International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com

ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105

JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

Volume 9, Issue 2 - February 2021 - Pages 47-80

MECHANICAL PROPERTY STUDIES ON FLAX/BASALT FIBER REINFORCED POLYESTER HYBRID COMPOSITE

Arun Balasubramanian K, Tamilarasan C, Sethu Raaman S A, Muralikannan R, Arunprasath K
Department of Mechanical Engineering, Sethu Institute of Technology, Virudhunagar, India

ABSTRACT

The utilization of natural and synthetic fiber composites in polymer matrices has garnered significant interest in material science and engineering due to their lightweight nature and comparable strength to traditional metals. This study explores the mechanical properties of hybrid composites comprising flax and basalt fibers, alongside the incorporation of basalt powder as a reinforcing filler material. Taguchi optimization was employed to determine the optimal fiber length and weight percentage for hybridization, leading to the identification of favorable mechanical properties such as tensile, flexural, and impact strength. The research extends to investigate the mechanical performance of bi-directional flax and basalt fiber composites, as well as combinations with basalt powder, under low velocity impact and dynamic mechanical analysis. The results indicate that the hybridization of flax and basalt fibers enhances the overall mechanical properties, with significant improvements in tensile strength, flexural strength, and impact resistance. Furthermore, the addition of basalt powder as a filler material contributes to the composite's load-bearing capacity and impact absorption. The findings suggest that these composite materials hold promise for various applications, including aircraft components, automotive structural parts, and construction materials, offering a cost-effective and environmentally sustainable alternative to traditional materials.

KEYWORDS

Composite materials, Polymer matrix composite, Flax and Basalt fiber, Polyester resin, Tensile property, Flexural property, Impact property, Basalt powder, Low velocity impact and Dynamic mechanical analysis.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

Volume 9, Issue 2 - February 2021 - Pages 47-80

Introduction:

Composite materials are one of the praised materials which produce some unique properties for various applications. The main advantage of these materials are their strength, composite materials is less weight with more strength. Composite materials consist of two phases namely reinforcement and matrix phase. The reinforcement phase in composite produces more strength and support for the material and the matrix phase distributes the load evenly. The composite reinforcement and matrix materials are classified into three types. In the reinforcement phase whiskers (short materials), flakes (long materials), sandwich and mat type shape materials are used. The matrix phase is normally classified with the materials used for binding and distributing medium. Polymer matrix composite (PMC), Metal matrix composite (MMC) and Ceramic matrix composites (CMC). In, polymer matrix composite the reinforcement materials are called as fibers and matrix materials are resins. Fibers are classified into two types, natural fibers and man-made (synthetic) fibers. The various types of polymer matrixes are such as polyester, vinyl ester, epoxy resin etc. The several types of manufacturing methods, proper standards are available to fabricate these polymer composite and testing. In the case of metal matrix composite the reinforcement phases may be metals like aluminum, copper and matrix phases may be silicon carbide, iron carbide. These are some of the predominantly used metal matrix composite, they also have separate methods of processing. The third type is ceramic matrix composite, here also both the phases with same type of materials namely silica and alumina are some of the ceramic materials widely used for this type of composite, these ceramics also has desired separate methods and standards. The composite materials have variety of application in several fields in this world. From the application purposes and need for the newer material for replacing an existing system. The inclusion of composite materials produced a variety of materials with different composite which satisfies the scarcity of materials with benefits. Application of composite now a days spread all over the world as different useful commercial products. The best and well known example is our human body which is made up of fleshes and bones. In this structure, the bones are stronger parts and fleshes are weaker parts in our body. Likewise, the application of composite spread all the areas especially in automobile, biomedical, marine, aircraft and other renewed areas. Era of composite will rule our world with the introduction of newer materials for satisfying different needs and applications of human intervention. Scope of the project.

Flax Fiber:

Flax fiber, derived from the flax plant of the Linaceae family, has been utilized for various purposes since ancient times. This natural fiber serves as a reinforcement material in composite production, offering several advantageous properties.

Flax fibers are commonly used in the production of linen fabrics, which are known for their durability and comfort. They are also rich in nutritional supplements, found in flax seeds, and are often used in cooking.

The strength of flax fibers, particularly those taken from the stem of the plant, surpasses that of cotton fibers, which are naturally smoother but less robust. This strength makes flax fibers suitable for applications requiring resilience to sudden loads and shock absorption.

In Europe and Northern America, flax fibers find applications beyond textiles, such as in paper manufacturing and as livestock fodder. They exhibit better chemical resistance to alkalis, acids, and bleaches compared to other natural fibers.

The elasticity and strength of flax fibers make them ideal for various textile applications, including fabrics, damasks, lace, and sheeting. Coarser grades of flax fibers are used in the manufacturing of items like twine, rope, and canvas webbing equipment.

Figure 1.2 illustrates a typical flax plant, its seeds, and the extracted fiber, while Table 1.1 provides physical properties of flax fiber [1]. This data assists in understanding and utilizing flax fiber effectively in various industries.

Table 1 Properties of flax fiber

S.No	Parameters	Observations
1	Length/diameter	The average length of flax fiber varies from 90-125 cm. The length of individual fiber cells varies from 6-65 mm with an average diameter of 0.02 mm (52 μm).
2	Color	Brownish, ivory, grey, light, yellowish.
3	Tensile strength	6.5 to 8 GPa.
4	Elongation	Elongation at break is approximately 1.8 % (dry) and 2.2% (wet).
5	Specific gravity	1.54 kg/m^3.
6	Effect of moisture	12% (standard).
7	Effect of heat	Heat resistance up to 120°C. The fibers begin faded after crossing temperature limit.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

8	Abrasion resistance	Moderate.
9	Dimension stability	More elastic so, it deforms easily.

(a)

(b) (c)

Figure 1 (a) Flax plant, (b) Raw flax fiber, (c) Flax seed

Basalt Fiber

Basalt fibers are extracted from the igneous rock of lava, which is primarily composed of minerals such as plagioclase, pyroxene, and olivine. They exhibit superior physio-mechanical properties compared to other types of synthetic fibers, and are also more cost-effective than carbon fibers. The technology behind the production of basalt fibers involves a one-stage process of melting and direct extraction from basalt rocks. At a manufacturing temperature of around 1500°C, the molten basalt is extruded through small nozzles for continuous fiber extraction. These extruded basalt fibers typically have a diameter range between 10µm to 20µm. Basalt fibers possess a high elastic modulus and are three times stronger than steel.

Thin basalt fibers are utilized as reinforcing materials in the textile industry for producing woven fabrics. Thicker fibers find applications in the manufacturing of large structural products used in aerospace, construction, and shipbuilding industries. Table 2 illustrates the physical properties of basalt fibers [1], while Figure 2 depicts typical images of basalt short fibers, basalt continuous fibers, and mat fibers. Basalt fibers hold significant potential for high-temperature applications and are increasingly being used as a replacement for cement concrete in structural buildings.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

Table 2 Properties of basalt fiber

S.No	Parameters	Observations
1	Length/diameter	The average diameter of basalt fiber in the time of extraction about 18µm.
2	Color	Dark Brownish.
3	Tensile strength	2.8 – 3.1GPa
4	Elongation	Elongation at break is 3.15%
5	Specific gravity	2.6 – 2.8 kg/m3.
6	Effect of moisture	18% (standard).
7	Effect of heat	Heat resistance up to 1500°C.
8	Abrasion resistance	High.
9	Dimension stability	More elastic and stable.

Figure 2 (a) Short basalt fiber, (b) Mat basalt fiber, (c) Continuous basalt fiber

Basalt Powder

Basalt rocks, naturally mined from igneous formations, are typically dark greenish in color. Basalt powder is prepared by crushing these rocks and finds applications in construction and various industries. Rich in magnesium, silicon, and iron minerals, basalt powder provides inherent strength to materials. It is non-toxic, non-combustible, and does not undergo chemical reactions.

Basalt powder serves as an excellent alternative to cement, offering comparable strength contributions. It is commonly used in the production of large structural hybrid composites. A unique property of basalt powder is that 1kg of basalt powder reinforcement equals 9.6 kg of steel, making it an efficient reinforcement material. Nowadays, many countries utilize basalt powder for diverse applications.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

Table 3 presents the physical properties of basalt powder [1], while Figure 1.4 provides a typical picture of basalt powder.

Table 3 Properties of basalt powder

S.No	Parameters	Observations
1	Length/diameter	The average diameter of 51% occupied by particles of about 19.89 μm.
2	Color	Green.
3	Elongation	Elongation at break is 3.15%
4	Specific gravity	2.6 – 2.8 kg/m3.
5	Effect of moisture	14% (standard).
6	Effect of heat	Heat resistance up to 1000°C.
7	Abrasion resistance	High.
8	Dimension stability	Stable.

Figure 3 Basalt powder

Polyester Resin

Basalt rocks, naturally mined from igneous formations, are typically dark greenish in color. Basalt powder is prepared by crushing these rocks and finds applications in construction and various industries. Rich in magnesium, silicon, and iron minerals, basalt powder provides inherent strength to materials. It is non-toxic, non-combustible, and does not undergo chemical reactions.

Basalt powder serves as an excellent alternative to cement, offering comparable strength

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

contributions. It is commonly used in the production of large structural hybrid composites. A unique property of basalt powder is that 1kg of basalt powder reinforcement equals 9.6 kg of steel, making it an efficient reinforcement material. Nowadays, many countries utilize basalt powder for diverse applications.

Table 4 presents the physical properties of basalt powder [1], while Figure 1.4 provides a typical picture of basalt powder.

Table 4 Properties of polyester resin

S.No	Parameters	Observations
1	Density	12 – 15 g/cm3.
2	Young's modulus	2 - 4.5 GPa.
3	Tensile strength	0.04 – 0.090 GPa.
4	Elongation	Elongation at break is 2%.
5	Compressive strength	0.090 – 0.250 GPa.
6	Effect of moisture	0.1 – 0.3%.
7	Cure shrinkage	4 – 8%.

Figure 4 Unsaturated polyester resin

LITERATURE SURVEY

Structural Analysis Of Flax Fiber Composite

Natural fibers found worldwide are biodegradable materials with a vast array of properties, suitable for numerous applications. One significant application is their use as reinforcement in

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

fiber composites, offering an effective alternative to synthetic fibers. Incorporating natural fibers as reinforcement can enhance the mechanical properties of polymers, providing both economic and eco-friendly benefits. Wobuyuki et al. [1] have highlighted two major drawbacks associated with matrix and reinforcement materials, which can be overcome by using natural fibers.

Mechanical Property Evaluation and Morphology Studies Of Flax Fiber Composite

Wang et al. [2] reported that the growing utilization of flax fibers in polymer composites has positioned flax reinforcement as a viable alternative to glass fibers. The shear properties of flax fibers were investigated using a model formation coupled with back-calculation techniques to evaluate micro bonding and interfacial shear strength.The study revealed that the composite exhibited low shear strength, attributed to poor adhesion properties. However, this issue can be mitigated by residual thermal stress, which facilitates hydrogen bonding.

Novel Performance of Flax Fiber Composites

Petrone et al. [3] investigated the failure criterion of flax fiber reinforced polypropylene composite under various water-absorbing loading conditions. They found that after absorbing 64% of water, the flax fiber reinforced composite exhibited favorable mechanical properties.

Application Based Flax Fiber Composites

Flax and hemp fibers have been increasingly utilized as reinforcement in polymer composites due to their significant stiffness compared to glass fiber composites for various applications [4].Sepe et al. [5] provided an overview of the technical arguments supporting this trend and highlighted the high damping properties exhibited by both flax and hemp-based composites. This breakthrough in new materials has led to their adoption in sporting goods and aerospace applications, expanding the visibility and utilization of composite materials beyond these specific industries.

Influence Of Fiber Weight And Fiber Length Of Flax Fiber Composite

Al-Hajaj et al. [6] reported that natural fibers are highly sensitive to environmental moisture conditions. The density, moisture content, and cellulose content, along with fiber length and content, are crucial parameters that determine the quality of the composite. Flax fiber, in particular, exhibits moderately beneficial properties at around 8.19% moisture content at normal room temperature.Density is a key property of fibers that influences the application-oriented purpose of composite materials. Flax fiber has a density of about 1.35 g/cc, which is relatively high compared to other commercially available natural fibers such as jute, cotton, and luffa. This high density makes flax fiber suitable for various applications, enhancing its

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

versatility in composite materials.

Hybridization Effect on Flax Fiber Composite

Han et al. [7] reported that fibers are frequently utilized in the manufacturing of various materials due to their strength and chemical composition. Among natural cellulosic fibers, flax stands out as one of the strongest. On the other hand, glass fiber, a man-made fiber, is renowned for its strength and reliability in applications.

The combination of flax and basalt fibers in a composite offers enhanced mechanical and thermal properties. This composite leverages the strength of flax and the durability of basalt fibers, resulting in a material with improved overall performance.

Orientation Effect on Flax Fiber Composite

Hao et al. [8] reported that natural fiber composites are increasingly finding applications in various fields such as automobiles, aerospace, and others. Researchers have explored different strategies to enhance the properties of these composites, and one notable trend is altering the orientation of the composite.

By changing the orientation of the fibers within the composite structure, researchers can optimize mechanical properties such as strength, stiffness, and impact resistance. This approach allows for tailoring the composite to specific application requirements, leading to improved performance and durability.

low velocity impact responses of flax fiber composite

Sims et al. [9] reported that the low velocity impact test is utilized to assess the ability of a material to absorb sudden energy. This test involves subjecting the material to impact events with velocities typically within the range of 20 m/s. During such impacts, internal collisions occur within the material, leading to internal damage that significantly degrades the material properties.

Dynamic Mechanical Analysis (Dma) Response of Flax Fiber Composite

Ridzuan et al. [10] reported that Dynamic Mechanical Analysis (DMA) techniques are precise methods used to evaluate and characterize polymers, particularly in terms of their elastic and plastic behaviors. Mechanical characterization is crucial for demonstrating improvements in the performance of composite materials. In addition to enhancing the mechanical performance of natural fibers, hybridization has been introduced.

The response of the composite to temperature changes, including expansion and contraction, is crucial. Delamination and crack formation due to temperature fluctuations can significantly decrease the mechanical properties of the composite. Increasing the number of cycles can exacerbate this issue. However, by introducing hybridization, the interface of the composite becomes more resistant to delamination, thereby improving its overall mechanical properties.

Damage Analysis on Woven Flax/Basalt Fiber Composite

Abdul nasir et al. [177] reported that studies on structural related applications of composite, because of its unique property of strength to weight ratio. The excellent properties like specific strength and stiffness are more while compared with other materials. Unseen damages in the time of applying a dynamic load on the layered composites subjected to low velocity impacts, caused by energy absorption or scattering in the composite structures. In general basalt fiber polyester composite have highest impact energy absorption after tensile impact and good mechanical properties than Kevlar and glass fiber composites.

RESEARCH METHODOLOGY

The proposed methodology of work, as shown in Figure 5, is derived based on the objectives discussed in earlier chapters.

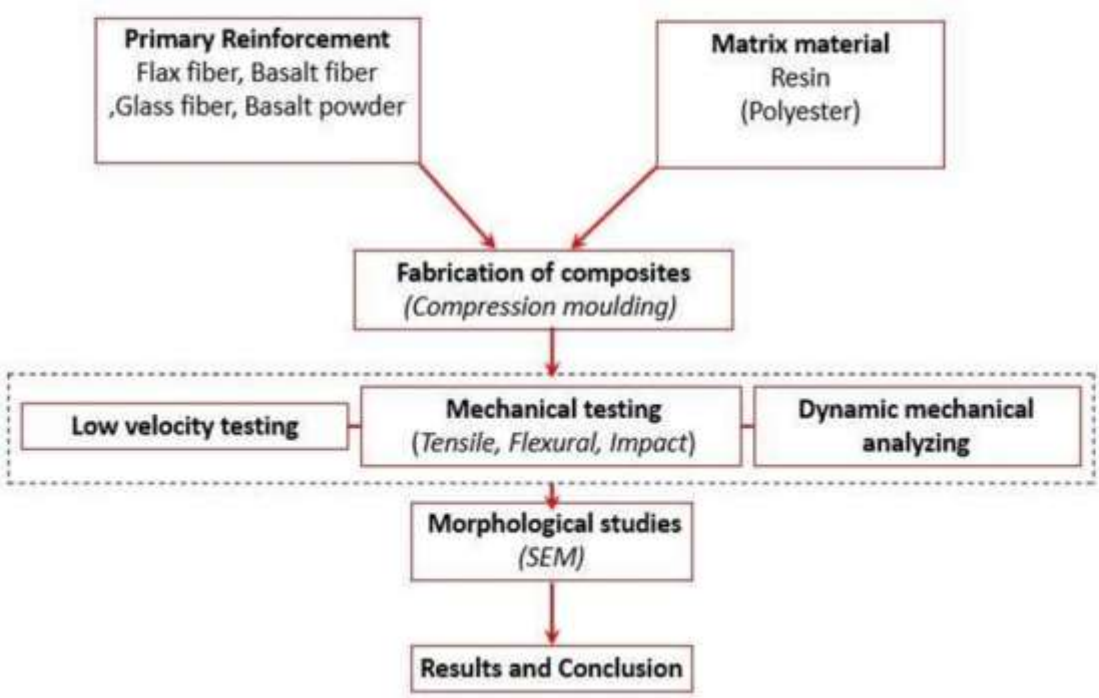


Figure 5 Research methodology

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

SUMMARY

This chapter begins with a literature discussion on the usage of flax fiber in various areas and its applications. Topics covered include structural analysis, mechanical properties, characterization techniques, novel technologies, and applications of flax fiber reinforcement composites. Additionally, the chapter explores the effects of hybridization, fiber lengths and percentages, orientation effects of flax fiber composites, and the influence of basalt/flax fiber composites. Various analytical techniques such as Dynamic Mechanical Analyzer (DMA), damage analysis in composites, low-velocity impact testing, compression after impact, and characterization of basalt/flax composites are also discussed. These discussions aim to address research gaps, define objectives, and outline the proposed methodology for achieving results.

In the next chapter, the materials and methods used for the fabrication of composites will be discussed in detail.

EXPERIMENTAL METHODOLOGY

In composite materials, reinforcement plays a crucial role in determining the strength and properties of the material. Reinforcing materials contribute to the composite's ability to resist corrosion and provide rigidity. Typically, in polymer matrix composites, reinforcing materials include fibers and powders. These fibers can vary in shape, size, and weight, ranging from short fibers to continuous fibers and mat fibers.

Natural fibers commonly used as reinforcement include cotton, hemp, animal fibers, jute, and flax, while synthetic fibers such as basalt, glass, carbon, and Kevlar are also utilized. In our research, we use short basalt fibers, bidirectional basalt fibers, short flax fibers, bidirectional flax fibers, and basalt powder as primary reinforcement.The properties and applications of flax fiber and basalt materials are discussed in Chapter 1. Flax fiber is chosen for its strength, being one of the strongest cellulosic fibers extracted from the skin stem of the flax plant. Basalt fiber is selected for its cost-effectiveness and superior mechanical properties compared to carbon fiber, while basalt powder enhances the rheological and surface morphology of the composite.

Figure 3.1 illustrates the different types of fibers and powders used: a) short basalt fiber, b) bidirectional basalt fiber, c) short flax fiber, d) bidirectional flax fiber, e) basalt powder, and f) short glass fiber. Flax fiber is procured from Varghese Fibers, Kerala, India, while basalt fiber and powder are imported from ASA Fiber International Pvt Ltd, Austria, and glass fiber is obtained from Vasavi Bala Fiber, Chennai, India.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

(a) **(b)** **(c)**

(d) **(e)** **(f)**

Figure 6 (a) Short basalt fiber, (b) bidirectional basalt fiber, (c) short flax fiber, bidirectional flax fiber, (e) basalt powder, (f) short glass fiber

Matrix

Matrix materials serve as binding and load-distributing agents in composites, protecting the fibers from surface damage and providing core support during compression-induced buckling. They play a crucial role in forming an infiltrate attachment between the fibers.

Matrix materials are typically classified into two types: thermoplastic and thermosetting. Thermoplastic materials, such as Teflon, nylon, and rubber, regain their original shape after composite processing. On the other hand, thermosetting materials, like polyvinylchloride (PVC) pipes, do not regain their original shape after processing.

In polymer matrix composites, polyester, vinyl ester, and epoxy resins are commonly used as matrix materials. For this research, we chose general-purpose (G.P) polyester resin as the matrix. It is readily available, cost-effective, and easy to process. The specific resin grade used is VBR 2303 general-purpose (G.P) unsaturated polyester resin, obtained from Vasavi Bala Resins, Chennai, India. The polyester resin was processed with accelerator and catalyst, specifically cobalt naphthalate and Methyl Ethyl Ketone Peroxide (MEKP), in a ratio of 1:3.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

Figure 7 illustrates: a) a typical image of general-purpose (G.P) polyester resin, b) accelerator (cobalt naphthalate), and c) catalyst, Methyl Ethyl Ketone Peroxide (MEKP).

(a) (b) (c)

Figure 7 (a) G.P polyester resin, (b) accelerator (cobalt naphthalate),(c) catalyst, Methyl Ethyl Ketone Peroxide (MEKP)

FABRICATION OF COMPOSITES

The fabrication of composites involves using a mold or a structured frame containing reinforcement and resin. There are several methods for fabricating composites, depending on the desired shape and the type of mold used. One of the most common and straightforward methods is the hand layup method, which is an open molding technique.

Other methods for fabricating composites include compression molding, resin transfer molding, injection molding, extrusion, filament winding, pultrusion, and various others. In this research work, the compression molding technique is employed to fabricate the composite.

Compression molding involves placing the reinforcement materials (such as fibers or fabric) in a mold cavity, followed by the addition of the resin. The mold is then closed under pressure and elevated temperature, allowing the resin to flow and cure around the reinforcement. This process results in a composite part with the desired shape and properties.

Compression molding technique

Compression molding is a commonly used fabrication method for composite materials, offering the advantage of producing large components with high volumes of reinforcement fabrics and resins. This method is particularly favored in industrial settings for creating large and complex shapes.

The mold used in compression molding measures 300 x 130 x 3 mm and is made of steel, as

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

depicted in Figure 8. The compression molding machine utilized is a Santec molding press with a capacity of 25 tons, as shown in Figure 9. The maximum pressure applied during the process is up to 80 bar.

The fabrication process begins with cleaning the mold with wax. The wax serves the dual purpose of mold cleaning and facilitating easy removal of the composite plate without damage. Subsequently, the fibers and resins are evenly distributed as per the requirements of the composite. The curing process takes approximately 3 hours at room temperature, with a maintained pressure of 80 bar throughout the process to fabricate the composite plates.

Figure 8 Open and closed part of the mold with cavity

Figure 9 Compression molding setup

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

STATIC MECHANICAL TESTING

Static mechanical testing involves applying load in a powered and rest state, where the load and displacement exhibit minimal movement during load application. This type of testing, also known as 'quasi-static' testing, involves minimal displacement and load movement and is used for quick inspection to validate results. One advantage of this testing method is its stability, as changes are not easily made once the test is initiated, resulting in precise measurements.

Tensile Test

The tensile test is used to determine the behavior of materials when subjected to elongation under load. Also known as tension testing, it is a fundamental engineering and material testing method. The tensile test provides information such as ultimate tensile strength, breaking strength, and maximum elongation of the material being tested.

Specimens for the tensile test are prepared according to ASTM standard D3039, with dimensions of 200 x 20 x 3 mm. Five specimens are tested, and the average values are calculated to measure the tensile strength of the material. Figure 3.5 depicts the Universal Testing Machine (UTM) used for conducting the tensile test.

Figure 10 Universal testing machine (UTM)

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

Impact Test

The impact test assesses the toughness of a material's behavior under high deformation speeds. There are two main types of impact tests: pendulum type and drop weight type. The Izod and Charpy tests are commonly used for examination. In this research, the Charpy impact test is utilized to evaluate the impact strength of the composite according to ASTM D256.

For the Charpy impact test, specimens with dimensions of 65 x 13 x 3 mm are prepared. Five specimens are tested, and the average value is taken for analysis. The Charpy impact testing machine, as shown in Figure 3.6, has a capacity of 25 J.

Figure 11 Charpy impact tester

DYNAMIC MECHANICAL TESTING

Dynamic mechanical testing involves testing materials by varying the working conditions to validate the results. These tests provide individual assessments of materials tested under various conditions. The maximum movement is noted with respect to time, displacement, and application of load. This technique is used to verify the accuracy of the results. One advantage of this type of testing is that changes can be made wherever necessary, and the results are provided with complete measurements.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

Flexural Test

The flexural test is a common mechanical testing method used to measure the flexural modulus of a specimen. It determines the maximum stress in the outermost area of the composite specimen. The slope is calculated from the graph plotted on the stress-deflection strain curve.

The flexural test is conducted using a Universal Testing Machine (UTM) with a three-point bending fixture. The test is carried out according to ASTM D790, with specimens measuring 125 x 13 x 3 mm. Five specimens are tested, and the average results are used for examination. Figure 3.7 illustrates a typical Universal Testing Machine (UTM) with a three-point bending fixture.

Figure 12 Universal testing machine (UTM) with three-point bending fixture

Low Velocity Impact Test

The low velocity impact test involves analyzing the impact of a drop weight falling from a certain height, applying sudden load on the material. This event occurs within a range between 1 to 10 m/s and depends on the stiffness of the target material. The mass and shape of the projectile determine the type of deformation that occurs in the specimen.

During low velocity impact, three types of deformation regions are observed:

Pristine region: The impacted area shows no deformation when load is applied.

Penetration: The specimen exhibits small deformation.

Perforation: A hole is formed in the impacted region of the specimen.

In this research, the low velocity impact test is conducted using the IMATEK IM10 drop weight impact testing machine, with specimens prepared according to ASTM D7136. The specimen dimensions are approximately 100 x 150 mm, with 12 J of energy and a drop height of 0.24 m. A hemispherical shaped impactor with a mass of 5 kg is used for all tests, and the

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

average values from five specimens are taken for analysis. Data related to energy and displacement are recorded using LABVIEW software. Figure 3.8 shows the setup for the low velocity impact test.

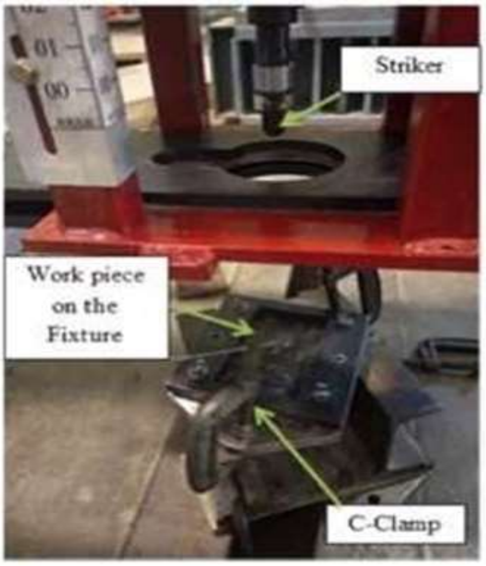
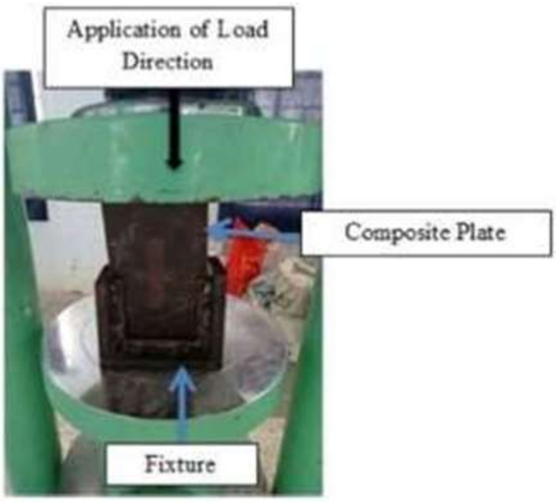


Figure 13 Low velocity impact setup

Compression After Impact Test

Compression after impact testing involves analyzing the specimen after an impact event has occurred. During the impact event, the material undergoes deformation, which leads to residual stress affecting its actual strength. This test measures properties such as modulus of elasticity, yield point, and compressive strength of the composite.

The test is conducted on specimens with dimensions of 100 x 150 mm, using a machine speed of 1.20 mm/min, in accordance with ASTM D7137 standard. Compression testing is performed using a Zwick Roell hydraulic testing machine with a customized fixture, as shown in Figure 3.9. The average values from five specimens are used for analysi



International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

Figure 14 Compression after impact test setup

Dynamic Mechanical Analysis (DMA)

Dynamic mechanical testing helps study the viscoelastic behavior of polymers, which refers to the deformation of the material between solids and fluids as temperature varies. DMA machines measure sinusoidal stress and strain of the polymer, allowing determination of the complex modulus of the material.

This analysis helps identify the glass transition temperature, indicating molecular motion transition. Parameters such as storage modulus (measuring stored energy), loss modulus (measuring energy dissipated as heat), and damping factor (tan delta) are considered in DMA testing.

Five specimens, prepared according to ASTM D4065-01 standard with dimensions of 60 x 12 x 3 mm^3, undergo testing using a Hitachi DMA7100 at a frequency of 1 Hz with a fixed load of 2 N. The setup is depicted in Figure 3.10.

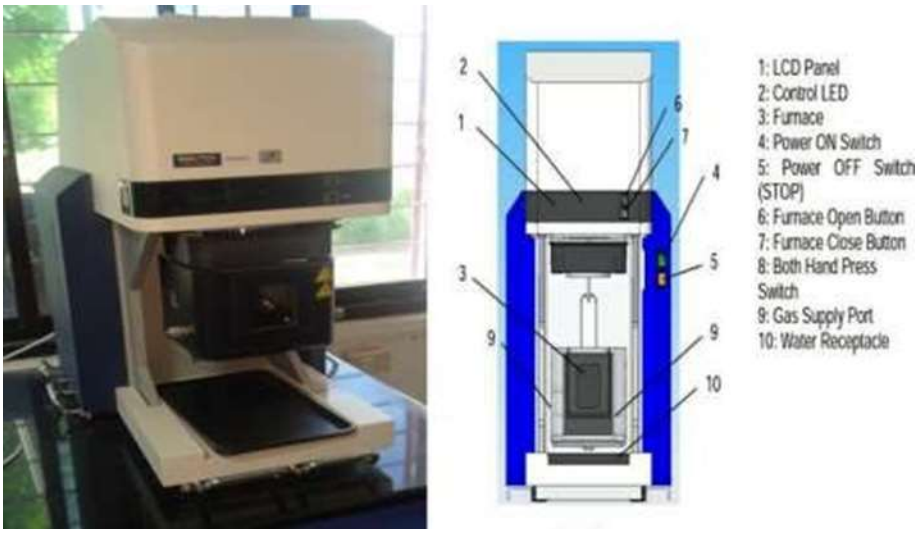


Figure 15 Dynamic Mechanical Analyzer DMA7100

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

OPTIMIZATION OF MECHANICAL PROPERTIES OF SHORT FLAX FIBER BY VARYING FIBER LENGTH AND FIBER WEIGHT PERCENTAGE FOR HYBRIDIZATION

This is focuses on optimizing the mechanical properties of short flax fiber by varying fiber length and fiber weight percentage for hybridization. Flax fiber is a natural material known for its strength and versatility, and optimizing its properties can lead to enhanced performance in composite materials.

EXPERIMENTAL SETUP

The experimental setup involves varying the length of flax fibers and the weight percentage in composite materials. Fiber lengths tested include 10 mm, 20 mm, 30 mm, 40 mm, and 50 mm, while weight percentages tested are 10 wt.%, 20 wt.%, 30 wt.%, 40 wt.%, and 50 wt.%.

Taguchi Method for Optimization

The Taguchi method, a robust design analysis technique, is employed to optimize the mechanical properties. An orthogonal array L25 is used, considering two factors (fiber length and weight percentage) at five levels each.

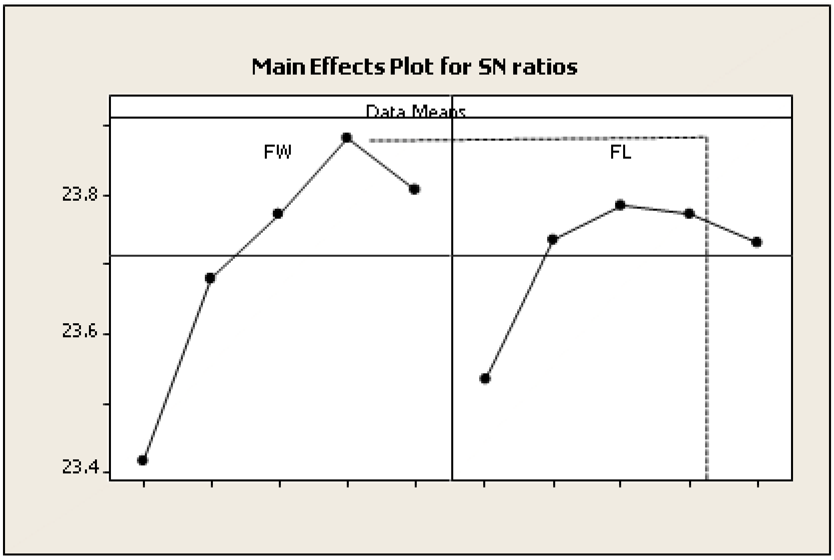


Figure 16 Effects of S-N ratio for (Tensile strength, Flexural Strength, Impact strength)

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

In this experimental analysis, ten samples with various relative percentages of fibers are used to prepare composite laminates. Table 4.1 provides a detailed view of the fiber content of each sample and the relative weight percentages.

Table 5: Sample Relative Weight Percentage of Flax/Glass Fiber Composite

Sample ID	Wt.% of Flax Fiber	Wt.% of Glass Fiber
1	100	0
2	90	10
3	80	20
4	70	30
5	60	40
6	50	50
7	30	70
8	40	80
9	10	90
10	0	100

These samples represent various combinations of flax and glass fibers in the composite material, with percentages ranging from pure flax to pure glass fibers. The mechanical properties of each sample will be evaluated to determine the optimal combination for enhanced performance.

The results obtained from tensile, flexural, and impact testing are plotted in Figure 4.5. Each graph shows the average strength obtained from the tests, with the x-axis representing the sample number and the y-axis representing the strength parameter.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com

ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105

JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

Volume 9, Issue 2 - February 2021 - Pages 47-80

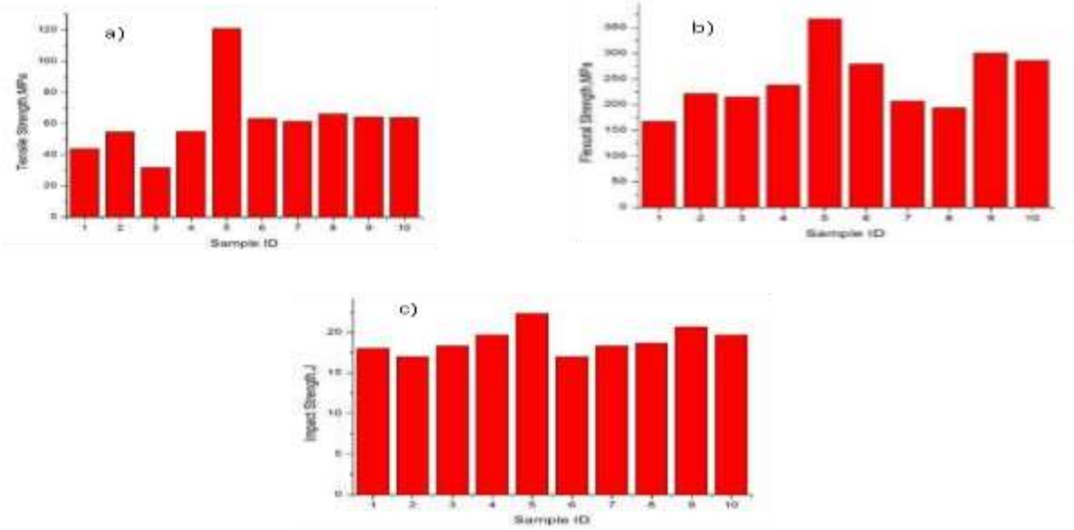


Figure 17 (a) Tensile strength, (b) flexural strength, (c) impact strength of 40 mm glass/flax fiber composite

(a) Tensile Strength

(b) Flexural Strength

(c) Impact Strength

In the tensile loading conditions (Figure 18a), the presence of the maximum amount of flax fiber shows a tendency to absorb the applied tensile force, reaching a strength of 120 MPa. This indicates the superiority of flax fiber in tensile loading conditions. Sample ID 5, which consists of 60 wt.% flax and 40 wt.% glass fiber composite, demonstrates superior strength compared to other combinations.

In terms of flexural strength (Figure 18b), the maximum strength is observed in the sample with 60 wt.% flax and 40 wt.% glass fiber composite, reaching 353 MPa. The graph shows the variation in flexural strength with increasing percentages of flax content in the composite.

For impact strength (Figure 18c), the results show good property enhancements with the inclusion of flax fiber. An increase in the content of flax fiber leads to better impact strength absorption, with the best result of 22 J of energy observed for the sample with 60 wt.% flax and 40 wt.% glass fiber composite.

Overall, the mechanical studies of the 40mm flax and glass fiber composite indicate that the combination of 60 wt.% flax and 40 wt.% glass fiber composite shows the best results in terms of tensile, flexural, and impact strengths.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com

ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105

JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

Volume 9, Issue 2 - February 2021 - Pages 47-80

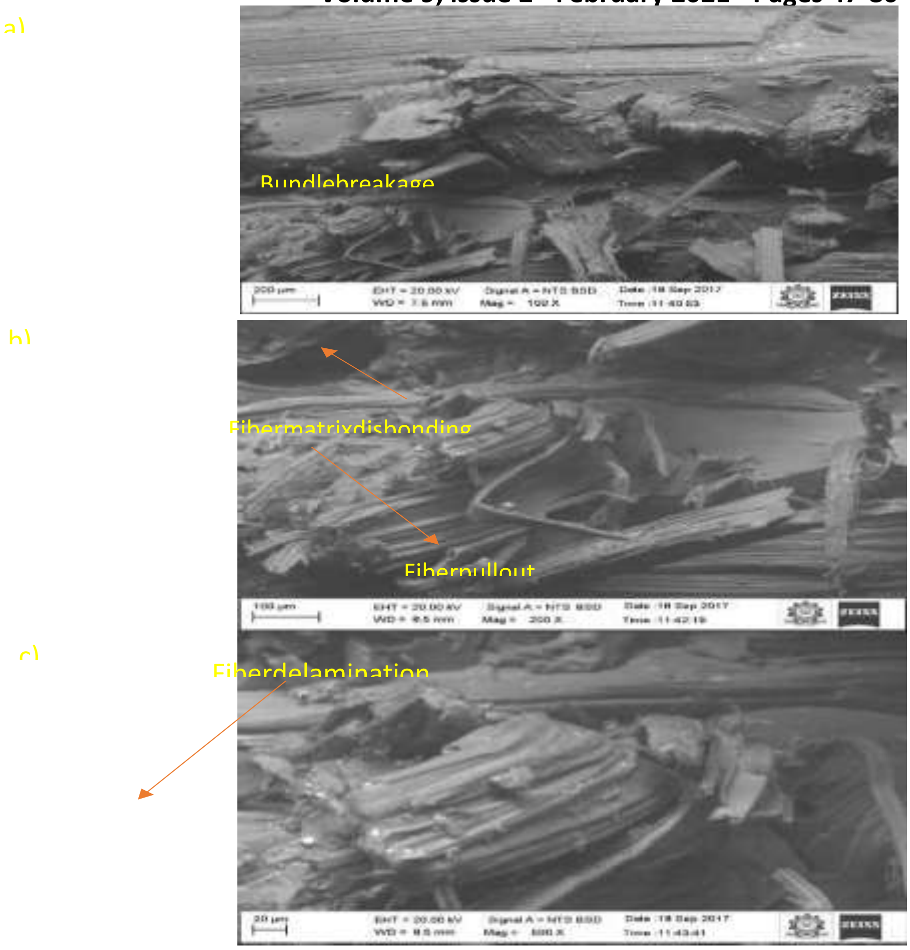


Figure 18 SEM image of (a) Tensile strength, (b) flexural strength, (c) impact strength of 40 mm glass/flax fiber composite

The SEM analysis provides micrograph responses of the composite material under different loading conditions:

(a) Tensile Strength Analysis:

The SEM image shows the tensile strength analysis of the composite containing 60 wt.% flax and 40 wt.% glass fiber.

Bundle breakage of fibers is observed due to the application of tensile load, which is common in flax and glass fiber combinations.

(b) Flexural Strength Analysis:

The SEM image depicts the flexural loading conditions of the composite with 60 wt.% flax and 40 wt.% glass fiber.

Two types of responses are noted in the cyclic load applications:

Fiber pullout

Matrix disbonding

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

(c) Impact Strength Analysis:

The SEM image shows the impact analysis of the composite containing 60 wt.% flax and 40 wt.% glass fiber.

Fiber delamination is observed, which is caused by sudden, improper impacts on the specimen. This response is typical in composite materials under impact loading.

These SEM images provide insights into the failure mechanisms of the composite under different loading conditions, aiding in understanding its structural behavior and failure modes.

MECHANICAL PROPERTIES ANALYSIS OF VARIOUS WEIGHT PERCENTAGES OF 40mm LENGTH FLAX/BASALT FIBER COMPOSITE

This is focuses on the analysis of tensile, flexural, and impact properties of various composite samples prepared with different weight percentages of basalt and flax fibers, each having a length of 40mm. Additionally, the failure morphology of these composites is examined using scanning electron microscopy (SEM). Table 5.1 presents the relative weight percentages, composite types, and designations of the basalt/flax fiber combinations.

Table 7: Relative Weight Percentage and Composite Designations

Sample ID	Basalt Fiber (wt.%)	Flax Fiber (wt.%)	Composite Type
1	100	0	Basalt Composite
2	90	10	Hybrid Composite 1
3	80	20	Hybrid Composite 2
4	70	30	Hybrid Composite 3
5	60	40	Hybrid Composite 4
6	50	50	Hybrid Composite 5
7	30	70	Hybrid Composite 6
8	20	80	Hybrid Composite 7
9	10	90	Hybrid Composite 8
10	0	100	Flax Composite

This table provides an overview of the composition of each composite sample, with varying weight percentages of basalt and flax fibers, leading to different composite types. The subsequent sections will analyze the mechanical properties and failure morphology of these composites.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

MECHANICAL PROPERTY ANALYSIS AND SEM MORPHOLOGY EXAMINATION

Influence of 40mm Flax/Basalt Fiber Composite on Tensile Property

The composite samples prepared with varying weight percentages of basalt and flax fibers are depicted in Figure 5.1. It is evident that the hybridization of flax and basalt fibers in the polyester matrix composites enhances the tensile strength. The maximum strength of 78.67 N/mm² is achieved for Composite C, which contains 40 wt.% basalt fiber and 10 wt.% flax fiber. Overall, increasing the basalt fiber content results in higher tensile strength. However, compared to pure flax fiber composite, the samples with pure basalt fiber exhibit lower tensile strength. The addition of flax fiber enhances the stiffness and tensile strength of the composite, supported by the strong bonding nature of basalt fiber with the polyester matrix. Nevertheless, with increased flax fiber content, the tensile strength decreases. This reduction is attributed to the decrease in interfacial strength between the fiber and matrix, leading to decreased resistance to crack propagation and stress concentration regions in the composite, commonly observed in flax and basalt composites.

The SEM images of tensile-tested specimens for pure (100 wt.%) basalt fiber, pure (100 wt.%) flax fiber composite, and their hybrid composite are shown in Figure 5.2.

In Figure 5.2(a), the micrograph of the tensile fractured specimen of pure flax fiber composite shows fiber splinters due to weak interfacial bonding between the matrix and fiber. Debris with small formations of fissures on the composite surface also indicates poor dispersion of the fiber into the matrix.

Figure 5.2(b) illustrates the micrograph of the pure flax fiber composite under tensile loading conditions, where similar weak bonding between the fiber and matrix is observed.

Conversely, in Figure 5.2(c), for the composite with 40 wt.% basalt fiber and 10 wt.% flax fiber, a healthy bonding between the fiber and matrix is evident. This is attributed to the higher amount of basalt fiber, which improves the bonding properties in both the skin and core layers of the composite.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

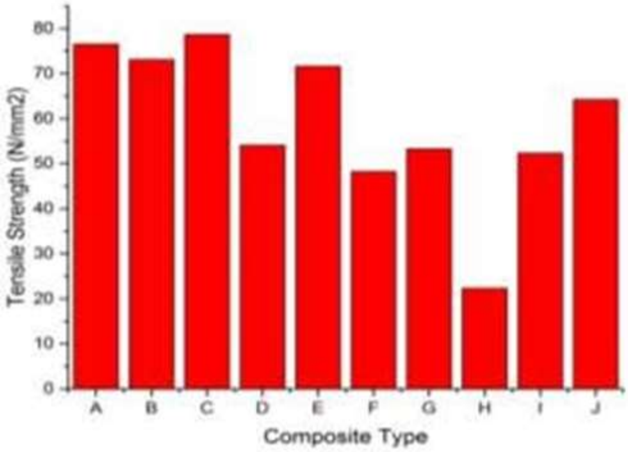


Figure 19 Tensile strength variation related to fiber weight percentage of 40mm basalt/flax fiber composite

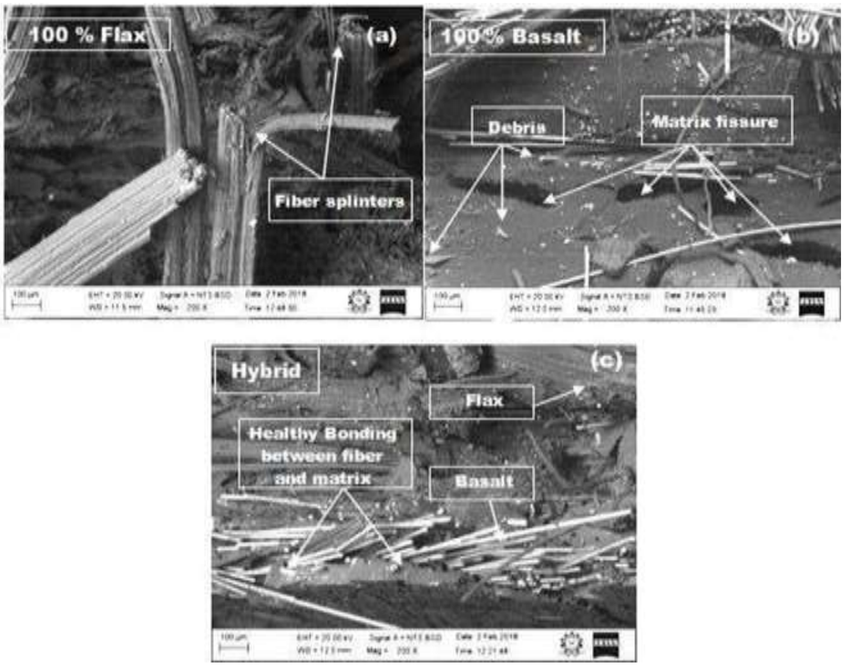


Figure 20 SEM micrograph of tensile tested specimen (a) 100 wt.% flax (a)100 wt.% basalt (c) hybrid 40 wt.% of basalt fiber and 10 wt.% of flax fiber

Influence of 40mm Flax/Basalt Fiber Composite on Flexural Property

The flexural strength of the hybrid composite was determined using a three-point bending test, and the results are illustrated in Figure 5.3. Basalt fiber-based composites exhibited better flexural strength than flax fiber composites. Hybridization of flax and basalt composites increased the flexural strength, with Composite D containing 35 wt.% basalt and 15 wt.% flax fiber showing the highest flexural strength of 504.85 N/mm². This result indicates a high-quality interface between

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

the fiber and matrix, which is crucial especially in the case of adding flax fiber. Flax fiber alone does not provide sufficient support during flexural loading conditions to absorb the load. Gradual failure was observed, but there was no fracture until reaching the maximum load in the hybrid composite, similar to the observation in the pure basalt fiber composite.

Comparison of flexural results between pure basalt and flax composites with the hybrid composite revealed that the hybrid composite exhibited superior properties compared to the pure basalt and flax composites.

Figure 5.4 displays the SEM morphology of the flexural property.

Figure 5.4(a) illustrates the poor interaction between flax fiber and the polyester resin, leading to fiber pullout from the bundle in the pure (100 wt.%) flax fiber composite.

Figure 5.4(b) shows the low amount of matrix adhering to the basalt fiber bundle, indicating loose fibers in the bundle in the pure (100 wt.%) basalt fiber composite.

In Figure 5.4(c), for the composite with 35 wt.% basalt fiber and 15 wt.% flax fiber, superior interaction in the bundles with no matrix remaining on the surface is observed, indicating better adhesion in the interfacial area of the composite during hybridization.

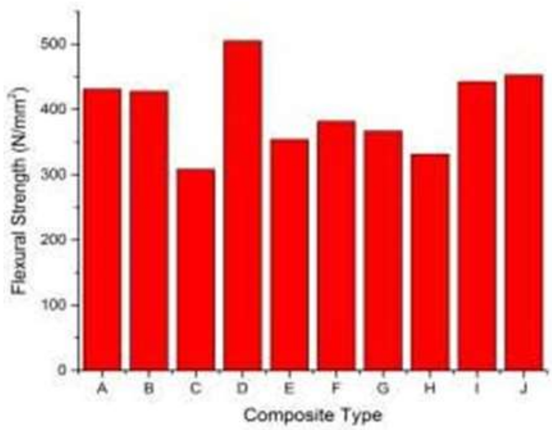


Figure 21 Flexural strength variation related to fiber weight percentage of 40mm basalt/flax fiber composite

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

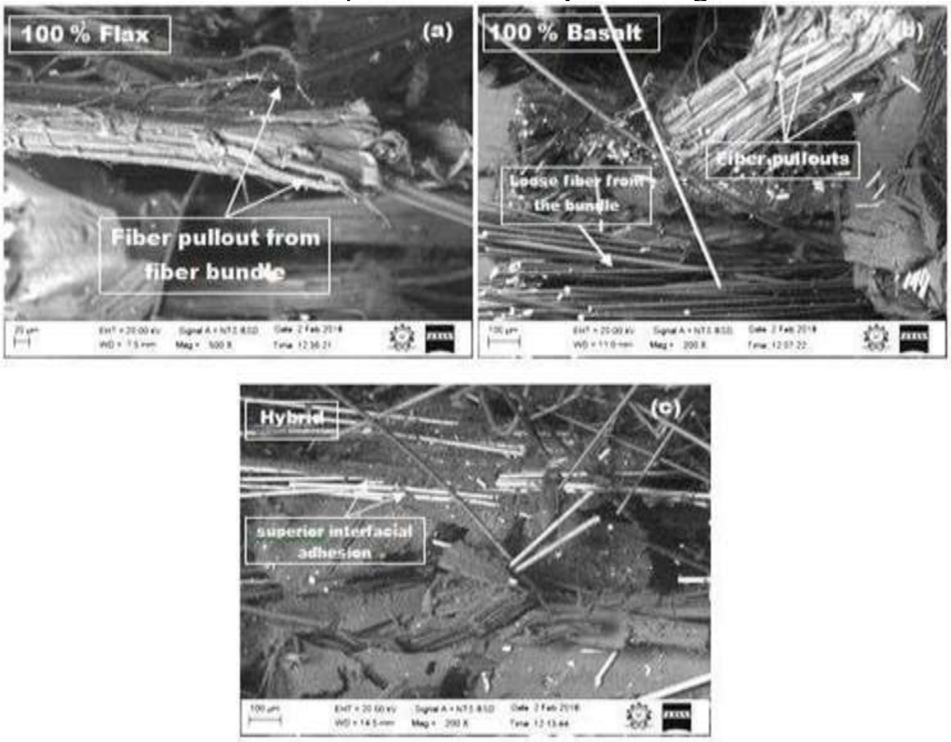


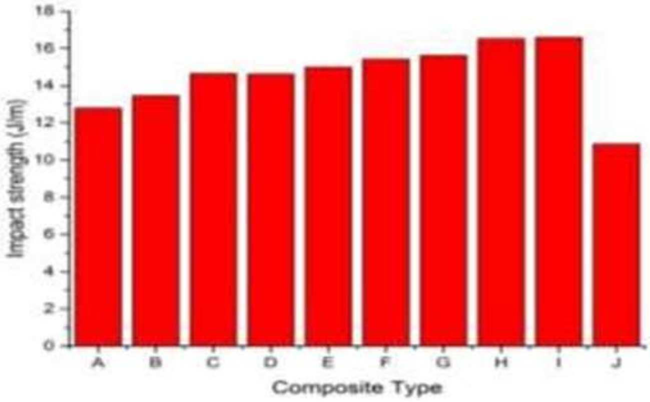
Figure 22 SEM micrograph of flexural tested specimen (a) 100 wt.% flax (b) 100 wt.% basalt (c) hybrid 35 wt.% of basalt fiber and 15 wt.% of flax fiber composite

Influence of 40mm Flax/Basalt Fiber Composite on Impact Property

In terms of impact strength, it was observed that the increase in the percentage of flax fiber enhanced the impact strength of the hybrid composites. Figure 5.5 illustrates the variation in impact strength related to fiber weight percentage. This emphasizes the significance of natural fiber in absorbing impact energy compared to synthetic fiber. Additionally, the addition of basalt fiber in the composite decreased the impact strength.

The maximum impact strength of 16.60 J/m was noted for Composite I, containing 5 wt.% of basalt and 45 wt.% of flax fiber. This value is 52% and 30% higher than that of pure flax and pure basalt composites, respectively.In the present work, a linear variation in impact strength was observed in hybrid composites. This is likely due to the full penetration of impact energy into the composites. Hybrid composites were found to absorb more impact energy than pure composites, attributed to the hybridization effect, which allows the composites to absorb more energy on impact due to the additional fiber loading.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80



The SEM morphology of impact failure is shown in Figure 23.

Figure 24(a) depicts the SEM image of the pure (100%) flax fiber composite, showing micro ploughing and bundle damages. The presence of voids on the surface may be responsible for detachments of the fiber from the bundle under sudden impact loading conditions.In Figure 24(b), the SEM image of the pure (100%) basalt fiber composite shows bonding failures between the fiber and matrix, resulting in microcracking.Figure 24(c) illustrates the SEM image of the composite with 5 wt.% of basalt and 45 wt.% of flax fiber, indicating bonding failures between the fiber and matrix resulting in microcracking.

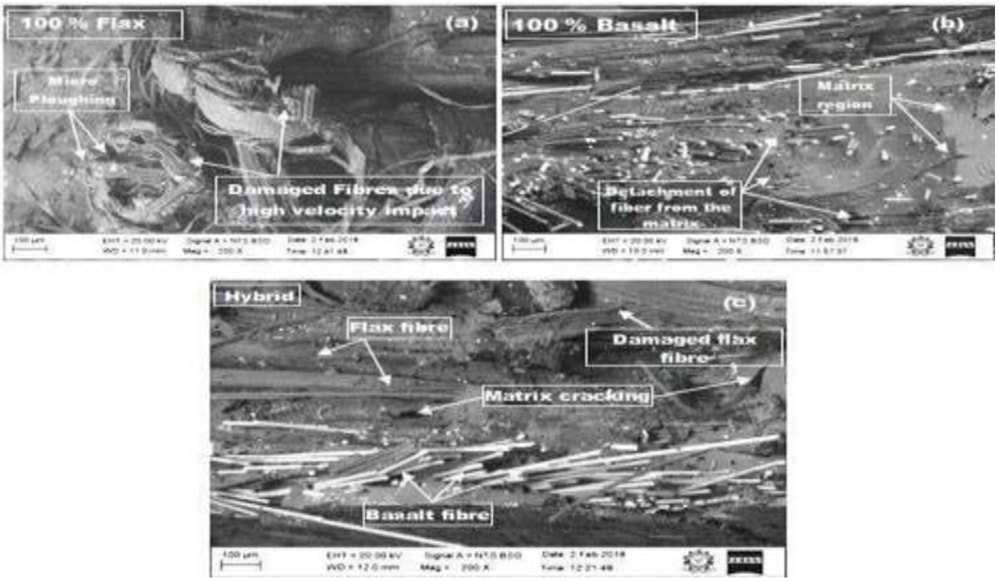


Figure 24 SEM micrograph of impacted tested specimen (a) 100 wt.% flax
(b) 100 wt.% basalt (c) hybrid 5 wt.% of basalt 45 wt.% of flax fiber composite

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 9, Issue 2 - February 2021 - Pages 47-80

CONCLUSIONS

The static and dynamic properties of basalt powder, basalt/flax fiber, and basalt powder reinforced polyester composite.

Hybridization in the 40mm basalt/flax composite reduced brittleness and offered good yielding properties, enhancing tensile strength. The maximum tensile strength was noted for the composite with 40 wt.% basalt and 10 wt.% flax fiber, showing a 22% increase compared to pure flax composite.

Flexural strength of the composite with 35 wt.% basalt and 15 wt.% flax fiber showed an 11% and 17% increase due to hybridization compared to pure flax and basalt composites, respectively. This was attributed to good interfacial bonding between reinforcements and the matrix.

Addition of basalt fiber reduced impact strength, with maximum impact strength noted for the composite with 5 wt.% basalt and 45 wt.% flax fiber, showing a 52% and 30% increase compared to pure flax and basalt composites, respectively.

SEM analysis showed the method of failure under different mechanical loading conditions. Poor interaction between flax fiber bundles and the polyester matrix caused fiber pull-out, while flexural testing revealed microploughing and bundle damages due to sudden impact loading conditions.

Overall, the composite with 35 wt.% basalt and 15 wt.% flax fiber exhibited optimized mechanical properties due to the combination of basalt and flax fiber. Taguchi analysis revealed that 40mm length of flax fiber and 40wt.% weight percentage of fiber resulted in better mechanical properties.

Equal proportions of flax (40 wt.%) and glass (40 wt.%) fibers produced high impact in tensile, flexural, and impact properties.

FUTURE SCOPE:

Using plant-based natural fibers as substitutes for synthetic fibers holds potential for better economic and environmental aspects.

Flax fiber's ability to produce low-cost, lightweight, and high-strength products makes it suitable for structural components and automobile parts.

Basalt and flax fiber combination possess better energy-absorbing capabilities for engineering safety. Further studies can compare experimental and theoretical model analysis (ETMA) for structural applications.

Thermal studies like Thermo Gravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC) can help understand the high-temperature behavior of basalt/flax composites.

Correct combinations of composites should be chosen for specific applications, especially for shockwave absorption and ballistic-related impact applications.

Inexpensive flax and basalt fibers can be used as reinforcement for producing polyester flax/glass composites, bringing economic value to products like aircraft wings, hulls, train compartments, and automobile structural components.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

Volume 11 Issue 5 – May 2023 - Pages 1-11

REFERENCE:

1. RizwanMudassir,etal.,“SwitchingActivityReductioninLowPowerBooth Multiplier”,IEEE, 2008.
2. M. Khanlou, P. Woodfield, J. Summerscales, G. Francucci, B. King, S. Talebian and W. Hall, Estimation of mechanical property degradation of poly (lactic acid) and flax fibre reinforced poly (lactic acid) bio-composites during thermal processing, Measurement, 116, (2018), 367-372.
3. C. Fragassa, A. Pavlovic and C. Santulli, Mechanical and impact characterization of flax and basalt fibre vinylester composites and their hybrids, Composites Part B: Engineering, 137, (2018), 247-259.
4. S. Fu, B. Yu, W. Tang, M. Fan, F. Chen and Q. Fu, Mechanical properties of polypropylene composites reinforced by hydrolyzed and micro fibrillated Kevlar fibers, Composites Science and Technology, 163, (2018), 141-150.
5. T. Lau, P. Hung, H. Zhu and D. Hui, Properties of natural fibre composites for structural engineering applications, Composites Part B: Engineering, 136, (2018), 222-233.
6. Z. Al-Hajaj, L. Sy, H. Bougherara and R. Zdero, Impact properties of a new hybrid composite material made from woven carbon fibers plus flax fibers in an epoxy matrix, Composite Structures, 208, (2019), 346-356.
7. M. Rajaei, K. Kim and D. Bhattacharyya, Effects of heat-induced damage on impact performance of epoxy laminates with glass and flax fibers, Composite structures, 185, (2018), 515-523.
8. S. Mahesh Babu and M. Venkateswara Rao, Effect of basalt powder on mechanical properties and dynamic mechanical thermal analysis of hybrid epoxy composites reinforced with glass fiber, Journal of the Chinese Advanced Materials Society, 6(3), (2018), 311-328.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

Volume 11 Issue 5 – May 2023 - Pages 1-11

9. S. Yu, H. Oh, Y. Hwang and H. Hong, The effect of amino-silane coupling agents having different molecular structures on the mechanical properties of basalt fiber-reinforced polyamide 6, 6 composites, Composites Part B: Engineering, 163, (2019), 511-521.
10. F. Sarasini, J. Tirillo, L. Ferrante, C. Sergi, P. Russo, G. Simeoli and V. Antonucci, Quasi-static and low-velocity impact behaviour of intraply hybrid flax/basalt composites, Fibers, 7(3), (2019), 26.
11. I. Ismail, H. Sultan, M. T. H., M. Shah, M. Jawaid and A. Safri, Low velocity impact and compression after impact properties of hybrid bio-composites modified with multi-walled carbon nanotubes, Composites Part B: Engineering, 163, (2019), 455-463.
12. Y. Shen, J. Zhong, S. Cai, H. Ma, Z. Qu, Y. Guo and Y. Li, Effect of temperature and water absorption on low-velocity impact damage of composites with multi- layer structured flax fiber, Materials, 12(3), (2019), 453.
13. M. Ravandi, U. Kureemun, M. Banu, S. Teo, L. Tong, E. Tay and H. Lee, Effect of interlayer carbon fiber dispersion on the low-velocity impact performance of woven flax-carbon hybrid composites, Journal of Composite Materials, 53(12), (2019), 1717-1734.
14. M. Bunea, A. Circiumaru, M. Buciumeanu, G. Birsan and S. Silva, Low velocity impact response of fabric reinforced hybrid composites with stratified filled epoxy matrix, Composites Science and Technology, 169, (2019), 242-248.
15. Z. Al-Hajaj, H. Bougherara and R. Zdero, Impact properties of a new hybrid composite material made from woven carbon fibers plus flax fibers in an epoxy matrix, Composite Structures, 208, (2019), 346-356.
16. P. Khalili, B. Blinzler, R. Kadar, R. Bisschop, M. Forsth, and P. Blomqvist, Flammability, smoke, mechanical behaviours and morphology of flame retarded natural fiber/elium composite, Materials,

12(17), (2019), 2648.

17. R. Siakeng, M. Jawaid, H. Ariffin and M. Sapuan, Mechanical, dynamic and thermomechanical properties of coir/pineapple leaf fiber reinforced polylactic acid hybrid biocomposites, Polymer Composites, 40(5), (2019), 2000-2011.
18. . Fortunato, L. Anghileri, G. Griffini, and S. Turri, Simultaneous recovery of matrix and fiber in carbon reinforced composites through a diels–alder solvolysis process, Polymers, 11(6), (2019), 1007.
19. V. Doddi, R. Chanamala, and P. Dora, Dynamic mechanical properties of epoxy based PALF/basalt hybrid composite laminates, Materials Research Express, 6(10), (2019),105343.
20. Y. Shen, J. Tan, L. Fernandes, Z. Qu and Y. Li, Dynamic mechanical analysis on delaminated flax fiber reinforced composites, Materials, 12(16), (2019), 2559.
21. M. Gupta, D. Prabhakaran and P.Mahajan, Non-linear material characterization and numerical modeling of cross-ply basalt/epoxy laminate under low velocity impact, Polymer Testing, 145, (2020), 106349.