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Determining the Potential of Layered Banana Fibre Weave Patterns for Enhanced Blast Resistance in Bomb Blankets

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ABSTRACT

The banana fibre is part of research aimed at creating materials for weaving bomb blankets. To determine whether plain and intra-ply woven banana fibre designs are feasible and effective in enhancing blast resistance, the primary purpose of this research is to analyse the practicability and efficiency of these designs. The method begins with extracting banana fibres, followed by applying an alkali treatment to enhance the mechanical properties of the fibres, and finally concludes with weaving the fibres into plain and intra-ply patterns. The scanning electron microscopy (SEM) technique was utilized to analyse the surface morphology and assess any damage that occurred as a result of the blast. Based on the findings, it was shown that plain woven banana fibres demonstrated greater tensile strength (7.39 MPa) and energy absorption (11,772 J) compared to intra-ply woven patterns. The SEM analysis indicated that plain woven fibres had a lower number of surface flaws, highlighting their increased resistance to explosive forces. In conclusion, plain woven banana fibres have significant potential to serve as an alternative to synthetic materials for blast-resistant applications. This alternative is not only cost-effective but also environmentally friendly. Therefore, it is possible for them to meet standards in terms of both environmental sustainability and security.

Keywords: Banana Fibre, Blast Resistance, Woven Pattern, Tensile Strength, Environmental Sustainability.

1. INTRODUCTION

Considering the current security situation, the necessity for effective blast protection is becoming an increasingly significant issue. In the process of mitigating the impacts of explosive devices on the surrounding environment, bomb blankets are crucial equipment used in this approach. Bomb blankets can contain and strengthen the impacts of a blast because their barrier, which is not only portable but also flexible [1]. Synthetic composites such as Kevlar and Aramid fibres, along with other materials known for their strength and durability, are utilised in the production process of these blankets [2]. Although synthetic materials are capable of fulfilling bomb blanket functions efficiently, these materials also come with several significant disadvantages, such as high costs and environmental difficulties associated with their manufacture and disposal. These disadvantages highlight that these materials are capable of providing blast resistance.

In recent years, banana fibre, extracted from the pseudo-stem of the banana plant, has emerged as a substance that has the potential to be an alternative material. The natural banana fibre possesses an extensive choice of good mechanical properties, such as its tensile strength, flexibility, and resistance to application [3]. Additionally, banana fibres are abundant and renewable, making them an appealing option for producing environmentally friendly composite

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materials [4]. The characteristics of banana fibres present several that should be taken as an alternative for bomb blankets.

The plain weave, which is also sometimes referred to as a tabby weave, is one of the most fundamental and extensively used types of weaving patterns [5]. Being comprised of each weft yarn going over and beneath each warp yarn in sequential sequence, the structure is straightforward and well-balanced. It is common knowledge that this pattern has been able to endure the passage of time, continue to be stable, and continue to be consistent. As a result of its resilience to wear and tear, it is frequently utilised in the manufacturing of textiles as well as other types of materials.

It is essential to interlace a significant number of yarns within the same ply of respective materials in order to make intra-ply weaves, which are more detailed than other types of weaves [6]. Additionally, this pattern has the potential to deliver benefits such as enhanced strength and flexibility, as well as resistance to stretching. Through the utilisation of an intra-ply weave, it is feasible to significantly enhance the mechanical properties of the material, including its tensile strength and stiffness. The intra-ply weave makes it possible for a bigger surface area contact to be made between the yarns, which is the reason for this.

Plain weaves and intra-ply weaves were selected so that a comparison could be made between the structural performance of the two types of weaves when applied to banana fibres. Due to the ease with which it may be constructed and the uncomplicated nature of its construction, the plain weave is utilised to establish a baseline. The intra-ply weave is expected to result in a mechanical property, which will increase strength and durability when subjected to a blast test. This experiment is probable to obtain a more detailed understanding of which weave gives the optimum performance during blast test and the best use to manufacture protective materials like bomb blankets.

The first objective of this study is to investigate the feasibility of using banana fibre for blast protection applications. The second objective focuses on examining how various weave patterns of stacked banana fibres enhance the material's resistance to blasts. This research aims to evaluate bomb blankets in terms of structural integrity, energy absorption, and overall performance. It has been demonstrated that banana fibres can effectively strengthen bomb blankets.

This research not only evaluates the technical performance of banana fibre composites in explosion scenarios but also considers the wider consequences associated with the use of natural fibres in security applications. To ensure the results of this study are accurate and reliable, rigorous testing was performed. Alternatively, the application of this technology is likely to lead to the production of protective materials that are less damaging to the environment and more cost-effective.

2. MATERIAL AND METHOD

2.1 Banana Fibre Extraction

Fresh banana pseudo-stems are the primary raw material, ensuring environmental cleanliness and preventing contamination from the utilisation of this material [7]. The preparation process for the pseudo-stems begins by placing them on a clean surface and cutting the banana fibre into smaller chunks, as shown in Figure 1. After it is done, the pseudo-stems are cut into strips of size 4 cm x 45 cm, as shown in Figure 2. Removing fibres requires manually scraping the soft material from these strips using knives until complete. This is a critical stage at the beginning of the process. The fibrous substance is carefully separated from any fleshy residue left behind throughout this step, which is carried out to achieve the previously mentioned goal. Following this, fibre is categorised into distinct groups according to quality parameters such as length and texture. The fibres are then prepared for drying by hanging or laying them flat in a warm environment with adequate air ventilation. This action is performed to protect fibre integrity and avoid potential damage.

Figure 1: Extract fibre into small strips.

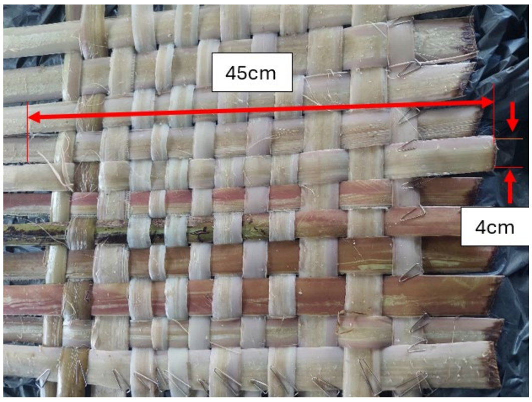

Figure 2: Size fibre strips.

2.2 Weave Patterns

These characteristics of these fibres can impact the material in various ways. Figure 3 shows how different weave patterns, such as plain, basket, herringbone, and banana-jute intra-ply, affect the mechanical properties and vibrational behaviour of fabrics [8]. For example, plain and intra-ply weaves are particularly well-known for their powerful tensile capabilities, making them suitable for applications that demand high durability and resistance to external loads. The plain and intra-ply weave is characterised by several distinguishing traits, including simplicity and uniformity, which contribute to balanced strengthening and stability. Additionally, this weave may enhance energy absorption and vibration-damping potential. For this blast test, two types of weaving were chosen, which are plain and intra-ply types, as shown in Figure 4. By examining various weaving procedures, it becomes clear that the design choice significantly influences the material's suitability for bomb blanket applications. Specifically, this research will focus on evaluating the influence of plain weave patterns on materials. This category of fabric is particularly well-suited for blast test protection in bomb blankets because certain fabrics perform exceptionally well in strain testing, underscoring their effectiveness in such applications.

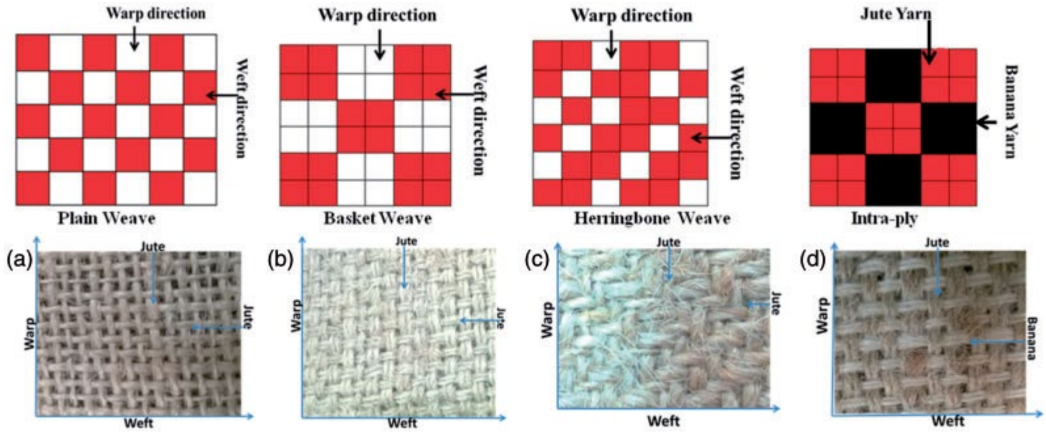

Figure 3: Type of Weave Patterns [8].

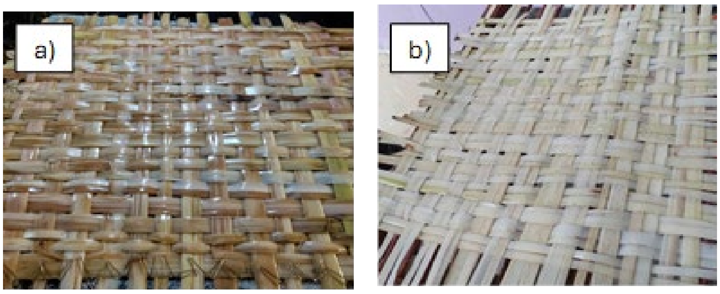

Figure 4: a) Plain Woven Pattern and b) Intra-ply Pattern.

2.3 Alkali Treatments

Alkali treatment, also known as mercerisation, is a procedure frequently utilised for the surface modification of natural fibres, such as banana fibres, to enhance fibre qualities for more complex applications, including bomb blankets [9]. In this process, banana fibres are subjected to an alkaline solution, typically sodium hydroxide (NaOH), which is shown in Figure 5 [10]. This treatment effectively removes multiple pollutants from the fiber surfaces, including lignin, hemicellulose, and natural oils. This treatment also eliminates a variety of other contaminants. The fibres can adhere more effectively to the environment when incorporated into a composite material, leading to improved adhesion [11].

As a result of alkali treatment, the tensile strength, stiffness, and thermal stability of fibres are enhanced. It is necessary for bomb blankets to possess all of these qualities to withstand high-impact forces and shrapnel. The treatment also reduces the hydrophilicity of the fibres, which in turn decreases the moisture absorption capacity [12]. The technique also results in lighter fibres by removing unnecessary components, contributing to a total reduction in the weight of bomb blankets without compromising performance. The application of alkali treatment during the production of bomb blankets enhances the material's mechanical and thermal properties, as well as contributes to the material's cost-effectiveness and sustainability [13]. Figure 6 shows the banana fibre after alkali treatment.

It is generally approved that this treatment offers some of the most significant benefits and advantages. The tensile strength of the material is improved when non-cellulosic components that operate as a barrier to the development of fiber connections are removed. There is a correlation between the removal of these components and the improvement in the material's tensile strength. Also, the elimination of pollutants results in an increase in the stiffness of banana fibres, which in turn leads to an improvement in the structural stability and rigidity of the banana fibres [14]. The alkali treatment not only enhances the mechanical qualities of the fibre, but also increases the fibre's resistance to water and decreases the fibre's susceptibility to microbial corrosion [15]. In other words, the alkali treatment improves the fibre's mechanical properties.

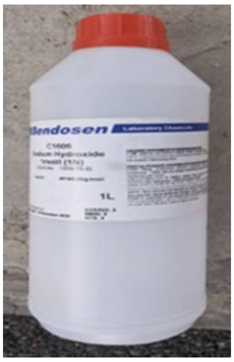

Figure 5: Sodium Hydroxide (NaOH).

Figure 6: Banana Fibre after Alkali Treatment.

2.4 Explosive Charge

An explosive substance known as Emulsion High Explosive, specifically a commercial grade, was utilised in a blast test. The test involved 40 g of the explosive subject to blast against two different weavings of banana fibre. The Velocity of Detonation (VOD) ranged from 4500 m/s to 5700 m/s, with an explosive energy of 4.17 MJ/kg and a density that ranged from 1.13 g/cc to 1.21 g/cc. Detonator No. 8 was used as the initiator during this test, and Figure 7 shows the Assembly of Explosive.

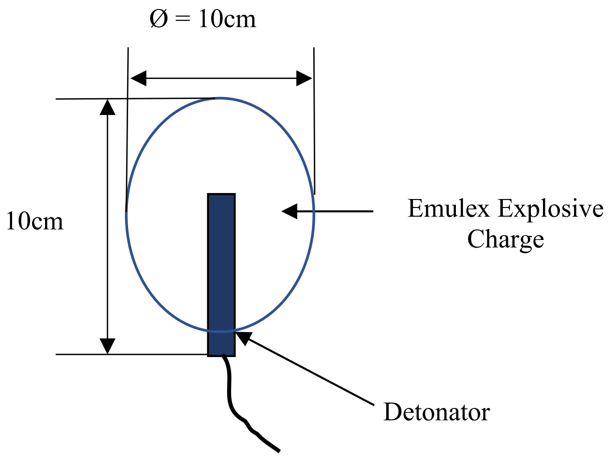

Figure 7: Assembly of Explosive.

2.5 Test Setup

To achieve a comprehensive understanding of banana fibre's mechanical characteristics, optimisation outcomes, and its integration into bomb blankets, a systematic and multi-phased experimental design will be established. This setup uses two methods to measure blast loading through an instrument method [16]. This setup is similar to a jig, where aluminium is used as a medium to capture blast loading. This experiment requires a modified setup placed at the height of 1 ft, with the booster charge positioned 1 ft above the banana fibre weaving, as illustrated in Figure 8. The 40 g of Emulex were blasted to two different weavings to determine which weaving would have more absorption blasts, while aluminium was used to capture the different blast loadings. After the blast, the fibres will be brought to the lab to measure the tensile test and monitored with a microscope to assess the banana fibre structure between the two types of weaving, as shown in Figure 9.

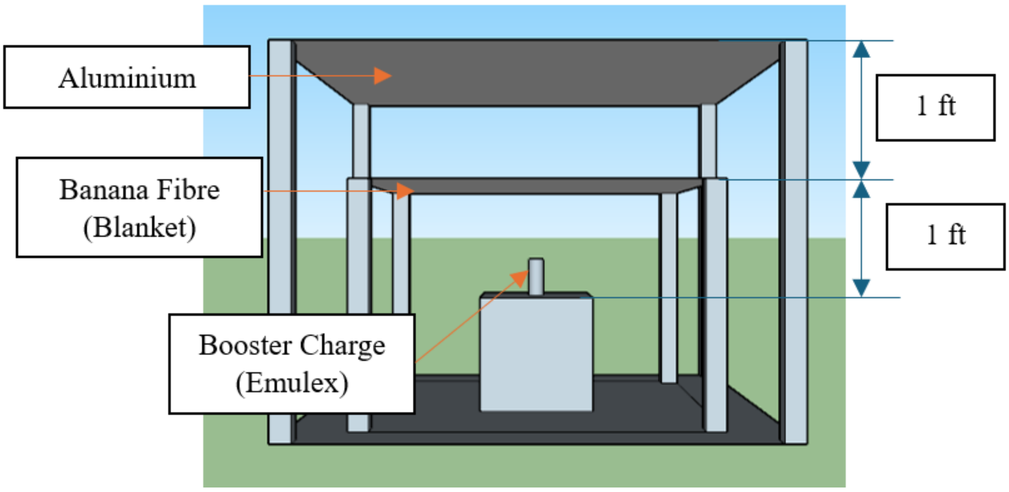

Figure 8: Assembly of Explosive.

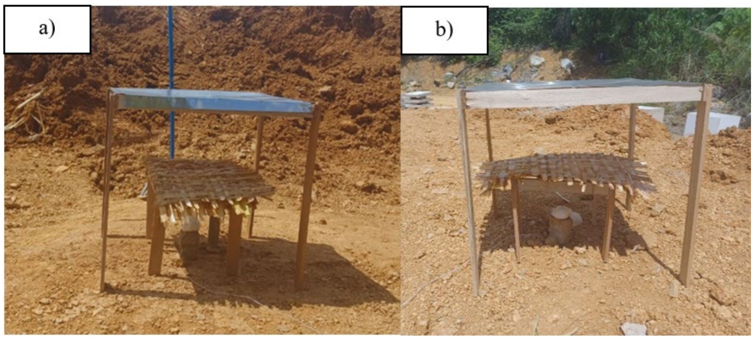

Figure 9: Test Setup: a) Plain Weaving and b) Intra-ply Weaving.

2.5.1 Equations

Initial Velocity (V_O) based on half flight, this equation refers to the initial velocity of the jig. "Half flight" refers to the vertical upward movement of the jig until it reaches the peak height [16].

$$V_O = \frac{(S_2 - S_1) + \frac{1}{2}g(t_2^2 - t_1^2)}{t_2 - t_1} \tag{1}$$

Variables:
$S_2 - S_1$ are the positions of the jig at the start and peak height.
$t_2 - t_1$ are the times corresponding to the positions.
g is the gravitational constant (9.81 m/s^2).

In the context of bomb blankets made from banana fibre, this equation measures the velocity of blast impact on test setups, determining how quickly the energy multiplies through the layered materials.

The Initial Velocity (V_O) can be calculated using the "full flight" method, which considers the entire flight path of the jig. "Full flight" refers to the jig's vertical upward movement until it reaches peak height and its vertical downward movement until it returns to the ground [16].

$$V_O = \frac{t_g}{2\,sin\,\Theta} \tag{2}$$

Variables,
t is the total flight time.
g is the gravitational constant (9.81 m/s^2).
θ is the angle of upward translation.

Energy Transfer (E = *mgh*), this formula calculates the potential energy transferred.

$$E = mgh \tag{3}$$

Where;
m is the mass of the object (jig or test sample).
g is the gravitational constant (9.81 m/s^2).
h is the height reached by the object.

In this experiment, E represents the energy absorbed or resisted by the banana fibre weave. A higher energy absorption capacity indicates better blast resistance of the layered material.

3. RESULTS AND DISCUSSION

3.1 Tensile Strength

A relative analysis was conducted to compare and contrast the mechanical properties of plain woven, intra-ply woven, and unwoven banana fibres, as shown in Table 1, which presents the tensile test results. This analysis allowed for a thorough comparison of these three types of banana fibres. The two metrics evaluated during the testing process were the tensile strength (stress) and the elongation at break [17]. The plain-woven pattern demonstrated exceptional mechanical qualities, including a tensile strength of 7.39 MPa and an elongation at a break proportion of 52.67%. These findings indicate that the plain woven pattern exhibits exceptional mechanical properties [8]. The enhanced performance can be attributed to the structure interwoven structures in the change and filling directions [18]. This structure enables better load distribution and boosts the material's ability to withstand stress, which is the primary reason for the improved performance [19]. In contrast, the intra-ply woven pattern displayed a tensile strength of 6.32 MPa and an elongation at break of 38.36%. The lack of interlacing in the weft direction is likely the cause of the lower performance of the intra-ply design. Due to the lack of interlacing, the pattern's structural integrity and capacity to stretch when subjected to load are reduced [20]. Unwoven banana fibre had the lowest tensile strength at 5.39 MPa, although it exhibited a comparatively high elongation at a break of 49.42%. As a result of the plain-woven pattern performing better than the intra-ply woven and unwoven fibres, it is considered the most suitable option for applications requiring high tensile strength and moderate elongation. This makes it particularly advantageous for materials designed to resist blasts.

Table 1: Result Tensile Test.

Product	Stress (MPa)	Elongation at break (%)
Unwoven	5.39	49.42
Plain woven	7.39	52.67
Intra ply woven	6.32	38.36

3.2 Air Blast Test

Another component of the experiment was an examination of the capacity of plain woven and intra-ply woven banana fibres to absorb and resist blast loading. This evaluation aimed to ascertain which type of banana fibre was more advantageous [21]. The results indicate that the plain-woven fibre demonstrated greater resistance to air blasts, as it successfully absorbed the blast energy when subjected to a height of 30 cm, with aluminium capturing the blast loading, as shown in Figure 10.

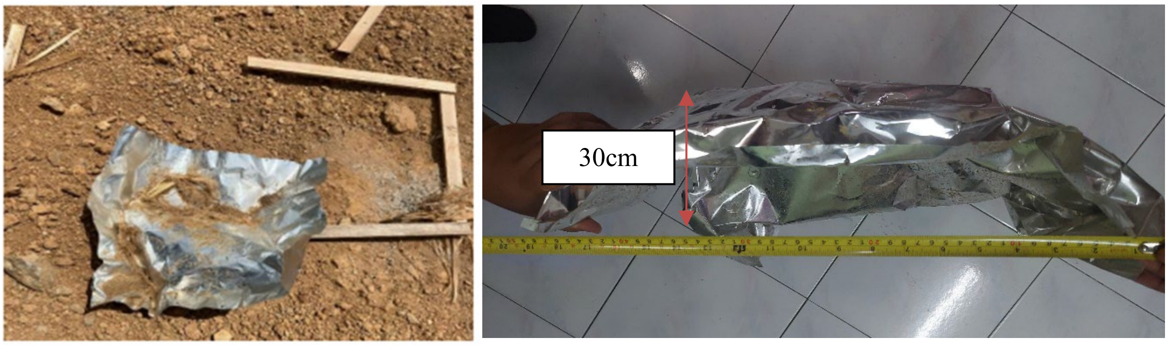

Figure 10: Plain Woven Blast Loading Capture.

When the intra-ply woven fibre was tested at the height of 45 cm, it displayed a performance that was less effective than what was anticipated in terms of its efficacy, as shown in Figure 11. This is due to the fact that a higher height indicates a decreased effectiveness in capturing and absorbing the air blast [22].

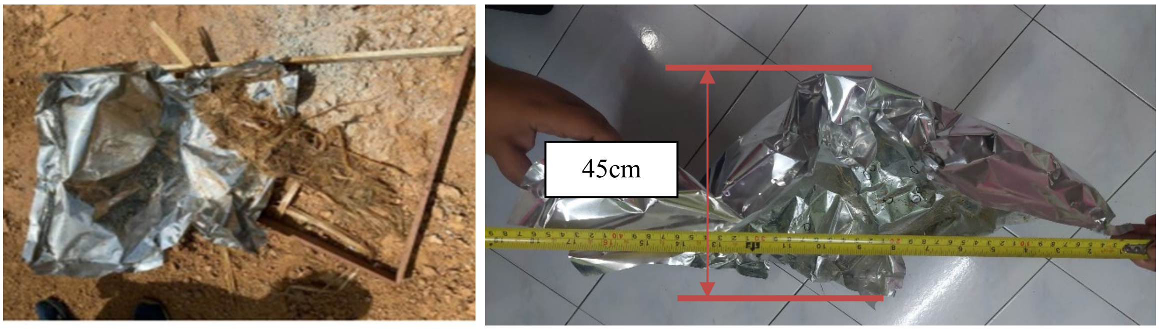

Figure 11: Intra Ply Woven Blast Loading Capture.

This reflects the ability of the banana fibres to absorb the energy released by the air blast. The efficiency of this absorption can be attributed to the structure of the interlaced warp and weft, which enhances energy dispersion and minimizes the impact transmitted [23].

Plain woven banana fibres and intra-ply woven banana fibres are compared in Table 2 regarding their capacity to absorb energy from a 40 g explosive, with a gravitational constant of 9.81 m/s^2. When the plain-woven fibre was measured at the height of 30 cm, it was found to absorb energy at 11,772 J. In contrast, the intra-ply woven fibre was evaluated at the height of 40 cm and absorbed 17,658 J. These findings show that plain woven fibre performed significantly better than the other fibres woven considered [24]. Additionally, the plain-woven fibre demonstrated a higher blast resistance level, making it more acceptable for applications that require efficient energy absorption over shorter distances. This is further illustrated in Figure 12, which presents an energy transfer history graph [16]. Overall, these results suggest that plain woven fibre is more suitable for use.

Table 2: Air Blast Result.

Banana Fibre	Explosive Weight (g)	Height (cm)	Gravitational (m/s^2)	Energy Transfer (J)
Plain Woven	40	30	9.81	11,772
Intra Ply Woven	40	45	9.81	17,658

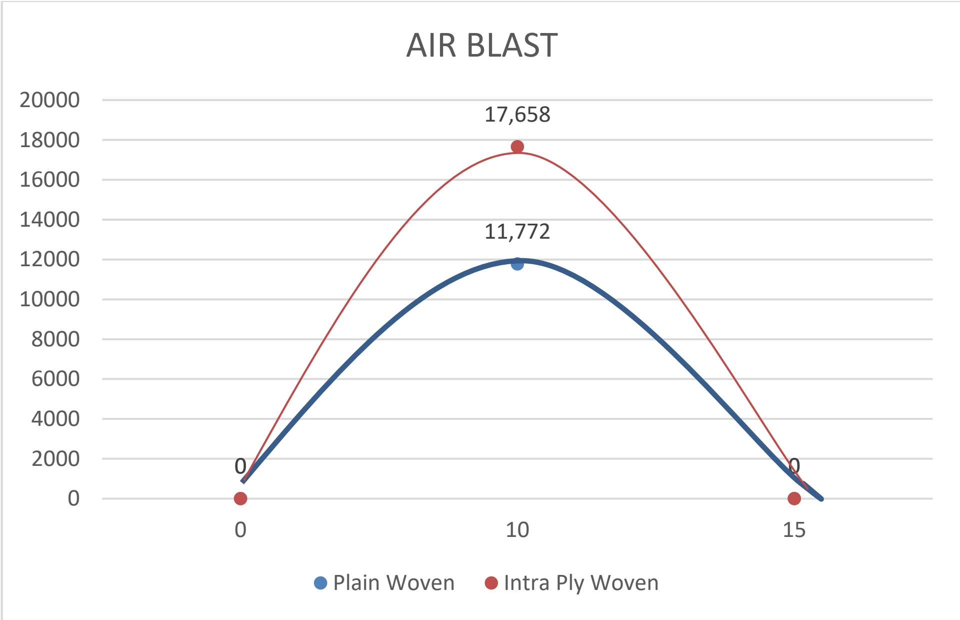

Figure 12: Energy Transfer History.

3.3 Scanning Electron Microscopy (SEM)

The result of Scanning Electron Microscopy (SEM) provides valuable insights into the surface morphology and structural integrity of fibres [25]. The SEM images of plain-woven shown in Figure 13 indicate surface imperfections and cracks visible to the naked eye. It demonstrates that the material has been subjected to strong forces, which negatively impact its structural qualities.

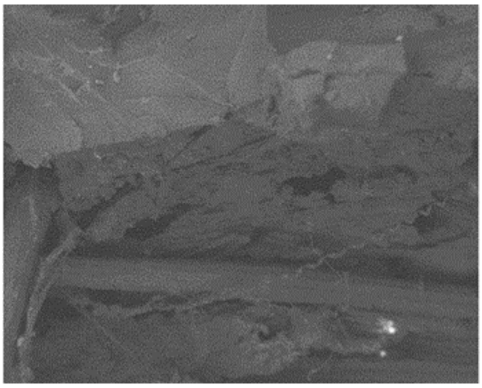

Figure 13: Plain Woven Banana Fibre Subjected to Blast.

Through SEM, the intra-ply woven fibres possess shapes with rough textures, as shown in Figure 14. Additionally, natural defects and debris on the surface indicate post-explosion residue, which may have affected the understood degradation. This shows that the fibres were subjected to secondary effects of the explosive event, such as heat or chemical interactions [26].

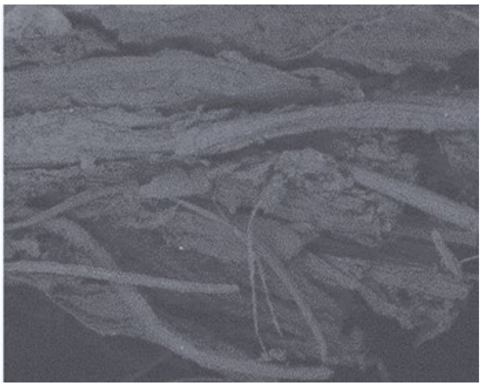

Figure 14: Intra Ply Woven Banana Fibre Subjected to Blast.

4. CONCLUSION

The conclusion compares two types of woven patterns based on the tensile test findings. Plain woven fibres achieved a tensile strength of 7.39 MPa and an elongation at a break of 52.67%. This value is significantly higher than intra-ply woven fibres, which recorded a tensile strength of 6.32 MPa and an elongation at a break of 38.36%. This difference remains noticeable even when the fibres are subjected to aggressive conditions.

The result of the air blast test offers further evidence of the superior capabilities of plain-woven banana fibres. When the plain-woven fibres were subjected to an explosive charge of 40 g, it demonstrated an energy absorption capability of 11,772 J at the height of 30 cm. In contrast, the intra-ply fibres had a capacity of 17,658 J at 45 cm, which contradicts the performance of plain-woven fibres. SEM analysis shows that plain woven fibres have fewer surface flaws and cracks compared to other types of fibres.

Research findings indicate that banana fibres subjected to alkali treatment have the potential to enhance mechanical qualities such as tensile strength, stiffness, and thermal stability. The treatment reduces the material's hydrophilicity, improves adhesion between fibres and matrix, and enhances overall durability and weight reduction.

Plain woven banana fibres provide a practical, environmentally friendly, and cost-effective solution for bomb blankets. Their exceptional mechanical performance, efficient energy absorption, and sustainability make them suitable for addressing security and environmental concerns. This makes banana fibre weaving an appropriate choice for the production of bomb blankets. By incorporating natural fibres into protective materials, this research contributes to the development of environmentally beneficial technology. These findings suggest that banana fibre weaving can provide a reliable and durable material, making it suitable for rendering safe procedures in bomb disposal applications.

Fabrics made from bananas are an alternative that is better for the environment and more sustainable than those made from synthetic materials. Banana fibre is also more sustainable than synthetic materials, meaning that banana fiber has a smaller environmental impact than synthetic materials. As a result of the fact that banana fibre is both biodegradable and environmentally friendly, banana fibre makes it possible for businesses to reduce the negative impact and environmentally.

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