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Bestow Pre-Garments Waste Second Life by Converting into a Composite

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Abstract. *The pre-garment waste consisting of offcuts, trimmings, and rejected materials generated by the garment industry has become a growing concern. Recent trends in sustainability have found a way to convert this garment waste into composite materials, offering a second life to discarded textiles. This study focuses on developing waste-based composite materials by using garment waste as reinforcement and virgin polypropylene as the matrix. The resulting composites serve as effective alternatives to conventional wood-based materials, as demonstrated through a series of mechanical property analyses. The composites were developed using a compression molding technique, and their mechanical properties—including tensile strength, elongation at break, and water absorption—were evaluated. Tensile strength tests were conducted using a universal tensile strength machine at 10 mm/min, while water absorption was assessed by immersing the specimens in water for 2 hours. A waste-based composite panel with a fiber-to-matrix ratio of 40:60 exhibited a maximum tensile strength of 31.6 N/mm², and its water absorption was recorded at 11%. Another composite sample with a 50:50 fiber-to-matrix ratio showed lower tensile strength (20.7 N/mm²) but greater elongation at break. The study demonstrates that the mechanical and physical characteristics of these waste-based composites are comparable to those of commercially available oriented strand boards (OSB) and plywood. With a tensile strength range of 31.6 N/mm², the waste-based composite panels can be used for false ceilings, hardboards, wall coverings, and even fashion applications. The development of such materials presents a promising solution to reduce environmental pollution while providing a practical method for recycling garment waste into sustainable, durable products.*
Keywords: *Pre-garments waste; Recycle; Polypropylene film; Non-woven; Matrix.*

Type of the Paper: Regular Article

1. Introduction

The fashion industry is an important part of the economy, with a value of more than 2.5 trillion USD and employing over 75 million people worldwide. This sector has shown spectacular

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growth over the past decades, as clothing production doubled between 2000 and 2014. The manufacturing of RMG and textiles has expanded globally. It will eventually have an upward trend. We can create a graphic trendline to show how fashion varies with the seasons. the release of new products and concepts Now that fast fashion is in vogue, most firms are concentrating on raising output levels for this sector, which in turn raises output levels for textile and RMG items. In the case of fast fashion, costs are minimal and the lifespan of the items is short. As a result, there is more clothing in the trash than usual in landfills and burning. Fast fashion's primary raw materials are plastic or synthetic fibers, which take decades to degrade. According to a report by UNEP, approximately 60% of all materials used by the fashion industry are made from synthetic raw materials [1].

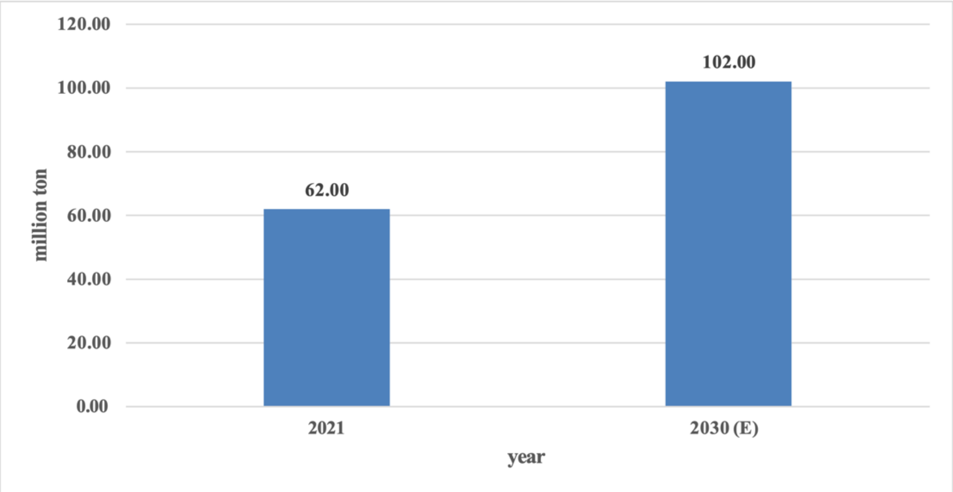

Fig. 1. Global apparel consumption

The environment is greatly impacted by the fashion industry itself. It generates 20% of the world's wastewater, 10% of the carbon emissions, and enormous volumes of garbage. One garbage truck load of textiles is landfilled or burned every second. In addition, the plastic from our garments is poisoning the seas [1].

Production, distribution, wear, and disposal of clothing as well as the extraction of basic materials, all have a significant influence on the environment. Every week, several clothes retailers provide new styles. According to the Ellen MacArthur Foundation, 50 billion new clothes were produced in 2000. Over 20 years later, that number has increased by half. The frantic speed of garment production has also sped up consumption. According to the data, the average individual now purchases 60% more clothes than they did in 2000 [2]. They not only purchase more, but they also dispose of more than before. The worldwide consumption of clothes will increase from 62 million metric tons in 2019 to 102 million tons in 10 years assuming demographic and lifestyle trends remain the same [2].

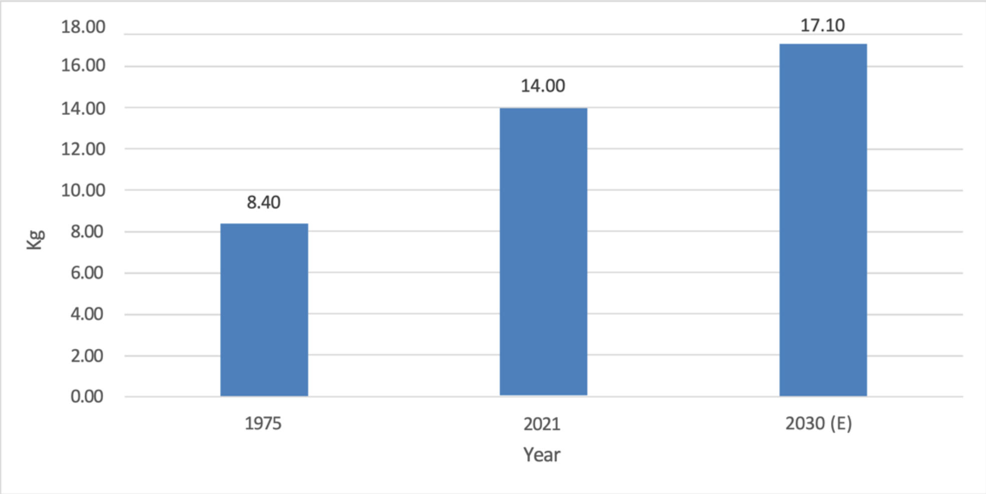

Fig. 2. Textile fiber consumption per person in a year [3]

From the perspective of textile products consumption per person each year, it has been shown that increasing the consumption from its introduction. Annually worldwide economic conditions are developing, and as a common formula buying capacity is increasing which is proportional to income [3].

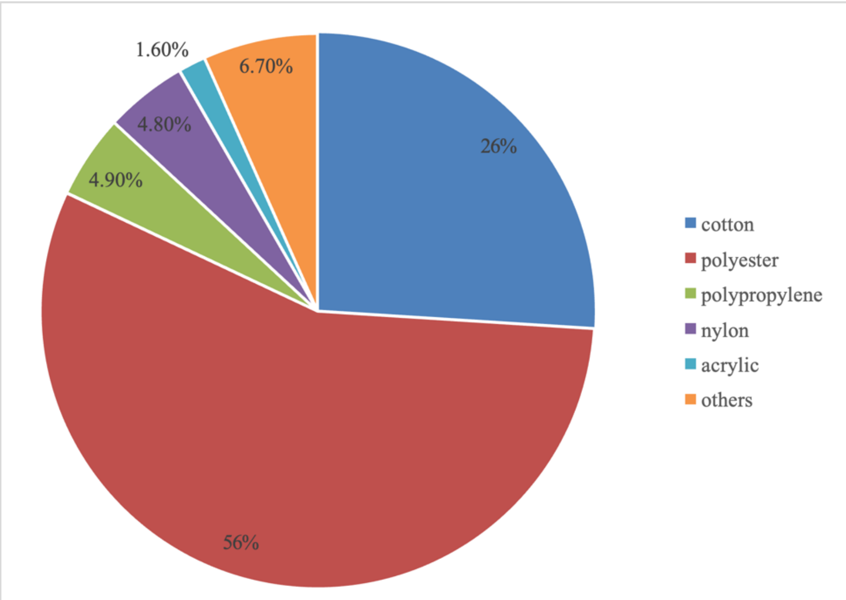

Fig. 3. Worldwide fiber consumption

According to Wood Mackenzie's fibers worldwide demand & supply study, polyester accounts for 56% of global fiber consumption, polypropylene 4.9%, nylon 4.8%, acrylic 1.6%, cotton 26%, and other fibers make the remaining [4].

Recycling is one approach to find a solution to this issue. In this research, we will try to develop a composite from pre-garments waste with a specific matrix. Nowadays demand of composite materials for different applications is increasing due to the high strength to weight ratio, more durability, versatile design facilities, and so on. It will help to reduce garments waste. Additionally, apart from its ecofriendly behaviour consistently offers an affordable composite product that is comparable with the commercially existing plywood and oriented stranded board [5].

Depending on the source, the majority of fibers can be classified as either natural or synthetic. Composite materials that contain both natural and synthetic fibers have attracted the attention of many scientists. Each of these fibers, however, has benefits and drawbacks [6]. Synthetic fiber- bonded thermoplastic composites surpass natural fibers in terms of mechanical performance. However, they are not eco-friendly. In this study, we utilized non-specific cloth to create a waste- based composite that was easy to use and affordable.

A composite is a unique kind of substance made up of two or more components that have been macroscopically combined and bonded. In general, reinforcing materials (fibers, particles, etc.) incorporated in a matrix make up a fiber-reinforced composite material (polymers, metals, ceramics, etc.) [7]. The reinforcement is held in place by the matrix, and the matrix's overall mechanical qualities are enhanced by the reinforced material [7].

Recycling used clothing also helps to safeguard the environment. Recycling pre- and post-garment waste eliminates the need for landfills and lowers the amount of carbon dioxide and other hazardous gases released into the atmosphere when garbage is burned or decomposed. Landfills put water supplies and the environment in danger. When it rains, water comes into touch with hazardous substances and bleaches as it flows through the garbage from abandoned clothing. It poisons the crystal-clean water. Natural fibers often provide less of a concern to the environment and readily decompose [5]. However, synthetic fabrics are difficult to break down. It is more harmful to the environment and human health since it takes decades to degrade. Recycled garments waste as composite uses less energy because it doesn't need to be colored. Consequently, it helps to lessen the use of dyes and chemicals, pesticides, water, mechanical processes, and intermediate chemicals that are necessary for their manufacturing and, in turn, lessens the impact of garment waste on the environment.

A considerable amount of literature has been published on reusing textile waste. However, there has been relatively little literature published on reusing garments waste in composites. Several studies have revealed waste recovery and current recycling in the composite world. Some researchers tried to develop textile waste-based composites. The main problem was compatibility and adhesiveness between the resin and fibers. This is because the textile waste properties were composed of different fibers such as polyester, cotton, wool, and acrylic. Many studies have considered the relationship between the type of matrix used [8,9].

Another study investigated three concepts for the reuse of cotton/PET fabrics for composites: compression molding above the Tm of PETs, the use of a matrix derived from renewable soybean oil, and the use of thermoplastic polyester bi-component fibers as matrix [10]. They used non-woven bi-component fabric and soybean resin which are slightly different from our materials.

To find possibilities of recycling, another study aimed to produce composites employing thermoset resins (epoxy) reinforced with recycled woven textile materials (denim fabric and hessian fabric bags) [11]. But epoxy resins are relatively costly, take a long curing time and have handling difficulties.

A comparative study manufactured a fabric consisting of 50% pineapple, 25% jute, and 25% cotton fibers by weight, to make composites using polypropylene (PP) as a matrix material [12]. The limitation of this study is the reduced mechanical properties observed due to the addition of jute and cotton fiber.

Detailed examination of a similar study by the researchers of the University of Minho, Portugal showed low mechanical properties [13]. A randomized controlled study of waste cotton fabric reinforced polymer matrix composite plate has been processed. Two different (12.5% and 25% by weight) waste fabric-reinforced composite plates were produced [14]. They have used high-density polyethylene as a matrix but polypropylene composites are stronger, clearer, and more resistant to chemicals, high temperatures, and scratches than polyethylene.

A team of researchers in Romania worked with a new composite material that is formed by using textile wastes as a reinforcement structure and a combination of bi-oriented polypropylene films (BOPP) waste, polypropylene non-woven materials (TNT) waste, and virgin polypropylene fibers (PP) as a matrix [15]. The use of virgin polypropylene fibers as a matrix brings no advantage compared to bi-oriented polypropylene film waste and polypropylene non-woven materials waste.

2. Materials and methods

2.1. Materials

This research aims to develop a useable waste-based composite material that is comparable with the existing commercially available OSB and plywood board in the market. To develop this composite material, garment waste is used as reinforcement material and virgin polypropylene is used as the matrix.

2.1.1. Material for reinforcement

The reinforcement consists of non-specific fibers such as **cotton, polyester, nylon, acrylic, viscose, wool**, and various fabric types (woven, knit, braided, and non-woven) from garments waste. Through the several assessment of fabric particles acts as reinforcement materials to provide structure and strength, aided by the thermoplastic resin polypropylene.

Fig. 4. Pre-garments waste

2.1.2. Matrix phase:

Thermoplastic polypropylene polymer serves as the matrix material due to its high glass transition temperature, flex resistance, low water absorption, and good electrical resistance. Its lightweight, non-toxic nature and high strength-to-weight ratio enhance both the quality and durability of the final composite product [6,16].

2.1.3. Hydraulic hot press machine:

The hydraulic hot press machine (Model 38914NE100, CARVER, USA), used for producing composite boards from garment waste and polypropylene, features 20 cm × 20 cm plates, a temperature capacity of up to 280°C, and a pressing force range of 0–25 bar. It includes water and air-cooling systems for efficient operation.

Fig. 5. hydraulic hot press machine

2.1.4. Other materials

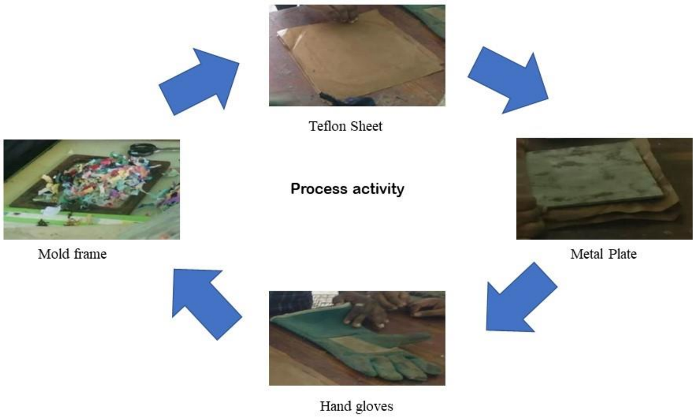

Fig. 6. The preparation of garments waste based composite panel

The process of preparing garment waste-based composite boards begins with a mold frame that has outer dimensions of 180 mm x 180 mm x 4 mm and inner dimensions of 175 mm x 175 mm x 4 mm. Two metallic plates (180 mm x 180 mm x 2 mm) are placed inside the mold to shape the composite material. Teflon sheets, which can endure high temperatures, are used to ensure that the resin does not stick to the mold. Pre-cut garment waste and polypropylene are layered into the mold, and the frame is loaded into a hydraulic hot press machine. The pressing parameters (temperature, pressure, and time) are adjusted, and the heated plates compress the materials into a uniform board. Throughout the process, heat-insulated gloves are used to handle the equipment and materials, ensuring safety when working with the hot press machine. The result is a solid waste-based composite board that maintains the shape and integrity set by the mold.

2.2. Composite Fabrication

In this research to produce a waste-based composite we have used the compression molding technique. The development of waste-based composite by utilizing garments waste and polypropylene is described stepwise in the following section.

- Initially, pre-garment waste is collected from tailoring shops, washed, and dried in the sun.
- Garment waste is cut into small pieces by scissors so that the matrix content can easily penetrate throughout every fabric piece and assist in developing a uniform board and maximum strength.

Fig. 7. Pre-garments waste (a) Before cutting (b) After cutting into small pieces

- To make a good composite, the application method of the matrix is a crucial point. In this attempt, from polypropylene chips polypropylene sheet was made at 180^0 C for 90 seconds by using the mentioned hydraulic hot press machine.

Fig. 8. Matrix (a) Polypropylene chips (b) Polypropylene sheet

- The main controlling parameters for producing waste-based composite boards are time, temperature, and pressure

Table 1. Different parameters of garments waste-based composite

Sample No.	Fabric: Matrix ratio	Temperature (^{0} C)	Time (min)	Pressing force (N/cm^2)

1	40: 60	180	15	147
2	40: 60	180	15	208.25
3	50: 50	180	15	208.25

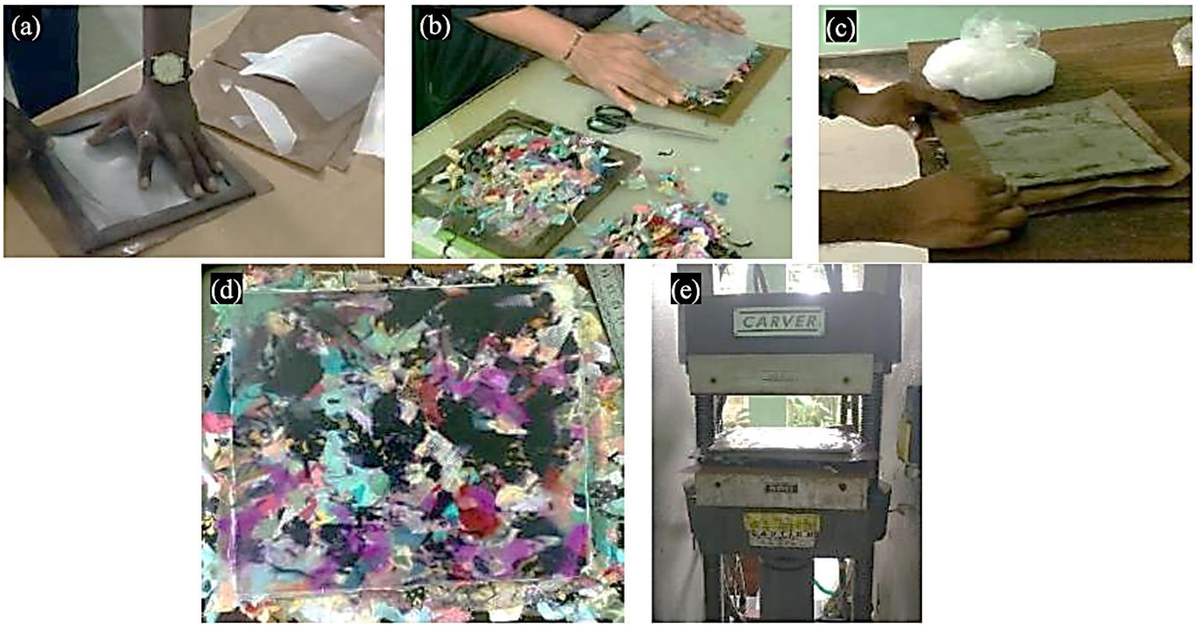

Fig. 9. (a) arranging polypropylene sheet in mold frame (b) making layer of fabric pieces and polypropylene sheet (c) preparing the mold frame for machine loading (d) loading the mold frame in hydraulic hot press machine (e) machine output, waste-based composite board

2.3. Characterizations

Tensile strength, elongation at break, and water absorbency tests were done to determine the performance of the waste-based composite and also assist in comparing it with the existing commercially available plywood and oriented strand board (OSB). Specimens were cut according to the specific testing method. Specimens were stored in a specific environment. Specimens were conditioned at 21± 2^0 C and in 50±5 % relative humidity for 24 hours.

These all tests are done in ITS Lab test Bangladesh Limited. They have used their own developed in-house method to perform the tests such as tensile strength, elongation at break, and water absorbency.

2.3.1. Tensile Strength

It was tested using a universal tensile strength machine. The maximum machine speed is 100 ±10 mm/min. During the test, the m/c speed was 10 mm/min. The sample size was 100 mm x 10 mm and the load cell capacity was 5 KN. Two different samples were tested, one in parallel and another one in a perpendicular direction concerning the machine application method.

2.3.2. Elongation at Break

This test is done using a universal testing machine. During the test, the machine speed was 10 mm/min, the distance between two clamps was 50 mm, and the sample size was 100 mm x 10 mm.

2.3.3. Water Absorbency

This test was done to determine how much water can absorb this waste-based composite in a specific environment within a certain period. For water absorbency, the sample size was 25.4 mm x 25.4 mm. It is immersed in 100 ml of water in a 250 ml beaker. It is kept in that situation for the next 2 hours. Three specimens per sample were tested to determine the average value of each sample.

3. Results and Discussion

The Table 2 represents the tensile strength of sample A and sample B as per direction, It has been determined through analysis of the data in the table that sample A has a higher tensile strength than sample B. Analyzing the fabric-to-matrix ratio reveals that sample A's matrix component is 10% more than sample B's. Cut fabric fragments have been employed as reinforcing materials and polypropylene has been used as a matrix in this effort to create a waste-based composite. The separated pieces of fabric are unconnected to one another. The matrix component helps to link the cut pieces and create a bridge between them, which in turn helps to increase the composite material's strength. There will be more joins between the fabric parts and an upper bound on the number of internal bonds if there are more matrix components. Because of this, sample A possesses greater tensile strength than sample B [17].

Table 2. Tensile strength of waste-based composite in the parallel direction

Sample	Fabric: matrix	Pressing time (min)	Pressing temperature (^{0}C)	Pressing force (N/cm^2)	Tensile strength (N/mm^2) In parallel direction
A	40:60	15	180	208.25	31.6
B	50:50	15	180	208.25	20.7

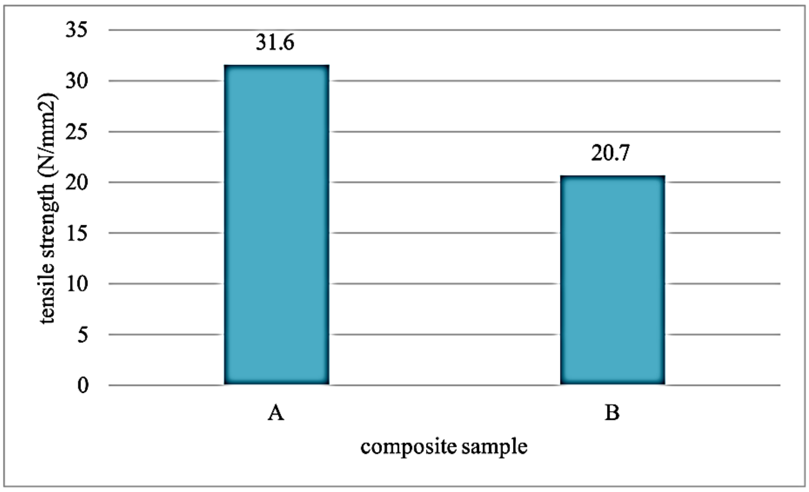

Fig. 10. Tensile strength of sample A and B (parallel direction)

The Table 3 represents the tensile strength from traverse direction, in this case, as in the previous one, sample A has a 10% higher matrix content than sample B. The greater the matrix content, the greater the tensile strength of any composite within a certain limit. This is the reason why sample A has a higher tensile strength than sample B [17]. In a parallel direction, the inner core of the bicomponent provides extra strength, which is why in a parallel direction every sample possesses high tensile strength [10].

Table 3. Tensile strength of waste-based composite in the traverse direction

Sample	Fabric: matrix	Pressing time (min)	Pressing temperature (^{0} C)	Pressing force (N/cm^2)	Tensile strength (N/mm^2) in traverse direction
A	40:60	15	180	208.25	31.6
B	50:50	15	180	208.25	20.7

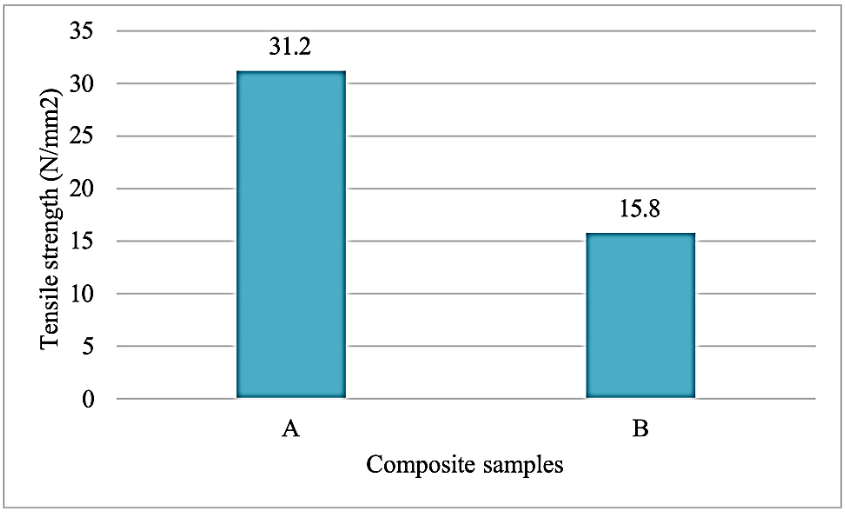

Fig. 11. Tensile strength of sample A and B (traverse direction)

The Table 4 represents the breaking elongation of both samples, in sample B, there is more elongation at the break in comparison to sample A in the parallel direction. The main reason is that sample B has 10% less matrix than sample A. That's why sample B has less connection among the reinforcement materials and also has less bonding among the reinforcement materials [17]. So, sample B is more prone to expand after applying pulling force. As a result, the elongation at break is greater in sample B than in sample A.

Table 4. Elongation at break of waste-based composite in a parallel direction for sample A and B

Sample	Fabric: matrix	Pressing time (min)	Pressing temperature (^{0} C)	Pressing force (N/cm^2)	Elongation at break (In parallel direction)
A	40:60	15	180	208.25	3.8%
B	50:50	15	180	208.25	4.7%

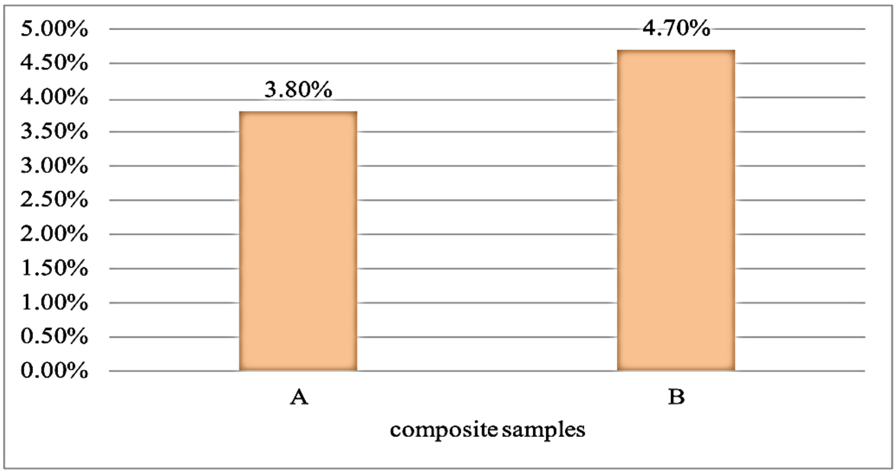

Fig. 12. Elongation at break of sample A and B (parallel direction)

In the perpendicular direction, sample B has more elongation at break than sample A. The reason is that sample B has 10% more matrix than sample A. That's why the interconnection of fiber reinforcement materials has less than sample A. So, sample B is more prone to expand than sample A when pulling force is applied. As a result, sample B has more elongation at break. In addition, samples A and B have more elongation at break in perpendicular directions compared to parallel directions because the inner core of a bicomponent gives less strength in perpendicular directions [10].

Table 5. Elongation at break of waste-based composite in the traverse direction

Sample	Fabric: matrix	Pressing time (min)	Pressing temperature (^{0} C)	Pressing force (N/cm^2)	Elongation at break (In traverse direction)
A	40:60	15	180	208.25	5.8%
B	50:50	15	180	208.25	6.5%

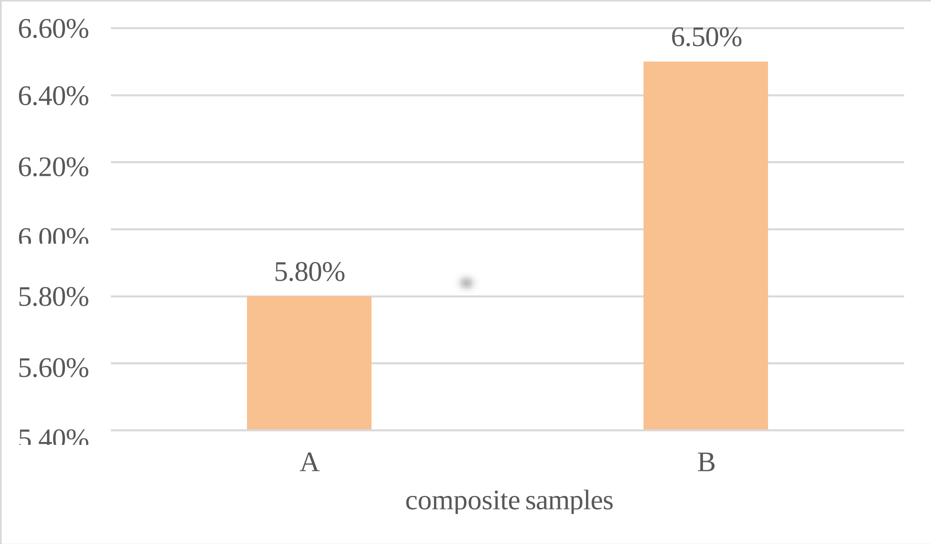

Fig. 13. Elongation at break of sample A and B (traverse direction)

This is the water absorbency test of sample A (represented as Table 6) determines water absorbency using for every sample 3 specimens were taken and coefficient of variation is too low which indicates the consistency of water absorbency by the sample A.

Table 6. Water absorption of waste-based composite (sample A)

Sample	Fabric: matrix	Pressing time (min)	Pressing temperature (^{0} C)	Pressing force (N/cm^2)	Water Absorbency	Mean	CV
A	40:60	15	180	208.25	11.0% 10.9% 11.1%	11%	0.909%

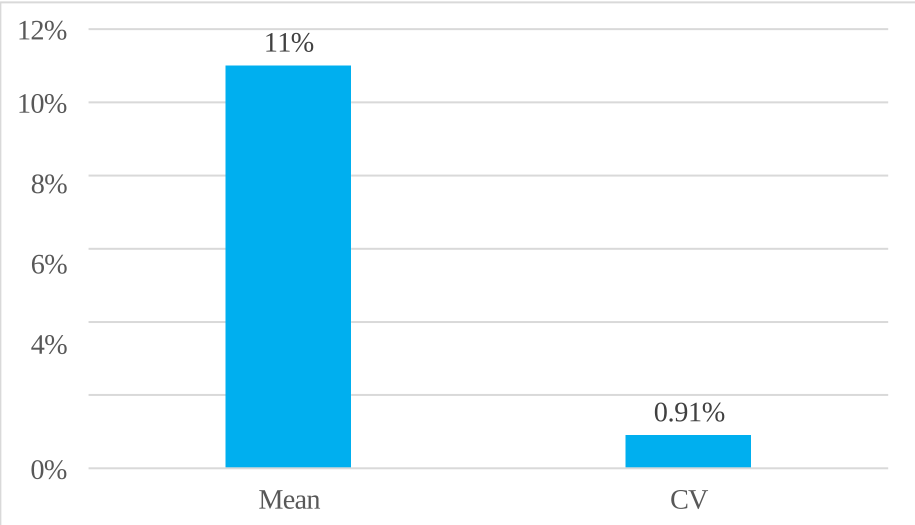

Fig. 14. Water absorption percentage of (sample A)

In Table 7 it represents the water absorption test of specimens to determine water observance, but the coefficient of variation of sample B is higher than sample A, which indicates sample B shows less consistency in the case of water absorbency.

Table 7. Water absorption of waste-based composite (sample B)

Sample	Fabric: matrix	Pressing time (min)	Pressing temperature (^{0}C)	Pressing force (N/cm^2)	Water Absorbency	Mean	CV
B	50:50	15	180	208.25	8.5% 8.3% 8.7%	8.5%	2.35%

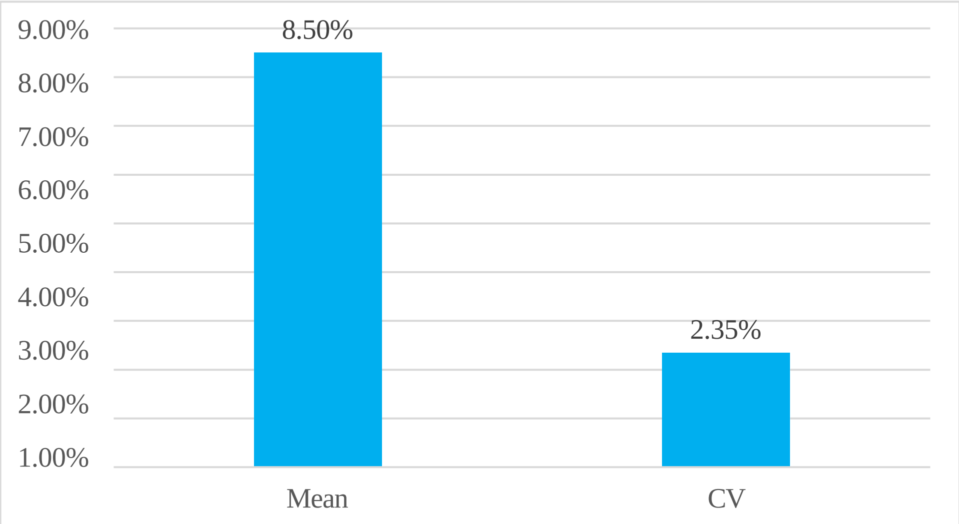

Fig. 15. Water absorption of (sample B)

In Table 8 it is represented as a coating of synthetic thermoplastic resin has been applied to both the upper and bottom sides of the composite, it will exhibit hydrophobicity. The hydrophilicity, which is mostly stored between the top and lower surface, can only be attributed to the presence of fiber-reinforcing material If the fiber reinforcing material's surface area rises, there will be a greater surface area to absorb water, which will result in increased water absorption [18]. Sample A has a 10% greater matrix content and 10% more polypropylene sheets than sample B, allowing for more layers and a larger overall surface area. This is the main factor that causes sample A to absorb more water than sample B.

Table 8. Water absorption of waste-based composite of (samples A and B)

Sample	Fabric: matrix	Pressing time (min)	Pressing temperature (^{0}C)	Pressing force (N/cm^2)	Water absorption
A	40:60	15	180	208.25	11%
B	50:50	15	180	208.25	8.5%

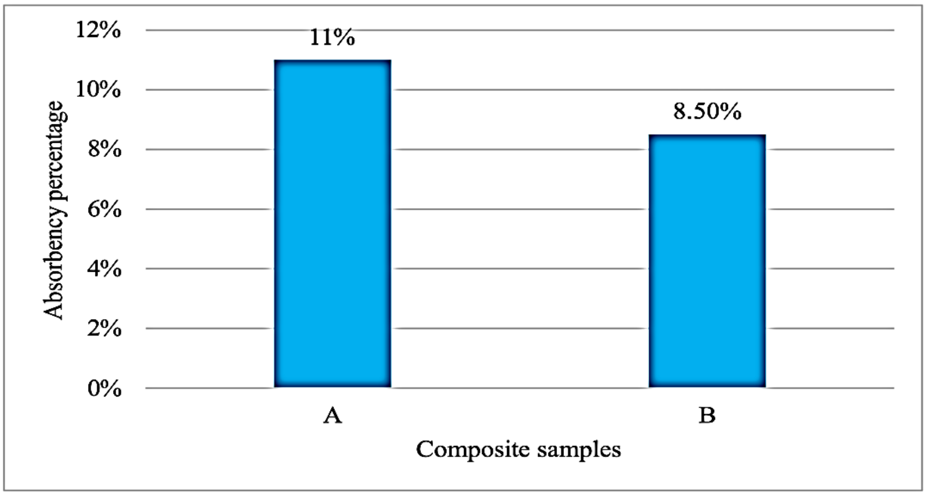

Fig. 16. water absorption percentage (sample A and B)

The Table 9 represents total summary of the tensile strength, density & water absorptions test, these results from of the waste-based composite of sample A are 31.4 N/mm^2, 1.163 g/cm^3, and 11%, respectively.

Tensile strength, density, and water absorption of the waste-based composite in sample B are 18.25 N/mm^2, 1.2275 g/cm^3, and 8.5%, respectively.

The tensile strength range for oriented strand board made from wood is 1000-1500 psi, or 6.89 N/mm2 to 10.342 N/mm2, and the tensile strength range for plywood made from wood is 1500- 4000 psi, or 10.342 N/mm2 to 27.57903 N/mm2 in the ASTM D350 method [19]. The water absorption of bamboo and wood based OSB composite varies from 27.01% to 73.60% due to the bamboo, wood, and resin combination [20]. The average density of the OSB composite is 0.72 g/cm3 [20]. When the same qualitative properties of waste composite and commercially available composite material are compared, it is clear that waste-based composite outperforms commercially available plywood and OSB.

Table 9. Tensile strength, density, and water absorption of waste-based composite (sample A and sample B)

Sample	Tensile strength (N/mm^2) Average of both direction	Density (g/cm^3)	Water absorption
A	31.4	1.163	11%
B	18.25	1.2275	8.5%

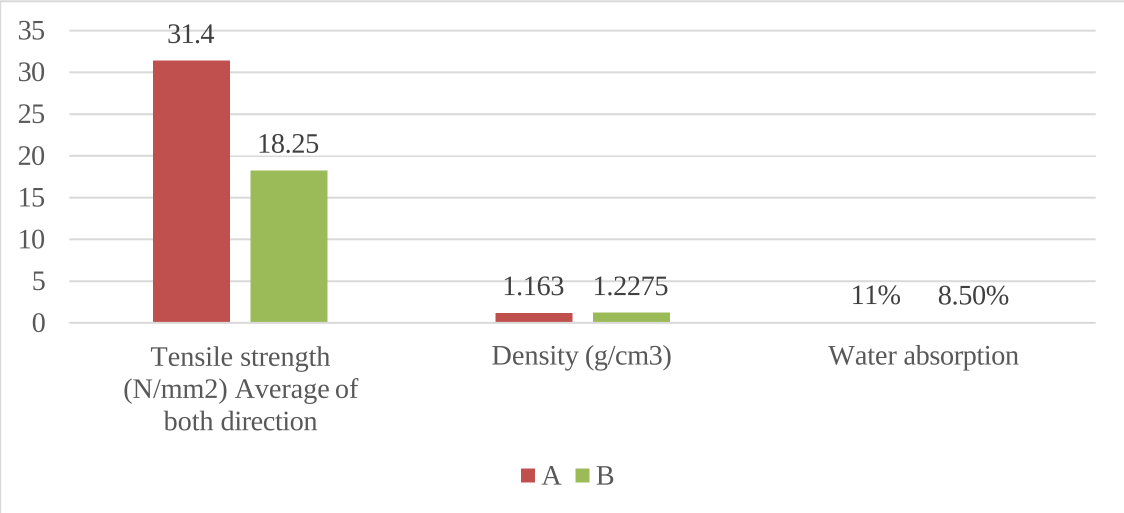

Fig. 17. Tensile strength, density and water absorption percentage of sample A and sample B

4. Conclusions

The primary focus of this research was to discover a method of recycling pre-garment waste that won't endanger the environment. To do this, composite materials from garments waste and polypropylene were created, and their characterization was examined. Although we are restricted to explore various fiber-reinforcing materials and matrix combinations, complicating the data collection process Our composite materials may be utilized as wall coverings, fake ceiling boards, OSB, hardboard, and decorative applications. Tensile strength, elongation at break, water absorbency, and density tests were carried out to characterize the created waste-based composite. When the matrix was more prevalent in the composite material, the results (tensile strength, elongation at break) were favorable. The link between the fiber reinforcement materials will be improved by the matrix. Additionally, it shows that the characteristics of composite materials may be altered by the matrix- to-fiber reinforcement materials ratio. From an application standpoint, it indicates that composite materials offer a great deal of versatility. However, since the composite is made from pre-garments waste as raw material, there is no added expense for the reinforcement material. Consequently, the composite material is very affordable. From an economic standpoint, it balances out the costs and benefits.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Md Sajid Hossain & Nafis Ahtasum: Original idea, Methodology, Conceptualization, Supervision, Formal analysis, writing – review & editing; MD. Mahmudul Hasan, MD. Zakir Hossan Imran, Monjur E Mowla Jim, krishno Roy, Md. Jakaria, Nusrat Jahan: Investigation, Sampling, Data generation, Visualization, Resources, making illustrations, writing—original draft preparation and reference management.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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