

Waste Polyethylene with Kithul Fiber as a Composite Material

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Abstract

In Sri Lanka, waste polyethylene leads to significant social and environmental issues. Daily increases in polyethylene trash exacerbate social and environmental problems. A significant requirement is to identify the best answer to this problem. This research aims at the possibility of converting waste polyethylene into a sustainable construction material by mixing it with Kithul fiber. The applicability of thermoplastic/Kithul fiber composites in the construction sector was the subject of an initial investigation. The physical and mechanical properties of Kithul fibers are significant before commencing the material development process and applications for this fiber. Several testing was carried out to evaluate the diameter, density, water absorption, and tensile strength of the fiber. The density and diameter of Kithul fiber were measured utilizing the psychometric method and an optical microscope respectively. The tensile strength and Young's modulus of the Kithul fiber were measured using an electronic tensometer. The average density of Kithul fibers was 0.904 g/cm³ and average diameters were 461.891 μm. The ultimate tensile strength and Young's modulus of the fibers were 25.6845 MPa and 2.416 GPa respectively. Varying Kithul fiber weight with an appropriate polymer matrix, the 2.5 mm and 3.2 mm thick composite sheets were created using a hot press machine. In this stage, the tensile and bending characteristics of the composite material were evaluated. The tests were carried out according to ASTM D3039 and ASTM D790, respectively. The maximum tensile strength and the maximum bending strength of 15.45 N/mm² and 22.959 N/mm² respectively were obtained when the Kithul weight fraction ranged from 10% of the total weight. The final application of this product cannot yet be defined. Further studies are suggested to finalize the application of this product.

Keywords— Kithul Fiber, Waste Polyethylene, Physical Properties, Mechanical Properties, Sustainable Construction Material

Introduction

Pollution due to plastic waste is the largest problem in the world because it is a hazardous substance and is very difficult to decompose. Plastic is widely used in many aspects of daily life, including garment packaging, furniture, food packaging, and other accessories. Plastics are classified into several different categories based on their chemical composition. Therefore, one of the biggest problems that have is separating plastic waste [1].

Plastic production and consumption have increased significantly since 1950 on a global level. Approximately 8300 million tons of plastic were produced, with 6300 million tons of plastic garbage being dumped in landfills or released into the environment [2]. Furthermore, 415 million tons of plastic are manufactured globally each year [3, 4].

As with many other developing countries in the region and world, Sri Lanka is also facing challenges in managing its Municipal Solid Waste (MSW) including plastic waste. Plastic usage in Sri Lanka is

estimated to be approximately 6 kilograms per year [5]. Furthermore, [6], presented some information on future trends in plastics consumption in Sri Lanka. In 2025, polyethylene would be the most popular plastic substance, while polystyrene would be the least popular. Because polyethylene is a popular plastic material due to its versatility, durability, and low cost, making it popular in packaging, bottles, and consumer products. Its barrier properties, resistance to moisture and chemicals, and recyclability make it a popular choice [7]. However, polystyrene, also widely used, faces increasing scrutiny due to its environmental impact. Styrofoam, a non-biodegradable polystyrene foam, contributes to litter and marine pollution, leading to increased demand for alternatives and stricter regulations [6, 3]. Additionally, he made note of the fact that 51.16% of the plastics that would be imported in 2025 will be wasted. Currently, Sri Lanka imports 500,000 metric tons of plastic and polyethylene per year, and 70% of that accounts for domestic consumption [8].

Polyethylene is being repurposed as a construction material globally, including in Sri Lanka, to address plastic waste and promote environmental stewardship. This sustainable approach offers economic and

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ecological benefits, such as the production of durable plastic lumber for decking, fencing, and outdoor furniture. In Sri Lanka, recycled polyethylene waste is transformed into lightweight, durable roofing sheets, reducing the need for conventional materials like metal or asbestos [9]. Polyethylene-based insulation materials, such as recycled polyethylene foam, are used in construction projects to enhance energy efficiency and comfort, offering excellent heat resistance and sound absorption properties. The reuse of polyethylene waste contributes to a more sustainable future, reducing the environmental impact of plastic waste and embracing innovative and eco-friendly solutions in the construction industry. Indeed, the utilization of polyethylene fiber composites has become increasingly favoured and considered one of the easiest solutions to minimize polyethylene waste [10]. The incorporation of fibers into polyethylene matrices offers a promising approach to repurpose and maximize the potential of polyethylene waste, addressing the global challenge of plastic waste management. [11]. Nowadays in many applications, new composites with polythene as the matrix coupled with fiber are used because they have excellent physical and mechanical properties compared with polymer alone. Because polyethylene-based composites are increasingly popular due to their superior physical and mechanical properties compared to polymers alone. These composites offer enhanced strength, stiffness, impact resistance, durability, and weight reduction, making them suitable for various applications across industries. Fibers act as reinforcement, distributing load-bearing capabilities throughout the material, making them suitable for structural applications [12]. The addition of fibers to the polyethylene matrix enhances the composite's impact resistance, making it ideal for applications where impact resistance is crucial, such as automotive components or sports equipment. Fiber reinforcement also increases the composite's durability and resistance to wear and tear, making it valuable in construction materials or marine structures.

Despite improved mechanical properties, polyethylene-based composites can maintain a relatively low weight, making them ideal for applications requiring weight reduction, such as aerospace or automotive industries. The choice of fiber type, content, and orientation can be adjusted to achieve specific performance requirements for different applications [13]. This versatility allows for the customization of composite properties to suit specific industry needs. Overall, the combination of polyethylene and fiber reinforcement in composite structures offers superior physical and mechanical properties, making them highly desirable for a

wide range of applications (Automotive, electrical, biomedical, space applications, and thermal energy storage)[7].

Synthetic fiber-reinforced polymer composites and natural fiber-reinforced polymer composites are two distinct types of fiber-reinforced polymer (FRP) composites. Synthetic fiber-reinforced polymer composites use synthetic fibers as reinforcements within a polymer matrix, offering excellent mechanical properties like high strength, stiffness, and impact resistance. They are widely used in applications requiring superior performance and durability, such as aerospace components, automotive parts, sports equipment, and high-performance structures [14, 15].

On the other hand, natural fiber-reinforced polymer composites incorporate natural fibers derived from plant sources as reinforcements in a polymer matrix. These composites offer advantages such as renewable and sustainable sourcing, lower energy consumption during processing, and reduced environmental impact. They find applications in automotive interiors, packaging, construction materials, furniture, consumer products, and other industries where sustainability, cost-effectiveness, and lower environmental footprint are important considerations [16, 7].

The popularity of natural fiber-reinforced polymer composites can be attributed to several reasons, including environmental sustainability, lower energy consumption, biodegradability, cost-effectiveness, and suitability for specific applications. Synthetic fibers are derived from renewable plant sources, reducing reliance on non-renewable resources, and reducing greenhouse gas emissions. Natural fiber composites are also more cost-effective than synthetic fibers, making them an attractive option for various industries [17, 18].

Natural fibers have gained popularity as an alternative to traditional glass and carbon fibers in thermoplastic composite production due to their environmental sustainability, cost-effectiveness, weight reduction, improved energy absorption, and reduced wear on processing equipment. These benefits are particularly valuable in industries like automotive and aerospace, where reduced weight is crucial for fuel efficiency and performance. However, natural fibers may have limitations in mechanical properties and moisture absorption, and ongoing research and development efforts aim to improve their performance and expand their application range (Fan, 2017), [19].

Natural fibers are found in various parts of plants or trees, including stem fibers, seed fibers, leaf fibers, bast fibers, and fruit fibers. Stem fibers are extracted from plants like flax, hemp, jute [20], kenaf, ramie,

and bamboo[7], while seed fibers are derived from cotton seeds or kapok pods. Leaf fibers, such as sisal [21] and agave, are extracted from the leaves of certain plants. Bast fibers are obtained from the inner bark or phloem of certain plants, while fruit fibers are extracted from coconut husks [22, 18, 23]. These fibers are sourced from cultivated plants or trees worldwide, with availability varying depending on geographical location and plant species.

According to reports, Kithul palms are common in Sri Lanka's mid- and lowland interior up to 1,500 m, with an ecological range limit of 1200 m. Kithul trees are mostly found in lowland natural forests [24, 25].

Perera, et al.[7] characterized the Kithul fiber to evaluate the properties of length, diameter, breaking force, tenacity, elongation, and moisture content of Kithul palm fibers. The research study was accomplished and obtained the length and diameter were 65 cm and 0.85 mm respectively. Breaking force, tenacity, and elongation values were shown as 35.67 N, 10.26 cn/tex, and 45.20% correspondingly. Conferred to the research paper, 14% of the moisture content value was attained in Kithul palm fiber [26].

After the extraction of the sap, the fibrous material left behind can be considered as Kithul fiber waste. While there may be limited available data on Kithul fiber-reinforced polymer composites specifically, the abundance of Kithul trees in Sri Lanka presents an opportunity to utilize the leftover fiber waste for composite applications. The availability of Kithul fiber waste locally in Sri Lanka makes it a viable and sustainable option for reinforcement in polymer composites.

This study focuses on the development of natural fiber-reinforced polyethylene composites using Kithul fiber as the reinforcement. Kithul fiber has been chosen for several reasons that make it a suitable candidate for addressing polyethylene waste in Sri Lanka. Firstly, the lack of previous data on Kithul fiber-reinforced polymer composites presents an opportunity for novel research and exploration. By studying the mechanical, thermal, and physical properties of Kithul fiber composites, this study aims to contribute to the existing knowledge base and establish the potential of Kithul fibers as reinforcements in polyethylene composites. Secondly, the utilization of Kithul fibers as reinforcement aligns with to utilization of waste materials. After the extraction of Kithul sap for jaggery production, the fibrous material left behind is typically considered waste. By repurposing this waste material, the study aims to create value and promote a circular economy approach by converting Kithul fiber waste into a valuable resource for composite production. Moreover, the availability of Kithul trees in Sri Lanka makes it a viable and sus-

tainable option for reinforcing polyethylene composites. Sri Lanka is home to a significant population of Kithul trees, providing a local and abundant source of Kithul fiber. Utilizing locally available materials reduces the dependence on imported resources and supports the growth of domestic industries.

In this research, the physical and mechanical properties such as average diameter, the density of fiber, the property of water absorption, and the tensile strength of Kithul fiber were analyzed. The durability characteristics of fiber were identified according to the previous research data. Then, a composite material was developed using waste polyethylene as a matrix material and Kithul fiber as reinforcement. This paper also presents the tensile and bending properties of this composite material. As a natural fiber composite material, this material would be used in several industries including the building construction sector.

Materials and methods

The composite material was developed using Kithul fiber and waste polyethylene. Then, the properties of the composite were evaluated.

Kithul fiber

There are several types of natural fibers available in Sri Lanka and many are abundant after harvesting. Among several such fibers, Kithul fiber was selected for this study. Kithul fibers were extracted from the husk of the Kithul tree and collected from Aththana-galla Temple in Sri Lanka for this research study. Figure 1 illustrates Kithul husk and Kithul fiber.



Figure 1: (a) Kithul husk and (b) Kithul fibers

Properties of Kithul fiber

The diameter, density, water absorption, and tensile strength of Kithul fiber were measured before manufacturing the composite.

Diameter The diameter of the fiber was measured using a digital high-resolution software-controlled Metallurgical Microscope (with 1µresolution). Three

equidistant points were measured on each fiber, and this process was repeated for a randomly selected sample of thirty fibers. The average diameter was calculated for all the fibers, and this value can be regarded as the mean diameter of each fiber [27].

Density The density of natural fiber was measured using the pycnometric method. An average of 20 fibers were taken as the density of the fibers. The selected fibers were dried for 96 hrs, in a desiccator containing silica, and they were cut into 5mm to 15 mm length segments. These fiber pieces were put into a pycnometer and then placed in the desiccator again for 24 hrs. Before commencing the density measurements, the fibers were soaked in a toluene solution for 2 hours to remove the microbubbles in the fibers. This testing process was repeated 5 times and the average value was calculated to have more accurate results [22, 28].

$$\rho_f = \frac{(m_2 + m_1)\rho_t}{(m_3 - m_1)(m_4 - m_2)} \quad (1)$$

Where:

- m_1 Mass of the empty pycnometer (g)
- m_2 Mass of the pycnometer filled with cut fibers (g)
- m_3 Mass of the pycnometer filled with toluene (g)
- m_4 Mass of the pycnometer filled with cut fibers and toluene (g)
- ρ_t Density of toluene (g/cm^3) which is 0.866 g/cm^3

Water Absorption For the water absorption test, the fibers were washed with deionized water and dried in an oven (temperature - 60°C) for 24 hrs. Then 9 fibers were placed in a desiccator to cool. Later, immediately upon cooling, the fibers were prepared into a bundle of individual fibers (5 g) bound together and weighed. Fibers were then kept inside the beaker containing water at room temperature (25°C). Measurements were taken after 2 hrs, 6 hrs, and every 24 hrs until a constant value was observed.[29]

$$M_C = \frac{M_a + M_d}{M_a} \quad (2)$$

Where:

- M_C - Moisture Content
- M_a - Weight of the fiber after dipping in water
- M_d - Dry fiber sample weight.

Tensile Strength The tensile test was conducted following the ASTM D 3822 – 07 standard [30]. The Universal tensile testing machine INSTRON tester was used to conduct the tests. Tests were led at a temperature of 25°C and 65% of relative humidity level with a gauge length of 50 mm. The crosshead speed was set at 5.0 mm/min with a static load of 50N for the Kithul fibers. 35 samples were tested

in each fiber to get a more appropriate value. Tensile strength, Young’s modulus, displacement, and tenacity were obtained [22].

Waste Polyethylene

Waste High-Density Polyethylene (HDPE) was used for this study and was purchased from the polyethylene collectors in the Biyagama district.

Properties of waste polyethylene

Fourier transform infrared analysis was done to identify the type of polyethylene purchased.

Fourier Transform Infrared Analysis (FTIR)

Fourier transform infrared spectra of the selected matrix was determined using an “IR spectrum”. The analysis was carried out with an FTIR spectrometer with 32 scans per minute and a resolution of 4cm^{-1} over the wavenumber range from 4000 to 500cm^{-1} . The size and shape of the peaks are assisted to determine the functional groups present in polythene.

Composite preparation process

The fiber was cleaned well to remove residual particles and adhered dust from the fiber surface before use for composite manufacturing. For that, the fibers were cleaned in running, potable water for about 30 minutes, and then allowed to naturally dry at room temperature. These thoroughly cleaned Kithul fibers were used to make a composite material. Waste polyethylene was gathered from particular factories and cleaned in clean water with washing powder to get rid of impurities and unwanted material. Before using the cleaned polyethylene, it was allowed to dry naturally in the air. Cleaned polyethylene was shredded and Kithul fibers were cut into small pieces (2.5 cm – 3.5 cm) to get uniformity of the mixed sample. Figure 2 shows shredded polyethylene and pieces of Kithul fiber.



Figure 2: (a) Shredded polyethylene and (b) pieces of Kithul

Fiber and polythene were mixed in different ratios as shown in Table 1 to determine the best fiber polythene ratio for the composite. Fibers and waste

polyethylene mix were laid on Teflon sheets according to the hand layup method, and a laminated hot press machine [Figure 3(a)] was used to create the laminated sheets using the compression molding technique. During this procedure, Kithul and waste polythene were compressed for about 2 minutes at a temperature of 140 °C.

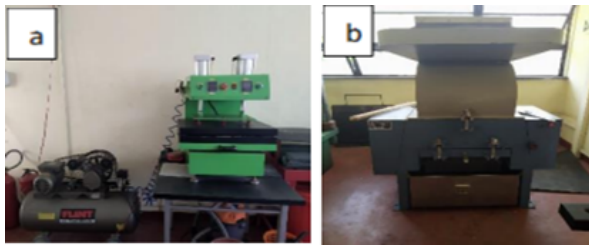


Figure 3: (a) Laminated machine and (b) shredded Equipment

Table 1: Sample preparation plan

Sample No	Fiber Weight Fraction by total weight (%)	Waste Polyethylene Fraction by total weight (%)
1	0.0	100
2	2.5	97.5
3	5.0	95
4	10.0	90
5	20.0	80
6	30.0	70
7	40.0	60

Then, the prepared samples were shredded using a shredder machine [Figure 3(b)]. The process of shredding aids in keeping the material uniform. Then, the shredded materials were uniformly stacked in a steel mold using the hand layup method. The final composite samples were prepared using a hot-pressed machine. During this procedure, a pressure of 25 psi load was applied in a hot press machine [Figure 4] for 6 minutes at 150°C temperature. After being prepared, the composite boards were kept in the cooler to cool until they reached room temperature. The prepared laminated sheets and the final composite samples are shown in Figure 5.

Experimental procedure

The tensile strength and flexural strength of prepared composite samples were determined. According to ASTM D 3039, seven samples were prepared to 250 mm length, 25 mm width, and 2.5 mm thickness for



Figure 4: Hot Press Machine

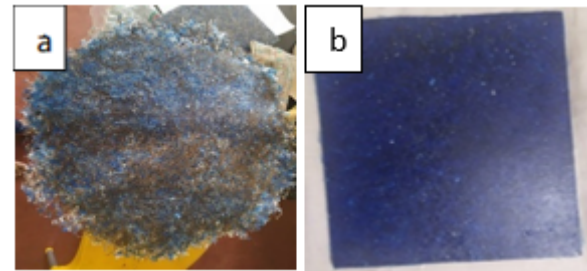


Figure 5: (a) Laminated sheets and (b) prepared composite board

tensile strength as shown in Figure 6 (a)/(b). Six samples were prepared in dimensions of 150 mm length, 12.7 mm width, and 3.2 mm thickness were prepared for the bending test.



Figure 6: (a) Tensile test equipment and (b) Tensile samples

Results and discussion

In this section properties of the fibers, waste polyethylene and the observed values of the tensile and flexural strength for composites will be discussed.

Properties of fibers

Fiber properties including diameter, density, water absorption, and tensile strength will be deliberated here.

Diameter The values occupied over three consecutive distances for each fiber and thirty Kithul fibers were measured and taken average diameter. The average diameter that resulted was 461.891µ. The software-controlled Metallurgical Microscope is shown in Figure 7(a) and the image of Kithul fiber through the microscope is shown in Figure 7(b).

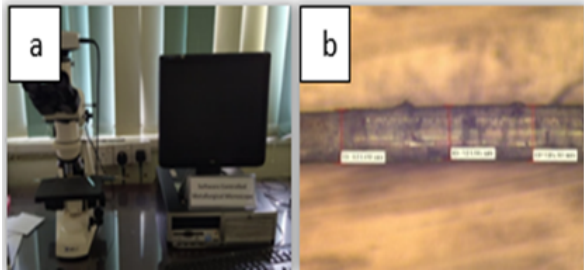


Figure 7: (a) Software-controlled Metallurgical Microscope and (b) Image of Kithul fiber through the microscope

The study compares natural fiber diameters, with coir fiber having the highest diameter at 100-450 μm [31], hemp fiber at 25 μm [31], Palmyra fiber at 8 μm [31], sisal fiber at 1.26-1.33 μm [31], banana fiber at 50-250 μm [32], and bamboo fiber at 240-330 μm [32]. Kithul fiber, derived from the *Caryota urens* tree in Sri Lanka and South Asia, has a higher diameter due to its robust and tall structure, large cross-sectional area, and age of the tree. The unique and larger diameter makes Kithul fibers suitable for applications requiring specific mechanical properties, such as reinforcing polymer composites and structural materials.

Density Natural fiber adds the qualities of lightweight, biodegradability, and recyclability to the developing composite. So, comparing the densities of these natural fibers is significant [33, 28] [30]. The density of natural fiber may vary depending on the growth rate and the surrounding environment of the plant. However, the study identifies Kithul fiber with a density of $0.904\text{g}/\text{cm}^3$, a significant contrast compared to other natural fibers. The wide range of densities observed among natural fibers can be attributed to their distinct botanical origins, inherent structures, and processing methods. Coir fiber, with a density of $1.2\text{g}/\text{cm}^3$ [32], has a higher density due to its dense and compact structure derived from the coconut husk. Jute fiber, with a density range of 1.3 to $1.5\text{g}/\text{cm}^3$ [32], shows variability due to factors like jute plant variety and growth conditions. Bamboo fiber, with a density range of 0.6 to $1.1\text{g}/\text{cm}^3$ [32], shows the greatest diversity due to different bamboo species and fiber extraction techniques.

Sisal fiber, with a density of $1.45\text{g}/\text{cm}^3$ [34], is relatively denser due to its tough and rigid properties. Flax fiber, with a density of $1.5\text{g}/\text{cm}^3$ [34], demonstrates a similar density to sisal. These differences highlight the diversity of natural fibers and emphasize the importance of considering a wide range of materials for specific applications.

Water absorption Water absorption test results of Kithul fibers after soaking the samples in water after 2 hrs, 6 hrs, 10 hrs, 24 hrs, 48 hrs, 72 hrs, and 96 hrs display in Figure 8. Water absorption of Kithul fiber

from 0% to 46.90%. The water absorption percentage was gradually increased until 48 hrs to the percentage of 46.87%. After 48 hrs water absorption percentage was shown at a constant value.

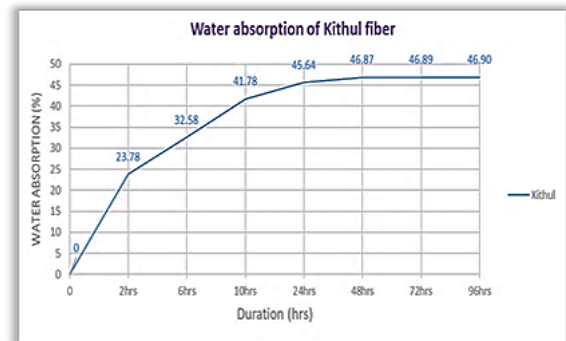


Figure 8: Results of the water absorption test

Kithul fiber has a water absorption rate of 46.87%, which is within the mid-range of other natural fibers. Cotton has a high water absorption rate, ranging from 32.5% to 50.5% [35], and due to its porous and hydrophilic nature. Areca fiber has the highest water absorption rate, with values ranging from 698% to 851% [36]. Banana fiber follows with a water absorption rate of 495% to 448.5% [7], indicating its propensity for moisture absorption. Pineapple fiber has a water absorption rate of 188% to 201% [35], indicating its moderate water uptake characteristics. Kithul fiber's water absorption rate is likely influenced by its fibrous structure and composition, which allows it to take up and retain a moderate amount of water. This makes it suitable for applications where controlled moisture absorption is desired. Cotton has the highest water absorption rate, making it suitable for textiles and clothing requiring comfort and breathability [15]. Areca fiber's high water absorption rate makes it a potential choice for moisture-regulating applications, such as bio-absorbable sponges or wound dressings [36]. Banana fiber's high water absorption rate may be used in industries where moisture retention is important, such as agricultural mulch or soil erosion control materials. Pineapple fiber's moderate water absorption rate may make it suitable for applications requiring a balance between water retention and controlled moisture release, such as nonwoven fabrics or food packaging [15]. Kithul fiber's moderate water absorption rate offers versatility for various applications requiring controlled moisture absorption. Its absorption characteristics could make it suitable for composite materials, packaging, and construction applications. Additionally, the moderate water absorption rate of Kithul fiber may contribute to its mechanical properties, impacting strength, stiffness, and durability in specific applications.

Tensile Strength Measuring the tensile strength of fibers is a key mechanical property to be observed in natural fibers. The test condition, properties of fiber dimensions, and, fiber-extracted species are some reasons for variations in the tensile values of natural fibers [22, 37]. The gauge lengths of the 30 Kithul fiber samples tested ranged from 1 cm to 5 cm. The Kithul fiber's ultimate tensile strength and Young's modulus were recorded as 25.6845 MPa and 2.416 GPa, respectively, in the current investigation.

Studies have shown that sisal fiber has a tensile strength of 268 MPa [38], while banana fiber has a range of 180-430 MPa [38], and coconut fiber has a range of 120-200 MPa. [38] Jute, hemp, and banana fibers have varying tensile strengths, with jute having a range of 393-800 MPa, hemp having a range of 690-1000 MPa, and banana fiber having a range of 500-700 MPa [39].

However, Kithul fiber has a significantly lower tensile strength of 25.6845 MPa, which is significantly lower than most other natural fibers. This lower strength can be attributed to factors such as its fibrous structure, chemical composition, and processing methods used during extraction. Kithul fiber may be limited in load-bearing or high-stress scenarios, but it is lower density and moderate water absorption rate make it suitable for certain applications, such as lightweight composite materials or textiles.

Properties of waste polyethylene

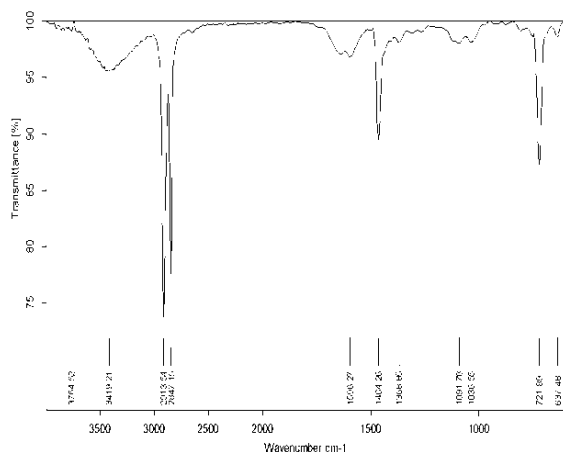


Figure 9: FTIR spectra of the waste polyethylene sample

Fourier Transform Infrared Analysis (FTIR) The Kithul fibers were characterized by their physical and mechanical properties. The average diameter and density of the Kithul fiber were $461.891\mu\text{m}$ and 0.904 g/cm^3 , respectively. Water absorption of the Kithul fiber ranged from 0% to 46.90%, with a gradual increase until 48 hours to 46.87%. The ultimate tensile strength and Young's modulus of the Kithul

fiber were recorded as 25.6845 MPa and 2.416 GPa, respectively.

HDPE is high-density polyethylene with a melting point ranging from 120°C to 140°C , depending on the grade and molecular weight. Its density is typically 0.93 to 0.97 g/cm^3 , making it denser than other polyethylene types [40]. The melt flow index (MFI) measures the polymer's flow ability at specific temperatures and loads. HDPE comes in various particle sizes, such as pellets, granules, and powders, and its tensile strength is typically 20 to 37 MPa, which can vary depending on the grade and processing conditions. Its flexural modulus measures a material's stiffness [41, 4].

Properties of composite materials

This section will elaborate on the properties of the composite material by accessing the tensile and bending strength of the developed Kithul: polyethylene composite.

Tensile Strength of Composite The variation of tensile strength of composite board versus the Kithul fraction that is applied to create composites is graphically represented in Figure 10. The results show that when the Kithul fraction increases, tensile strength increases up to 10%, and as Kithul fiber content increases further, the values begin to decrease. This is because Kithul fibers and the polymer matrix have weak interfacial adhesion [22]. The maximum tensile strength can be observed when the Kithul fiber content is 10% (10%:90% Kithul: polyethylene ratio) and it is 15.45 N/mm^2 .

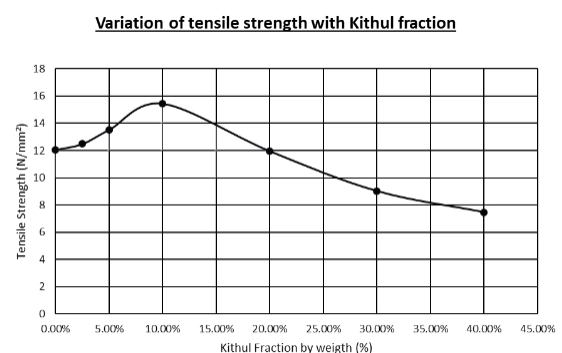


Figure 10: Tensile strength variation of the Kithul fraction (%)

Dharmaratne, et al.[22] investigated the effect of the tensile strength of composites with varying different coir weight fractions and found that the maximum tensile strength of 6.75 N/mm^2 occurs when the coir weight fraction is between 20% and 30% of the total weight [22]. Another investigation was done to determine the tensile characteristics of a composite

made of polyethylene and sisal fiber with a 30% fiber loading. 5.8 mm of length were arranged. According to their findings, the final tensile strength was 14.7 N/mm². This study insults that, the tensile strength observed for the developed composite material is very close to the tensile strength of sisal fiber composite. These studies suggest that the tensile strength will be significantly impacted by the type of fiber [42].

Flexural strength of composite Figure 11 illustrates the variations in flexural strength as a function of Kithul fraction by weight. With an increase in the Kithul fraction, the flexural strength increases, and as the Kithul fraction increases further, it begins to decrease. When Kithul fiber content is 10% (10%:90% Kithul: polyethylene ratio), the maximum flexural strength of 22.959 N/mm² is observed.

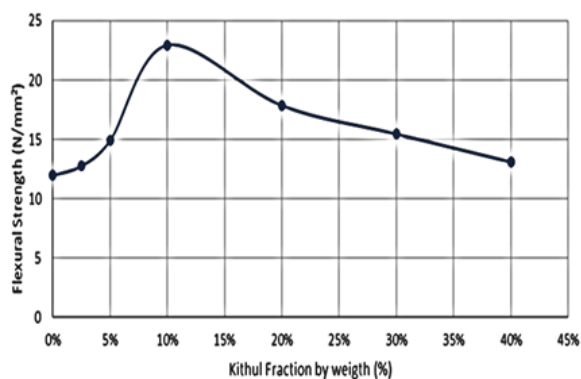


Figure 11: Flexural strength variation of the Kithul fraction (%)

Dharmaratne, et al.[22] investigated, the flexural properties of coir fiber reinforced composites are 29.85 N/mm² occurs when the coir weight fraction is 25%. This study reviles that, the flexural strength observed for the developed composite material is very close to the coir fiber-reinforced composite. Kumar, et al. [7] studied the flexural strength of the 8mm untreated Kenaf fiber composite as 139.5 N/mm² and the composite with treated 4mm fiber has shown the highest flexural strength of 166.2 N/mm² [43]. This indicates flexural strength of the Kithul fiber reinforced composite is comparatively low than the Kenaf fiber-reinforced composites.

Conclusion

This research investigated the use of Kithul fiber-reinforced waste thermoplastic composites for building materials. The composites were developed by varying the amount of waste polyethylene added to the fiber content, and their tensile strength and flexural strength were tested. The highest tensile and flexural strength was obtained in lower fiber content

with a ratio of 10%: 90%, Kithul fiber: polyethylene. The Kithul fiber composite has a maximum tensile strength of 15.45 N/mm² and a maximum flexural strength of 22.959 N/mm². When the Kithul weight fraction is 10% of the overall weight, the optimum results are exhibited in both tensile and flexural strength.

The Kithul fibers were characterized by their physical and mechanical properties. The average diameter and density of the Kithul fiber were 461.891 μm and 0.904 g/cm³, respectively. Water absorption of the Kithul fiber ranged from 0% to 46.90%, with a gradual increase until 48 hours to 46.87%. The ultimate tensile strength and Young's modulus of the Kithul fiber were recorded as 25.6845 MPa and 2.416 GPa, respectively.

The durability of Kithul fiber is understood according to previous studies, which show that it can be decreased by fiber deboning, corroded fibers, and exposure conditions. Natural fibers have less durability than synthetic fibers, but bonding with the polymer can increase durability.

The composite material generated in this study could be utilized as a building material with further development. However, the final application of this product cannot yet be defined, and further studies are suggested to finalize its application. The total cost for a 1m² board is approximately 150 LKR, as all raw materials are waste materials.

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