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The Study of Characterization of Eco-Friendly Geotextile based on Low-Density Polyethylene (LDPE) Plastic Waste

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Abstract: The study presents the utilization of plastic bag waste reinforced geotextile. The objective of this research is to determine the optimum layer of Low-Density Polyethylene (LDPE) plastic bag waste to produce geotextile. This study is involved the different layers of LDPE plastic bag waste which are 4 layers, 6 layers, 8 layers, 10 layers, and 12 layers by using a hot press process with 120 °C and 140 °C temperatures. LDPE plastic bag wastes were cut with dimensions of 270 mm width x 400 mm length. Then, the samples were cut into pieces to evaluate their physical and mechanical properties. For physical properties test, samples shows that the nitrile group is identified at sample of 10 layers of LDPE plastic bag waste after heat treatments of 120 °C. The 12 layers of LDPE plastic bag waste that undergo 140 °C has highest thickness of 0.3712 mm. The rougher surface was found on 12 layers of LDPE plastic bag waste that undergo 140 °C in optical microscopy test. For the mechanical properties test, the 10 layers of LDPE plastic bag waste that undergoes 120 °C withstood the highest elongation at break at 490.02 mm and highest percentage strain at break at 653.36. The 12 layers of LDPE plastic bag waste that undergo 120 °C has highest burst strength with 8.55 kg. The 12 layers of LDPE plastic bag waste that undergo 140 °C has highest coefficient of friction with 0.585. In a nutshell, the study found that 10 layers of LDPE plastic bag waste that undergoes 120 °C are suitable for eco-friendly geotextile.

Keywords: LDPE Plastic Bag Waste, Geotextile

1. Introduction

Geotextiles are widely used to strengthen the soils that build roads, embankments, pipes and earth retaining system [1]. It has the ability to separate, absorb, stabilize, secure, and drain when used in conjunction with soils. Geotextile is any textile product used under the soil that is a permeable fabric used to help control erosion and maintain soil stability [2].

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Plastics are ideal materials for a wide range of applications, including packaging, medical devices, construction, and transportation because of their quality, strength, and lightweight. Since plastic development and use is growing and leading to increased plastic pollution and environmental problems, the researcher has studied improving waste management and recycling systems will minimize pollution. Recycling will also create ways to minimize oil consumption, carbon dioxide emissions and the volume of waste that needs to be disposed [3].

Plastics take hundreds of years to degrade [4]. Plastics waste that ends up in the oceans degrade into small pieces and about 100,000 marine mammals and one million seabirds are killed by this pollution yearly [5]. Hence, transforming the plastic bag waste into geotextile is one of the best solutions to improve waste management. In this research, different layer of LDPE plastic bag waste have been used for geotextile application.

2. Literature review

2.1 Plastic bag waste

A study found that around 8 million tonnes of plastic waste discharges from coastal nations into the oceans every year. Plastic production increasing from 2.3 million tonnes in 1950 to 448 million tonnes by 2015. It is estimated to double by 2050 [6]. A research found that accounting 53.00 % of the 7.5 million tonnes of plastic waste imported by the United States, Japan and Britain to Malaysia in first seven months in 2018. However, only 9.00 % of this plastic waste is pure plastic, which can be recycled, while the remaining 12.00 % of the plastic waste is incinerated and 79.00 % is disposed of in landfills or discarded in the natural world [7].

Plastic production has increased vividly over the last 65 years comparative to other manufacturing products. The durability and resistance to flexible degradation of plastic in various applications, make these materials difficult to assimilate by nature [8]. There are two main groups of polymers which are thermoset plastics and thermoplastics. The differences of the polymer affect the performance of these plastics, making them appropriate for unlike applications.

Thermoset materials are classified as materials that undergo or have undergone a chemical reaction by heat, catalyst or ultraviolet light. Once the material has undergone a chemical reaction, it cannot be softened twice after reheating and hardened after cooling [9]. There is a wide range of thermoset plastics, some of which depend more than others on their heat-resistant properties. For example, they can be used as a cost-effective way to replace metal parts when thermoplastics are simply melted [10]. Meanwhile, thermoplastics will be softened when heated and allow for mold and solidify when cooled [11]. It is used for a wide variety of uses depending on the material category. It can be remodeled and recycled without harmfully impacting the physical properties of the material due to its unique chemical properties. This makes thermoplastics an ideal material for injection molding [12].

2.2 Geotextile

Geotextiles are permeable textile fabrics which can be woven, unwoven or knitted. It is a part of a broader family called geosynthetics. Geotextile is one of the first textile items of human history. It has played a major role in modern engineering design and maintenance techniques [14].

There are three types of geotextile which are woven geotextile, non-woven geotextile and knitted geotextile. Woven geotextile is manufactured by blending and weaving fibres. It has high load capacity and suitable for applications like road construction it will resist corrosion and hold up for long-term applications. Woven geotextile is also ideal for some erosion control project where water have to passed over a surface without draining through the soil under [15]. Non- woven geotextiles are created by fibre, long or short, by punching needles or by other methods. Some thermal therapy is then used to further increase the geotextile strength [16]. Knitted geotextile is formed by interlocking a number of yarn loops. All knitted geotextiles are manufactured with a knitted process along with some other geosynthetic method, such as weaving. Other than geosynthetics are geonets, geogrids, geocells, geomembrane and geocomposites. Each has its characteristics, implementations and uses [17].

Studies found that there are two types of fibres used in manufacturing geotextile which are natural fibre and synthetic fibre. Different fibres from both the natural and the synthetic categories can be used as geotextiles for various applications such as reinforcement, filtration, separation and drainage. [18]. Natural fibres in the form of paper strips, jute nets, wood shavings or wool mulch are used as geotextile while synthetic geotextiles are made of polymers and plastics. The raw material for its production are hydrocarbon, petrochemicals and fossils. This is related to all greenhouse gases and effects [19].

3. Methodology

In this research, the low-density polyethylene (LDPE) plastic bag wastes are prepared into different layers which are 4 layers, 6 layers, 8 layers, 10 layers and 12 layers. The samples have been undergone heat transfer process at 120 °C and 140 °C. This is because the melting point for LDPE plastic is 110°C [20]. All of the samples of plastic bag waste also have been analyzed by using the mechanical and physical testing to determine the effectiveness of plastic bag waste for geotextile application. There three tests for the mechanical testing which are tensile strength test, burst test and abrasion test while for the physical testing are thickness test, FTIR analysis and optical microscopy.

3.1 Preparation of material

In this study, the LDPE plastic bag wastes were brought from the same material which are bought from the same shop. This is because to get the similar properties. The LDPE plastic waste is shown on Figure 1 below.

Figure 1: LDPE plastic bag waste

For pre-treatment, LDPE plastic bag waste was cleaned from all dirt and substances, such as oil and detergent liquid. The LDPE plastic bag wastes were cut using scissors and then proceed to cleaning process to confirmed in dry condition. LDPE plastic bag waste then folded same dimensions of 270 mm width x 400 mm length. Lastly, the hot press process starts.

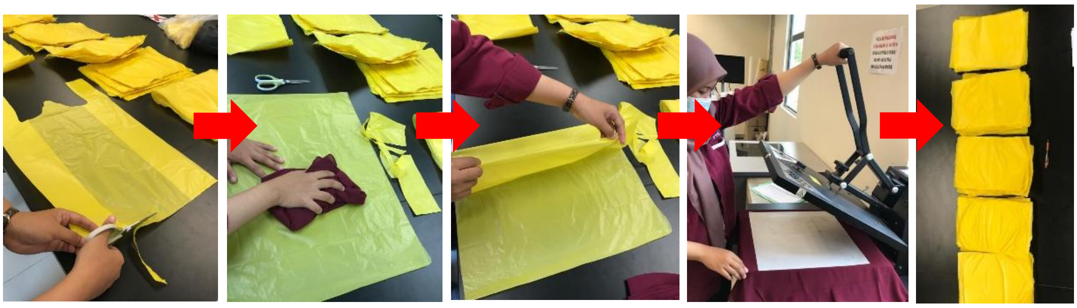

Figure 2: Geotextile sample process flow

3.2 Preparation of samples

In the preparation of geotextile sample, ten types of samples were prepared with different layer of LDPE plastic bag wastes. The geotextile samples were prepared in different of 2 layers each from 4 layers until 12 layers of LDPE plastic bag waste which shown in Table 1.

Table 1: Geotextile samples prepared

Layers of LDPE plastic bag waste	Quantity
4 layers	2 units
6 layers	2 units
8 layers	2 units
10 layers	2 units
12 layers	2 units

4. Results and Discussion

In this study, the mechanical and physical properties of geotextile samples were determined by six experimental testing, which are tensile strength test, burst test, coefficient of friction test, FTIR test, thickness test and optical microscopy test.

The total number of samples for each testing which are tensile strength test, burst test, coefficient of friction test, FTIR test, thickness test and OM test are 10 samples. The sum of the total sample is 60 samples. All the data were presented in the table and the graph were plotted for statistical analysis. All results are being analyzed as to compare the overall performance of samples for geotextile application as shown in Figure 3 – Figure 10.

4.1 Tensile strength test

Tensile strength test was conducted according to standard ASTM D5035. This test method covers ravelled strip and cut strip test procedures for determining the elongation and strain of breaking. The sample is clamped in a tensile testing machine and a force applied to the sample until it breaks. Values for the breaking force and elongation of the test sample are obtained from computer interfaced with the testing machine.

Figure 3 shows the graph elongation at break versus layers of LDPE plastic bag waste. The graph shows for samples that undergoes 120 °C, 10 layers of LDPE plastic bag waste withstood the highest elongation at break of 490.02 mm, followed by 8 layers with 438.57 mm, next 6 layer with 349.42 mm, then 4 layers by 321.02 mm elongation at break. There are sharply drop in tensile strength by 12 layers of LDPE plastic bag waste that undergo 120 °C with 291.57 mm because the bond of each LDPE layers was not fully attached. For samples that undergoes 140 °C, 8 layers of LDPE plastic bag waste withstood the highest elongation at break with 70.02 mm, followed by 6 layers at 61.82, next 10 layers at 57.82, then 12 layers at 37.77, and lastly 4 layers at 27.42 mm.

As conclusion, 10 layers of LDPE plastic bag waste that undergoes 120 °C is suitable for geotextile application because it has 653.36 percentage strain at break. This is because a study in 2005 had found that the permittivity of the exhumed geotextile samples increased between 59 percent and 449 percent after washing, indicating clogging of the geotextiles [20].

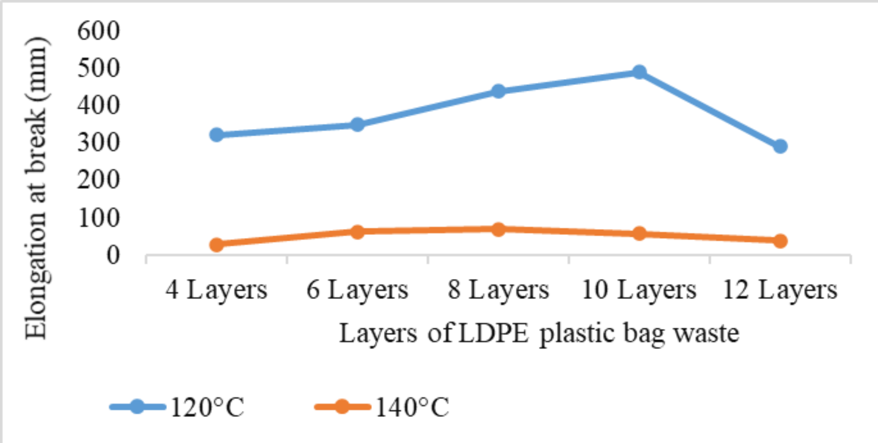

Figure 3: Elongation at break, mm of different layer of LDPE plastic bag waste

Figure 4 shows the graph elongation at break versus layers of LDPE plastic bag waste. The graph shows for samples that undergoes 120 °C, 10 layers of LDPE plastic bag waste withstood the highest percentage strain at break with 653.36, followed by 8 layers with 584.76, next 6 layer with 465.90, then 4 layers by 428.03. There are sharply drop in percentage strain at break by 12 layers of LDPE plastic bag waste that undergo 120 °C with 388.76 because the bond of each LDPE layers was not fully attached. For samples that undergoes 140 °C, 8 layers of LDPE plastic bag waste withstood the highest percentage strain at break with 93.36, followed by 6 layers at 82.43, next 10 layers at 77.10, then 12 layers at 50.36, and lastly 4 layers at 36.56.

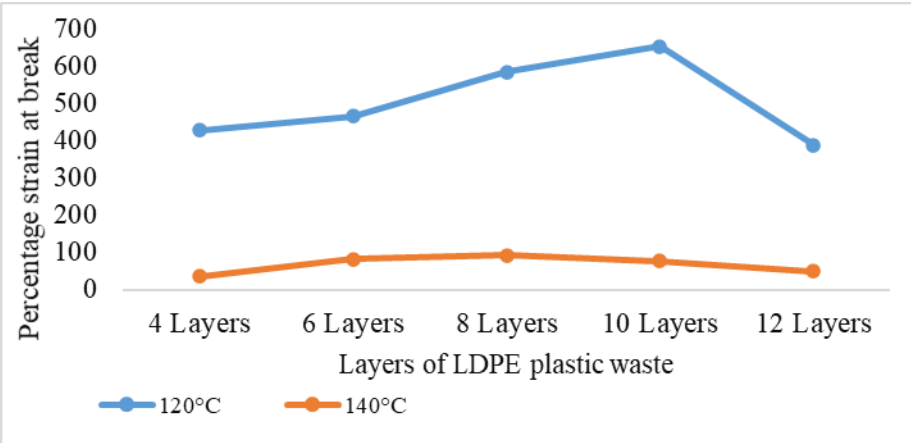

Figure 4: Percentage strain at break of different layer of LDPE plastic bag waste

4.2 Burst test

The burst test was conducted according to standard ASTM D3786 which the sample is securely clamps firmly and uniformly between two annular on a stainless-steel surface, without slippage during the test. A sufficient pressure is used to affect the practicable minimization of slippage. The upper and lower clamping surfaces have a 75 mm (3 in.) circular opening in diameter and coaxial apertures of 31±0.75 mm (1.22±0.03in.) in diameter. The surfaces of the clamps between which the sample is placed have concentric grooves spaced which is 0.8 mm (1⁄32 in.) apart and a 0.015 mm (0.0006 in.) depth than from the edge of the aperture. The surfaces of the clamps were metallic. The lower clamp was integral with the chamber in which a screw was operated to force a liquid pressure medium at a uniform rate of 95±5 mL/min against the rubber diaphragm.

Figure 5 shows the samples that undergoes at 120 °C, 12 layers of LDPE plastic bag waste withstood the highest burst strength with 8.55 kgf, followed by 10 layers with 7.71 kgf, next 8 layers with 6.51

kgf, then 4 layers with 5.39, lastly 4 layers with 4.73 kgf. For the samples that undergoes 140 °C, 12 layers of LDPE plastic bag waste withstood the highest burst strength with 7.06 kgf, followed by 10 layers with 6.63 kgf, next 8 layers with 5.54 kgf, then 6 layers with 4.77 kgf, lastly 4 layers with 3.83 kgf. A study on 2016 found that, polyethylene crystallises by a folded-chain process to form a lamella-type structure. Increasing the number of inter-lamellar binding molecules will give a reinforcing effect and resulting in a tougher product [21].

A study in 2012 found that the number of fibres that resist multi-directional load increases and the load shared by the individual fibres before rupture decreases. In addition, as the number of fibres is higher for higher mass per unit area, the contact and friction forces between the high number of fibres increase, resulting in higher burst [22].

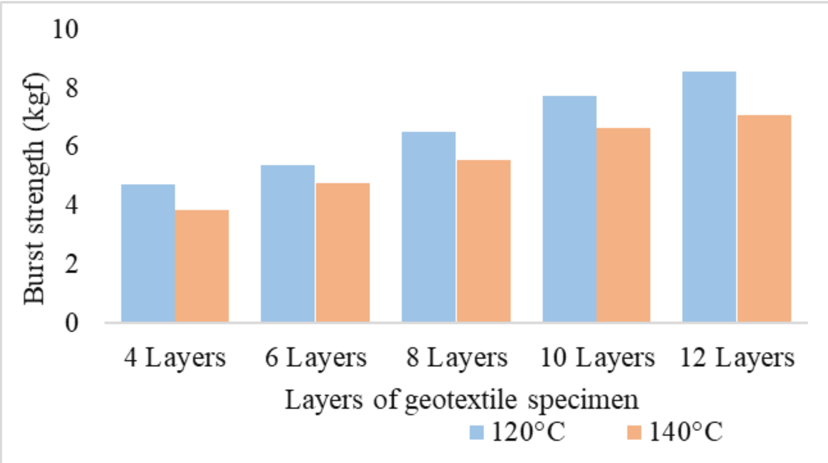

Figure 5: Burst strength by geotextile sample layers

4.3 Coefficient of friction

The coefficient of friction test was conducted according to standard ASTM D3786. The surfaces to be tested are placed together in plane contact and under uniform contact pressure. The force needed to displace the surfaces relative to each other is recorded. The sled weight is 200±2 g and the size is 63 mm x 63 mm. The plane size is 150 mm x 300 mm. The speed of 150 mm/min is use in this test.

From the Figure 6, the samples that undergoes 140 °C, 12 layers of LDPE plastic bag waste withstood the highest coefficient of friction with 0.584, followed by 10 layers with 0.577, next 8 layers with 0.570, then 4 layers with 0.516, lastly 4 layers with 0.270. For the samples that undergoes 120°C, 12 layers of LDPE plastic bag waste withstood the highest coefficient of friction with 0.213, followed by 10 layers with 0.209, next 8 layers with 0.197, then 6 layers with 0.186, lastly 4 layers with 0.144. As the number of layers of LDPE plastic bag waste increase, the coefficient of friction also increases.

So, as a conclusion, the samples of 6, 8, 10 and 12 layers of LDPE plastic bag waste that undergoes 140 °C is suitable for geotextile application because they have coefficient of friction that greater than 0.5. A study in 2006 found that, obtained coefficients of interaction of cohesive soils and geotextile that greater than 0.5 can be successfully reinforced with various types of geogrids [23].

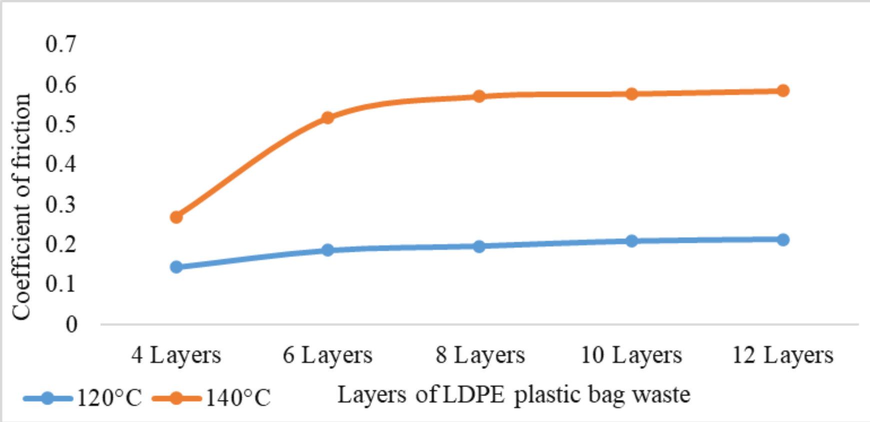

Figure 6: Coefficient of friction by geotextile sample

4.4 Fourier Transform Infrared (FTIR) analysis

This practice covers the spectral spectrum from 4000 to 50 cm^{-1} and involves techniques that are useful for qualitative analysis of liquid, solid and vapour phase samples by infrared spectrometric techniques for which the amount of sample available for analysis is not a limiting factor. These techniques are also useful for recording spectra at frequencies above 4000 cm^{-1} in the near-infrared region.

Figure 7 presented the infrared absorption spectra of untreated 1 layer and 10 layers of LDPE plastic bag waste after heat treatments of 120°C. There are two main regions characterize of this group that can be identified. The first one appears at peak 2840-2915 cm^{-1} are assigned to the C-H stretching and the second region is represented by well-defined peaks at 2330-2360 cm^{-1} is corresponded to C≡N stretching. The alkane group is identified by medium absorption band at 2914 cm^{-1} on both samples while nitrile group is identified by weak absorption band at 2357 cm^{-1} at sample of 10 layers of LDPE plastic bag waste after heat treatments of 120 °C.

The nitrile compound found in the samples shows that the samples is suitable for geotextile application because it has the characteristic of good abrasion resistance, tear resistance, water and oil resistance, and low flexibility. The prove is found in the study on 2001. The study found that the more nitrile within the polymer, the higher the resistance to oils but the lower the flexibility of the material [24].

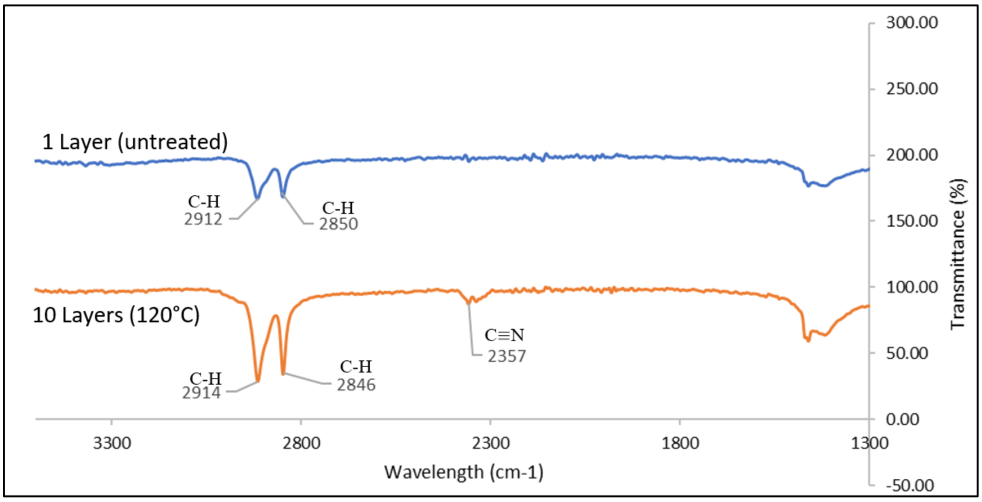

Figure 7: Comparison of FTIR result of 1 layer and 10 layers of LDPE plastic bag waste

4.5 Thickness test

The thickness test was conducted according to standard ASTM D5199. The thickness of geotextile is determined by observing the distance between two parallel surfaces confining the tested material while under a specified pressure after 5 seconds. The thickness gauge has a base and a free moving presser foot plate whose planar faces are parallel to each other to <0.01 mm. A gauge with a 56.4 mm (2.22 in.) diameter presser foot, the base extends at least 10 mm (3/8 in) in all directions further than the edge of the 2500 mm² (3.88 in²) is being used in this test. The thickness of the geotextile sample is taken three times at the different area of the sample. The average is calculated.

From the Figure 8, the samples that undergoes 140 °C, 12 layers of LDPE plastic bag waste is the highest thickness with 0.371 mm, followed by 10 layers with 0.3038 mm, next 8 layers with 0.2052 mm, then 6 layers with 0.1856 mm, lastly 4 layers with 0.1241. For the samples that undergoes 120 °C, 12 layers of LDPE plastic bag waste withstood the highest coefficient of friction with 0.2926, followed by 10 layers with 0.29266 mm, next 8 layers with 0.1921 then 6 layers with 0.1501, lastly 4 layers with 0.1021.

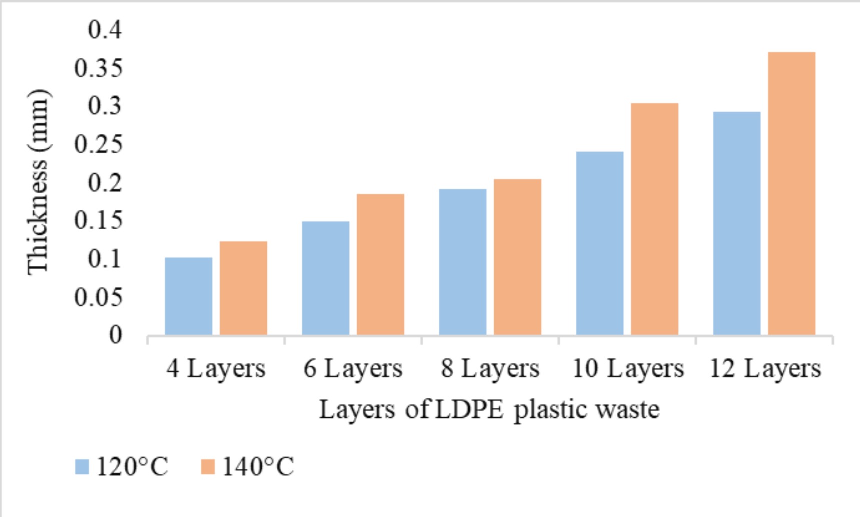

Figure 8: Sample thickness by layers of LDPE plastic bag waste

Generally, the thicker the fabric, the heavier the weight will be [25]. Thermally bonded non-woven contain a wide variety of opening sizes and a standard thickness of about 0.5-1 mm, whereas chemically bonded non-woven are typically 3 mm thick. Mechanically bonded non-woven have a standard thickness of 2-5 mm [18].

4.6 Optical Microscopy

In OM analysis, the geotextile samples were conducted with 10x image magnifications. It was to determine the matrix-reinforcement bonding and external surface for each geotextile sample. Based on the pattern that obtained on surface of sample by using optical microscope as shown in Figure 9 and Figure 10, clearly shown that the 140 °C sample has rough surface while the 120 °C sample has smooth surface. This is because the sample that undergoes 140 °C is over melt.

A study in 2020 found that the melting enthalpy is related to the crystallinity. The lower crystallinity, the fewer the heat required for heating and melting. In the study, the composite manufactured by hot pressing and extrusion showed clear melting peaks at 121.97 °C and 122.61 °C, respectively, values similar to that of LLDPE, at 122.28 °C. The endothermic peaks might possibly be caused by the melting of LLDPE [26].

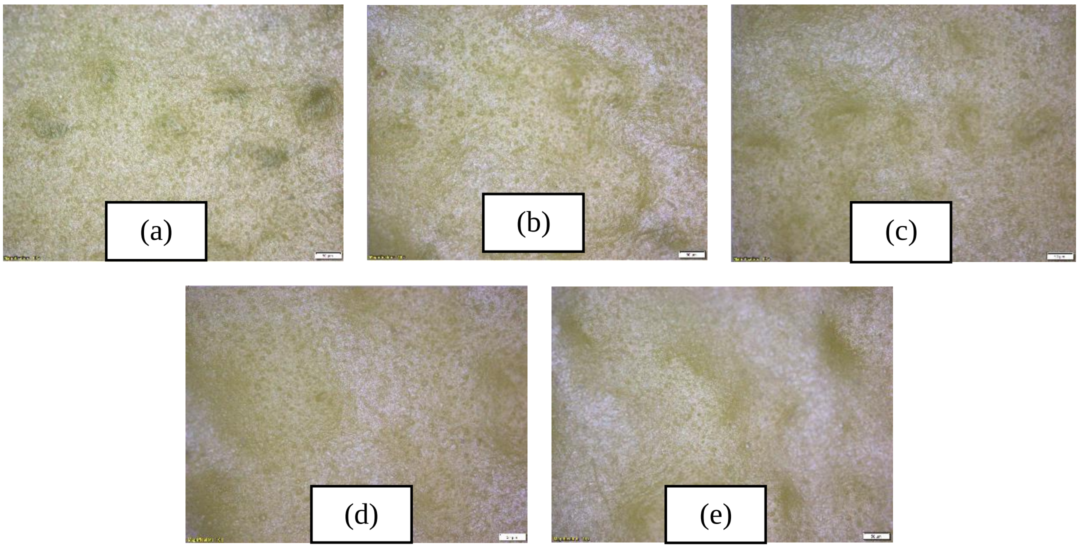

Figure 9: Geotextile samples that undergoes 120°C heat transfer process; (a) 4 layers; (b) 6 layers; (c) 8 layers; (d) 10 layers; and (e) 12 layers

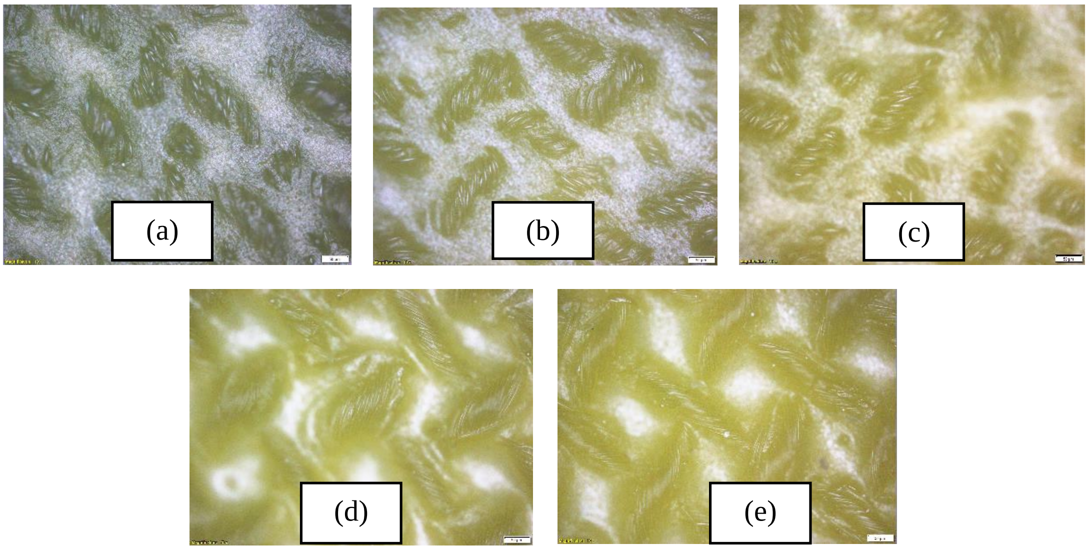

Figure 10: Geotextile samples that undergoes 140°C heat transfer process; (a) 4 layers; (b) 6 layers; (c) 8 layers; (d) 10 layers; and (e) 12 layers

A 2006 studies found that for smooth geomembrane interfaces, unregulated geotextiles have resulted in a slightly higher sensitivity over the same range of natural stresses. The findings may be due to the interlocking and resistance of the geotextile filaments near the interface, which are the key causes of the sliding friction on a smooth surface. Meanwhile for interfaces with a textured geomembrane, the constricted geotextiles displayed a higher sensitivity of 50 to 100 kPa of normal stress. The findings are due to the initial heavy interlocking of texture-geotextile components and the resulting wear of texture at peak resistance [26].

5. Conclusion

In conclusion, the objectives of this study are achieved. The optimum layer of 10 layers LDPE plastic bag waste that undergoes 120 °C heat transfer process is possible to be use as filtration geotextile. Mechanical and physical experiments were performed and analyzed on the basis of various layers of geotextile LDPE plastic bag waste. The results of geotextile samples obtained are suitable for geotextile especially in horticulture application. The utilization of plastic bag waste for application in horticulture would decrease the environment problem of plastic bag waste and able to cut cost from producing raw material for geotextile.

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