilic absorb more water, this will lead to an increase in the rate of absorption for the material (MLFNF). These results are similar to those of some authors who showed in their work that hydrophilic fibers are responsible for the water absorption of materials [13-18].

Standards EN 771-1[19], NBN EN 206-1:2001 and NBN B 15-001:2004 [8] require an absorption rate by immersion of less than 6 or 7% for a material can be used in construction. It can then be deduced that MLFSF materials from 70% EPS and MLFNF materials from 75% EPS can be used as coating materials because they have absorption rates of less than 6 or 7%.

3.3. Influence of Polystyrene Content on Bending Strength

Figure 9 shows the results of varying the 3-point bending strength.

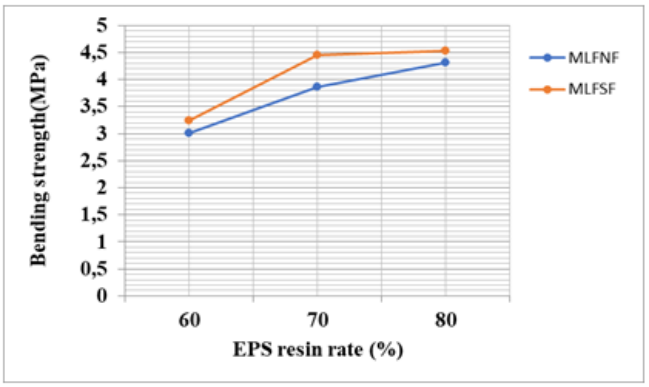

Figure 9. Variation of strength as a function of the EPS resin content in the material

The figure shows that the bending strength of the materials (MLFSF and MLFNF) increases with the content of EPS resin. Thus, for contents of 60% to 70% of PSE resin, the strength increases and run from 3.236 to 4.530 MPa for the MLTSF; and 3.011 to 4.321 MPa for MLFNF.

Indeed when the rate of EPS increases, we obtain more and more of a mixture containing a sufficient quantity of EPS to bind or coat the tissues, thus reinforcing the cohesion of the material by inducing a high resistance. These results are similar to those of some authors in their work on polypropylene composites reinforced with abaca and banana fibers [20,21]. As well as those of Zizumbo et al. [22], concerning their work on composites based on sugar cane bagasse fibers and polystyrene and those of Traore [23] based on plastic and sand. It is also noted that the flexural strength of the MLFSF material is greater than that of the MLFNF material. Indeed during thermoforming, the pieces of synthetic fiber fabrics (LFSF) will soften, in addition to the binder (EPS resin) to bind or coat the unsoftened tissues, thus generating high strength.

On the other hand, in the MLFNF material, the pieces of natural fiber fabrics do not soften and only the binder (EPS resin) softens to bind or coat the pieces of fabrics. Hence its low strength compared to the MLFSF material. These results are also true with those of Vilaseca et al. [12], who showed in their work that chemical fiber composites have a mechanical property in bending superior to those of natural fiber composites. The same for Umanath et al [24] on their work with pineapple and carbon fibers. According to the standards (NF EN 12390-3 [25], NF EN 1339 [26] and depending on the stress, for a material to be used as a wall or floor covering, its three-point bending strength is greater than 3.5 MPa.

These materials having flexural strengths varying from 3 to 4.5 MPa, can then be used as coating materials from 70% EPS.

3.4. Influence of Polystyrene Content on Wear Strength

Figure 10 shows the variation of wear as a function of EPS resin content.

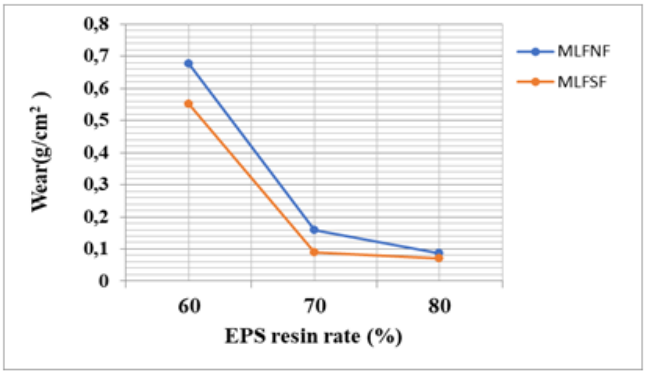

Figure 10. Variation of wear as a function of EPS resin content

These curves show that the wear decreases when the EPS resin content increases from 60 to 80%. Indeed, for PSE resin contents varying from 60 to 80%, wear drops and goes from 0.675 to 0.087 g/cm^2 for MLFNF and from 0.552 to 0.07 g/cm^2 for MLFSF. This drop in wear can be explained by the increasing contribution of EPS in the mixture which will bind the pieces of fabrics. When brushing, the pieces of fabrics that are not bound are easily torn off. When the content of EPS resin increases, the materials (MLFSF and MLFNF) resist wear because the cohesion between the pieces of fabrics becomes strong. Thus, when brushing, the loss of mass of the materials becomes low, hence the drop in the rate of wear. This is true with the results of some authors who show in their work that wear decreases with increasing latex content in the material [27,28].

4. Conclusions

The objective of this study was to recover sewing and polystyrene waste by developing a composite material using in construction. The experimental results allow to say that the strengths increase with the rate of EPS. The rate of water absorption also decreases with the rate of EPS. By comparing the results obtained with some standards that relate to coating materials, we can then say that these materials can be used as flooring materials. This method of developing materials turns out to be one of the solutions for recycling this industrial waste.

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