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*Retraction*

# Retracted: Investigation on Interlaminar Shear Strength and Moisture Absorption Properties of Soybean Oil Reinforced with Aluminium Trihydrate-Filled Polyester-Based Nanocomposites

**Journal of Nanomaterials**

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] L. Natrayan, S. Kaliappan, S. Baskara Sethupathy et al., "Investigation on Interlaminar Shear Strength and Moisture Absorption Properties of Soybean Oil Reinforced with Aluminium Trihydrate-Filled Polyester-Based Nanocomposites," *Journal of Nanomaterials*, vol. 2022, Article ID 7588699, 8 pages, 2022.

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*Research Article*

# Investigation on Interlaminar Shear Strength and Moisture Absorption Properties of Soybean Oil Reinforced with Aluminium Trihydrate-Filled Polyester-Based Nanocomposites

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In recent years, research has shifted away from conventional materials and alloys to composite materials to create lighter, more efficient materials for specific applications. In order to generate lighter, more efficient materials for specific purposes, research has migrated away from traditional materials and alloys and toward composite materials in current years. Blended microbially nanocomposite that takes advantage of organic flax fibres and nanoreinforced biobased polymers can increase characteristics while keeping the environment in mind. Adding aluminium trihydride (ATH) powder to the natural resin allows it to sustain rigidity without compromising toughness while increasing barrier and mechanical characteristics. Investigation of several composite samples confirmed this positive effect, with systems that contain 10% epoxidized methyl soyate (EMS) and 2.5 wt.% ATH maintains the original resin's rigidity, strain to fracture, and hygromechanical characteristics while enhancing toughness. Mechanical testing like interlaminar shear strength (ILSS) was found per the standard ASTM testing method. Among the various combinations, the second combinations (77.5 wt.% polyester, 2.5 wt.% ATH, and 20 wt.% of flax fibre) provide the highest value of ILSS (34.31 MPa). Scanning electron microscopy was used to examine the fractured surface of the nanocomposites and the degree of dispersion of the ATH filler.

## 1. Introduction

Environmental responsiveness has had a tremendous influence on materials engineering and design worldwide in recent years [1, 2]. Concerns about the impact of artificial or hydrocarbon polymeric composites on the environment have led to the development of organic or regenerative composites. Biological adhesives, made up of organic fibres in an artificial or organic polymeric matrix, have recently gained a lot of interest due to their low cost, ecologically benign nature, and competition with synthetic composites. Biobased composites' utilization has been limited due to their lower mechanical and thermal qualities than synthetic composites and traditional structural materials. Environmental challenges like renewability and pollution prevention have sparked a growing interest in using organic fibres. Because of their excellent strength and rigidity capabilities, artificial fibres such as carbon, graphite, and aramid are now commonly employed in polymer-based composites [3, 4]. Glass fibre-reinforced composites (GFR) are presently accessible at a variety of pricing points and structural qualities. Construction, automobile, and turbine manufacturing are examples of industrial applications. GFR composites, on the other hand, are created from nonrenewable materials and are known to consume a lot of energy throughout production. Apart from that, recycling GFR is difficult. As environmental concerns become more prominent, more ecologically friendly composite materials have been developed. Natural fibres are usually thought to be more environmentally friendly than glass fibres. Natural fibres have several benefits over synthetic materials, such as recyclability, low weight, and cheapness. Since it lowers fuel usage, unsprung weight potentially reduces costs, particularly in the automotive sector. Natural fibre-reinforced composites have been employed in the automobile industry for many years, although primarily for nonstructural purposes [5, 6]. Owing to their qualities and quantity, coco fibre, wool, hemp, kenaf, and cotton are the most commonly used biofibres in composites.

Flax (Linum usitatissimum L.) is a member of the Linaceae group, which includes thirteen families and 300 genera, and has been the family's only agriculturally important genus. Flax, the first fabric taken from crops and strengthened into a matrix, was cultivated and unearthed in Egyptian burials around 4000 B.C. It is among the most extensively used biofibres [7, 8]. Flax has been farmed for so many centuries because of its fibres and oil, and it is a valuable commodity. Flax focuses on extensive research and the adoption of desirable characteristics such as glyphosate tolerance, resistance to abiotic stresses, and higher oil and fibre grades. Flax is a 0.5–1.25 m tall evergreen shrub with 16–32 mm stems. Phytoemployees in flax production are more effective on inferior grounds, where abiotic environmental factors generate increased mortality than on rich soils [9]. The study's goal, which took place in 2020 and 2021 on two different soil types, was to test the effectiveness of acetylsalicylic and salicylic compounds in cultivating flax fibre. During tests, salicylic acid did not influence the number of flax outputs. Even though natural fibres are never a problem-free alternative to artificial fibres, due to the degradation of natural materials, low surface characteristics among fibres and polymer matrices often limit their effectiveness as reinforcement materials.

Hybrid composites are composites that have more than two fibres in a single matrix. Hybridizing can improve the mechanical characteristics of natural fibre-reinforced polymer composites by overcoming the disadvantages of separate composites [10, 11]. Microbially adhesives, or bioblends, are a potential balance among environmental protection and effectiveness, produced by substituting part of a petrol-based adhesive with natural bioresin. Microbially, resins increase the resultant resin mix's durability and have a greater natural component. This gain in hardness, however, comes at the expense of rigidity, barriers, and thermal characteristics. Rigidity and hardness are two opposing performance criteria that must be balanced for a successful composite. Including nanobased powder particles like ATH is one technique to achieve this equilibrium. This research is aimed at figuring out how to make the industrial aluminium trihydrate-laden polycomposite waste powder more usable. The ATH might be utilized as fresh material for novel goods since its worldwide output is anticipated to be around 86000 tonnes yearly [12, 13].

Growing environmental compatibility, ideal rigidity balancing, and other tunability attributes like enhanced and/or controlled humidity and mechanical properties need a perfect or complementary balancing act of the various constituents in the final hybrid's biomaterials. This study is aimed at demonstrating that a complementary balance may be achieved. The major goal of this research was to develop and characterize novel multiresolution hybridized biomaterials produced from microbially mixed polyester resin and epoxidized methyl soyate enriched with ATH and organic flax slices. Compression moulding was utilized to develop biomaterials that changed the concentration of organic in UPE and the ATH concentration. To evaluate mechanical qualities, traditional tests were utilized. The degree of ATH dispersion in the resin systems and the features of fracture surfaces were determined using scanning electron microscopy.

## 2. Investigational Resources and Methods

*2.1. Reinforcement Materials.* The flax fibre was collected from GVR Fiber Industry, Madurai, Tamil Nadu, India. To remove the dampness in the fibres, they were properly laved with clean water and sun-dried for two days. The extraction of flax reinforcing materials from their plants is depicted in Figure 1. After that, the flax fibre was immersed in NaOH solution for 4 hrs. Then, the fibre was laved carefully with clean water and placed in the oven at 75°C. The HN361 type of alumina trihydride (ATH) and polyester matrix was employed in this study. Naga Chemicals Industries, Chennai, Tamil Nadu, India, supplied the matrix and ATH fillers. The chemical construction of ATH is revealed in Figure 2. A biobased modification, epoxidized methyl soyate (EMS), was used as a supplementary component to replace sections of the polyester resin. EMS is a fatty acid composed of the transesterification reaction of the fatty acids found in soybeans. The chemical structure of EMS is shown in Figure 3. Table 1 lists some of the mechanical and physical properties of flax and polyester matrix.

*2.2. Processing of Nanocomposites.* The bonding agent (polyester+EMS+ATH) substituted polyester with various quantities of ATH and EMS. ATH was stirred continuously in propanone at a resolution absorption of around acetonitrile to one kilogram of ATH, with a magnetic stirrer continually stirring it. The polyester and EMS were then introduced to an acetonitrile solution and stirred for 3–4 hours on a hot


Figure 1: Flax fibre extraction from flax plant.

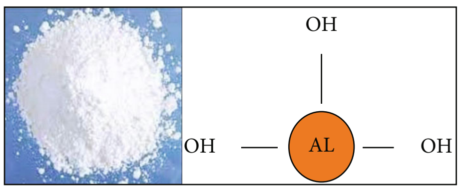


Figure 2: ATH powder and its chemical structure.

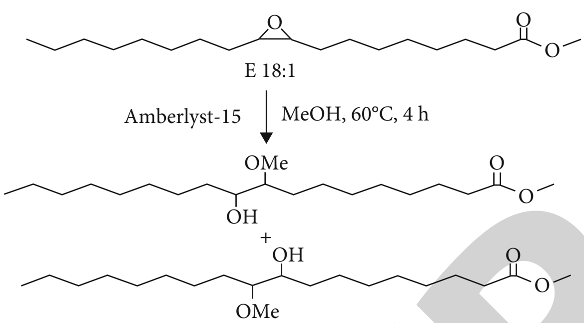


Figure 3: Chemical structure of epoxidized methyl soyate (EMS),

Table 1: List of mechanical and physical properties of flax and polyester matrix.

| Sl. No. | Properties | Flax fibre | Polyester resin |
|---|---|---|---|
| 1 | Cellulose (%) | 64.57-75.38 | — |
| 2 | Hemi cellulose (%) | 12.96-26.07 | — |
| 3 | Lignin (%) | 4.78-7.44 | — |
| 4 | Density (g/cm$^3$) | 1.4 | 1.16 |
| 5 | Tensile strength (MPa) | 500-1500 | 8-19 |
| 6 | Young's modulus (GPa) | 50-70 | 0.58 |
| 7 | Elongation (%) | 1.8-2.1 | 1.6 |

plate with magnetic stirring to eliminate the bulk of the acetone. The residual acetone was extracted using a pressure extractor at 55°C for 12–24 hours. For all resin systems, the quantity of oomph expended on the sonicating process was kept constant at 31 kilojoules. The polyester employed in this investigation had a styrene concentration of 34.56 wt.%. The total styrene percentage of the final resin mix was lowered by replacing sections of UPE with bioresins. The lower styrene concentration was suspected of causing early curative of the polymeric mixture after propanone elimination. As a result, cinnamene was additional to the natural polymeric mixture to keep the complete cinnamene pleased of the resin system at 34.56 wt.%. In a hybrid bio-

Table 2: Configurations of hybrid nanocomposites.

| Sample No. | Configuration (%) Polyester | ATH | EMS | Flax weight fraction (wt.%) |
|---|---|---|---|---|
| 1 | 80 | 0 | 0 | 20 |
| 2 | 77.5 | 2.5 | 0 | 20 |
| 3 | 70 | 0 | 10 | 20 |
| 4 | 67.5 | 2.5 | 10 | 20 |
| 5 | 60 | 0 | 20 | 20 |

composite material system, the produced polymeric nanocomposite (polyester+EMS+ATH) was employed as the matrix for natural fibres [14].

*2.3. Fabrication of Nanocomposites.* Compression moulding was used to make flat nanocomposite specimens for the following substantial arrangements mentioned in Table 1. Before use, the fibres were dried for 12 hours in a muffle furnace at 70°C with a pressure of 90 kPa. The promoters and initiators were combined with the nanoreinforced binder system (polyester+EMS+ATH). The fibres were then manually soaked with the binder system till the consistency of the material was achieved. After that, the soaked fibres were inserted into a frame mould. Natural fibres have a propensity to cluster and tangle together, so it was important to carefully dispense the fibre substantial in the mould to guarantee a consistent specimen. The frame mould was sandwiched between two Teflon-coated steel plates. The specimen was then dried in a press at 100°C for 2 hours with 555 kPa pressure, then at 150°C for 2 hours. Table 2 shows the configurations of hybrid nanocomposites.

*2.4. Testing of Hybrid Composites.* The fabricated composite samples were cut and rendered to the ASTM standard of D-2344 replicas with a dimension of $45 \times 3 \times 3$ mm for interlaminar shear strength of the biobased nanocomposites.

*2.5. Fractographic Study.* SEM was utilized to conduct microscopic investigations into fractured composite samples. The specimens were laved, dehydrated, and surface coated with 10 nm of gold before SEM clarity to increase the composites' electrical conductivity.

## 3. Result and Discussion

Adding ATH or EMS could have a positive or negative effect on the variable tested. Consequently, all of the findings in the subsequent subsections are compared to the reference

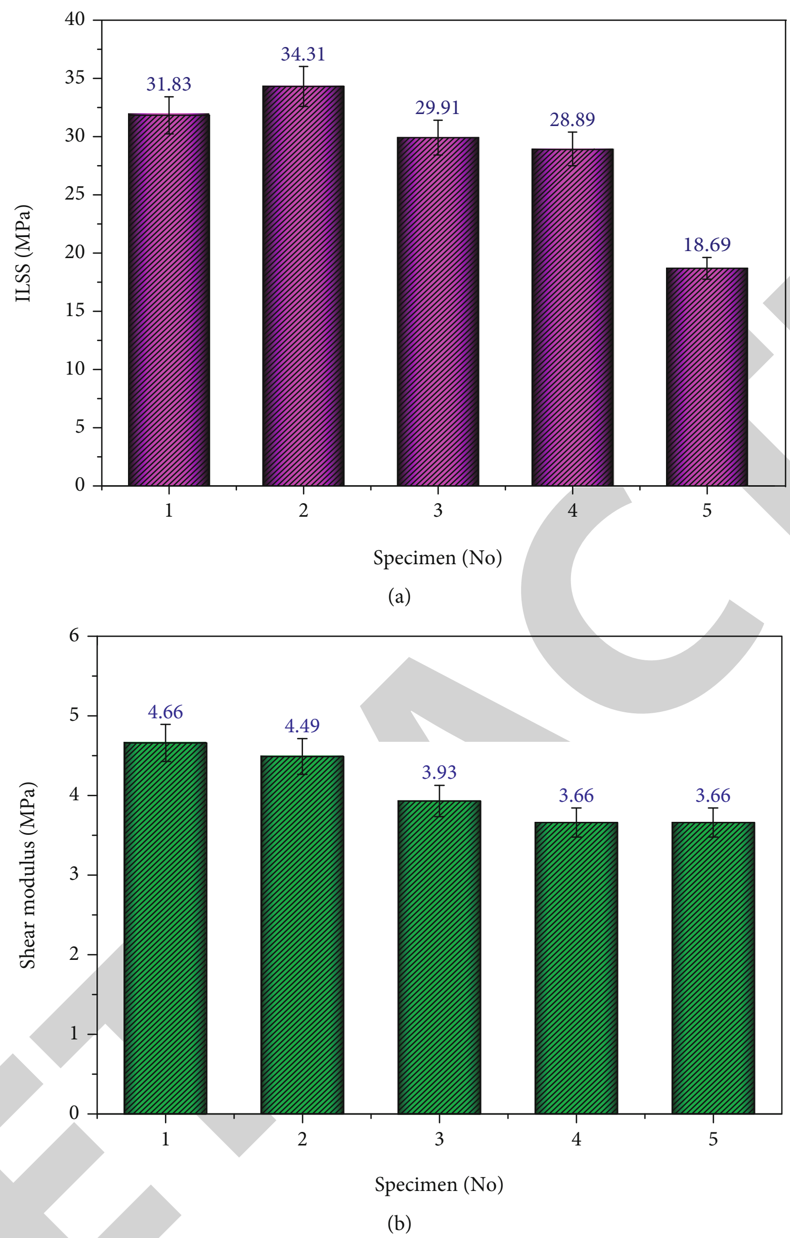


Figure 4: Mechanical properties: (a) ILSS; (b) shear modulus.



biocomposite sample 1, which is made entirely of polyester (0% EMS and 0% ATH).

*3.1. Interlaminar Shear Strength.* A universal testing machine (UTM) with a load cell limit of 5 kN was used to assess the composite frame's interlaminar shear strength. The ASTM standard D-2344 was used to cut the sample. Under three-point bending, a 45 mm long bar with a minimum thickness (width equals thickness) and square cross-segments was loaded. The ILSS response of composites is used to determine if there is shear behaviour between the layers of the material. The ILSS examination is performed on composites to determine the bonding between layers to resist shear pressure at a specified spot [15]. Figures 4(a) and 4(b) show the interlaminar shear strength and their modulus values. Due to the bio-low-resin's rigidity, the introduction of bioresin to polyester lowered shear properties. The shear modulus of biocomposite samples 3 and 5 was condensed by around 9% and 31%, correspondingly [16, 17].

Likewise, the ILSS of biocomposite samples 3 and 5 fell by roughly 5% and 21%, correspondingly [18, 19]. Because the shear modulus is predominantly determined by natural fibre reinforcement, a significant rise in shear modulus is owing to 2.5 wt.% ATH was not anticipated [20]. Despite this, biocomposite sample 2, which included 2.5 wt.% of ATH in UPE, exhibited a shear modulus increase of around 5% on average. A comparable rise was predicted for biobased nanocomposite materials containing 10% EMS (samples 3 and 4). The ATH benefits were more noticeable in polyester nanocomposites than in polyester/EMS nanocomposites [21]. This suggests

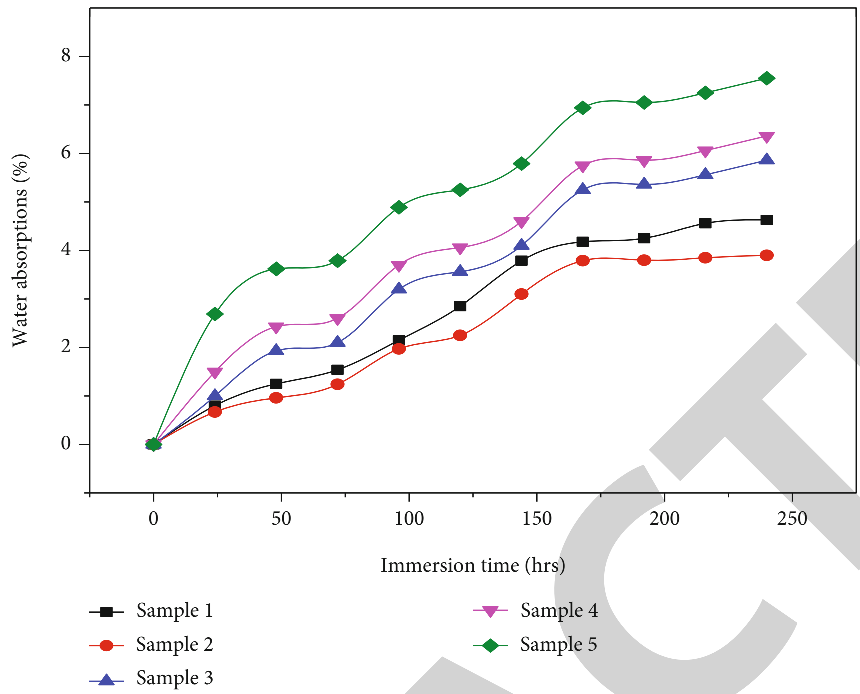


FIGURE 5: Moisture absorption characteristics of flax and ATH-based nanocomposite.



that the detrimental effect of EMS was greater than the benefit offered by ATH, raising doubts about EMS and ATH interaction [2, 22]. The concordance, according to the writers, was satisfactory. Component design refinement of a three-phase system was conducted in simultaneous computational analysis to determine their dispersion by comparing computationally homogenized shear modulus to experimental results [23]. According to the findings, the bioresin accumulates surrounding the ATH platelet, implying a bond between them [24]. The stress transmission is affected by depositing more complaining EMS surrounding the ATH powder, which promotes a lower degree of interlaminar shear strength improvements [25]. The bending modulus and deformation between the plies strongly rely on the delamination between layers. If the load is applied on one-ply, the failure between the composite layers results in complete failure. This failure is assessed through the ILSS testing [26]. Generally, the higher value of ILSS indicates the strong adhesions between aluminium filler, polyester matrix, and flax fibres.

*3.2. Moisture Absorption Behaviour.* The moisture absorption characteristics of flax and ATH-based nanocomposite are shown in Figure 5. The findings of moisture absorption experiments are represented in the following segment. Moisture absorption was shown to be higher with higher bioresin (EMS) concentration and lower with the inclusion of ATH nanopowder. The inclusion of 10% EMS (specimen 3) and 20% EMS (specimen 5) increased hydrophilic nature by around 7% and 19%, correspondingly. For specimen 5, the rise in water uptake was roughly 21% [27]. The inclusion of 2.5 wt.% ATH decreased the moisture content of specimens 2 and 3 by around 2.5 and 9%, correspondingly [28]. With 10% EMS and 2.5 wt.% ATH, nanocomposite specimen 4 performed similarly to reference nanocomposite specimen 1.

Generally, it was discovered that adding ATH powder restored the drop in water absorption characteristics resulting from the addition of bioresin [29]. The inclusion of EMS improved the nanocomposite's hydrophilic nature. Furthermore, the results show that the negative impacts of bioresin on porosity may be mitigated by using ATH augmentation [30]. According to the water uptake data, the bio-based nanocomposite materials retain less water than natural fibres alone [31]. The flax fibres alone would be claimed to collect 6% water, whereas the nanocomposite specimen 1 retained about 4% humidity. As a result, the matrix acts as a barrier, limiting the amount of water captured by the natural fibres [32]. Bioresin is much more porous than its artificial equivalent in biobased polymers [33]. ATH additives create a convoluted channel for water flow, improving the matrix's barrier characteristics and allowing the detrimental effects of bioresin addition to being recovered [34].

*3.3. Microstructural Analysis.* SEM was used to examine the nanocomposite morphologies at the broken interface (after ILSS) (Carl Zeiss, supra-55). The images back up the prior results that the composites had reduced permeability due to uniform fibre distribution [35]. Pull-outs of fibres and fibre packs result in surface holes that can be observed in SEM.

As seen in the SEM image, a single fibre was torn out during the rupture. The SEM examination confirmed that the relationship between matrix and reinforcement is good. For instance, the reinforcements are all moistened by the resin. Additionally, it indicated that the fibres are well scattered in the resin system. Figure 6(a) shows the fibre breakdown in the unfilled flax fibre-reinforced composites. The long fibres' fibre breakdown occurs in the middle. As noted

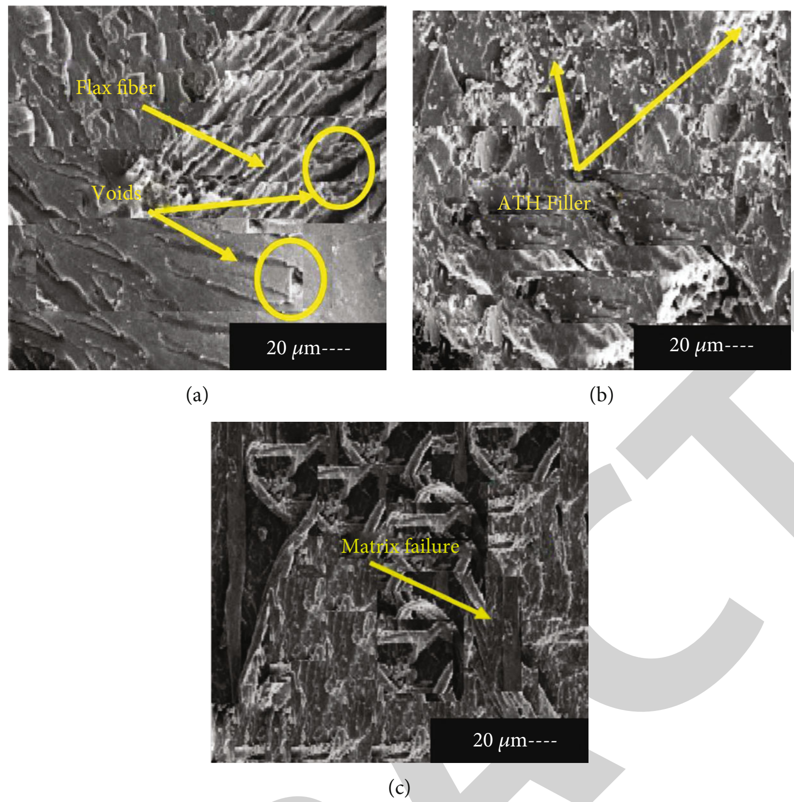


Figure 6: Microstructural image of flax and ATH-based nanocomposites.

in Section 3.1, this might be attributed to flax fibres that did not adhere effectively to the polyester matrix, affecting the mechanical characteristics of the plastic encapsulation composites. The scattering of micronized ATH nanoparticles can be seen in Figures 6(b) and 6(c) with white nanoparticles that appeared on the polyester matrix surface in the microscope.

Furthermore, the inclusion of micronized ATH, as illustrated in Figures 6(b) and 6(c), results in a rougher matrix surface than the empty ATH composites (a). The mechanical property of nanocomposite is also affected by the nanoscale distribution. To minimize aggregation and provide excellent dispersion of the nanoscale ATH particle, which influences its mechanical characteristics, the constancy of the mixing time during production, either hard or lengthy swirling, is critical. Flax fibre readily breaks into bundles when shear pressures operate on the polyester matrix due to the poor connection between reinforcement and resin.

## 4. Conclusion

Interlaminar shear properties have been proven to be enhanced by considering mechanical properties. This research presents a green approach for increasing the mechanical performance of flax, ATH, and EMS-based polyester hybrid composites. The mechanical characteristics of the materials were assessed, and the findings were compared to raw fibre-based materials. As the concentration of the ATH grows, the initial breaking situations, which are linked to the stress-strain graphs relaxing, correspond with higher strength and deformity values because the highest weight percent of ATH provides better interfacial bonding between matrices and their fibres. This aids in removing fibre pulls and voids. Similarly, the recommended ATH addition enhances the water absorption characteristics of the nanocomposites produced. Direct analysis of the fractured surfaces using SEM, which strongly supports the treatment's better impact on fibre-matrix adhesion, backed up the concept, which had been obtained implicitly based on the mechanical data.

## Data Availability

The data used to support the findings of this study are included within the article. Should further data or information be required, these are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

## Acknowledgments

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