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Exploring the mechanical impact of fine powder integration from ironwood sawdust and COCO dust particles in epoxy composites

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ABSTRACT

Bio-composite materials are gaining momentum as eco-friendly substitutes for synthetic fiber-reinforced composites across various sectors. This study investigates how varying fine powder loads affect the tensile, transverse, and compressive properties of hybrid composites comprising Malabar Ironwood sawdust and COCO dust particles. A hybrid composite formulation was devised using a 1:1 ratio of sawdust and COCO dust particles as fillers. Different levels of reinforcement, ranging from 20% to 60%, were examined. ASTM testing was performed on the produced composites, revealing a notable influence of filler reinforcement on their mechanical characteristics. The elongation at fracture increased until 40% filler loading before declining, whereas tensile strength, transverse rupture strength, transverse modulus, and compressive strength consistently improved up to 50% filler loading. These results underscore the potential of composites integrating Malabar Ironwood, COCO dust, and epoxy for lightweight applications, thereby catering to diverse industries seeking sustainable alternatives to traditional materials. Ultimately, such initiatives contribute to solid waste management efforts, offering sustainable alternatives to conventional materials in diverse industries.

Keywords: Malabar Ironwood; COCO dust particles; Fine powder loads; Hybrid composites; Solid waste.

1. INTRODUCTION

In recent years, there has been a remarkable surge in interest and research activity surrounding the development of bio-composite materials. These materials are increasingly viewed as sustainable alternatives to conventional synthetic fiber-reinforced composites across a multitude of industries [1]. The motivation behind this trend stems from the pressing need to address environmental concerns, reduce reliance on finite resources, and promote more eco-conscious manufacturing practices.

Bio-composites offer a range of advantages over traditional materials, including reduced environmental impact, enhanced biodegradability, and the utilization of renewable resources [2]. By incorporating natural fibers and fillers derived from agricultural and forestry waste, bio-composites contribute to circular economy principles by repurposing materials that would otherwise be discarded as waste. Furthermore, these materials have the potential to exhibit comparable or even superior mechanical properties compared to their synthetic counterparts, making them increasingly attractive for various applications [3].

Among the myriad natural fillers used in bio-composite formulations, two stand out for their promising mechanical properties and sustainability credentials: Malabar Ironwood (Mesua ferrea) sawdust and COCO (coconut) dust particles. Malabar Ironwood, a tree species native to the Indian subcontinent, is renowned for its exceptional strength, durability, and resistance to decay [4]. Its utilization as a filler in composite materials offers the dual benefits of enhancing mechanical performance while harnessing a renewable resource. Similarly, COCO dust, a byproduct of the coconut processing industry, presents a lightweight and fibrous filler option with inherent eco-friendly characteristics [5].

This research endeavors to delve into the mechanical behavior of hybrid composites comprising Malabar Ironwood sawdust and COCO dust particles. By focusing on the influence of fine powder loading on key

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mechanical properties such as tensile strength, transverse strength, and compressive strength, the study aims to elucidate the synergistic effects of these natural fillers within the composite matrix [6]. The use of a 1:1 ratio of sawdust and COCO dust particles as fillers in the hybrid composite configuration underscores a novel approach to achieving optimal mechanical performance while maximizing the utilization of sustainable materials [7]. The experimental methodology employed in this research involves varying the filler content within the composite matrix across a range of reinforcement levels, spanning from 20% to 60%. This comprehensive investigation allows for a nuanced understanding of how different filler loadings impact the mechanical properties of the hybrid composites [8]. Rigorous ASTM testing protocols, including standardized tests for tensile, transverse, and compressive characteristics, provide quantitative data to facilitate detailed analysis and interpretation [9].

The outcomes of this study hold significant implications for a diverse array of industries seeking sustainable solutions for lightweight applications. By elucidating the mechanical behavior of hybrid bio-composites reinforced with Malabar Ironwood sawdust and COCO dust particles, this research contributes to the growing body of knowledge surrounding eco-friendly materials [10]. Moreover, the findings may inform the development of optimized composite formulations tailored to specific performance requirements in sectors such as construction, automotive, aerospace, and beyond [11]. This research endeavor represents a concerted effort to advance the frontier of sustainable materials science by exploring the mechanical potential of bio-composites. Through meticulous experimentation and analysis, the study aims to uncover insights that not only enhance our understanding of hybrid composite materials but also pave the way for their widespread adoption in real-world applications. Ultimately, by harnessing the power of nature's resources and ingenuity, bio-composites offer a pathway towards a more sustainable and resilient future [12].

2. MATERIALS AND METHODS

2.1. Raw materials

2.1.1. Malabar Ironwood sawdust

Sawdust particles obtained from the milling or grinding of Malabar Ironwood were used as one of the filler materials in the composite formulation. The sawdust was sourced from sustainable forestry practices to ensure consistency and quality.

2.1.2. COCO dust particles

Waste material generated from the processing of coconuts, such as coconut shells or husks, was collected and processed into fine dust particles. These COCO dust particles served as the second filler material in the composite formulation.

2.1.3. Epoxy resin

A commercially available epoxy resin system was used as the matrix material to bind the sawdust and COCO dust particles together in the composite. The epoxy resin provided adhesion between the filler particles and imparted structural integrity to the final composite material [13].

2.2. Composite formulation

The hybrid composite formulation was prepared by mixing Malabar Ironwood sawdust and COCO dust particles in a predetermined ratio. A 1:1 ratio of sawdust to COCO dust particles was selected to achieve a balanced blend of properties, taking into consideration the unique characteristics of each filler material. The epoxy resin was then added to the mixture in the appropriate proportion to ensure adequate wetting and bonding of the filler particles. The mixing process was carried out thoroughly to achieve a homogeneous distribution of the filler materials within the epoxy matrix.

2.3. Chemical treatment of Malabar Ironwood sawdust

Malabar Ironwood renowned for its durability and strength was procured from a local woodworker in Coimbatore. The timber was meticulously sawed using a fine-toothed saw blade to obtain high-quality sawdust. To prepare the sawdust for incorporation into the composite material, it underwent a chemical treatment process. Initially, the sawdust was immersed in a 10% NaOH solution at room temperature for a duration of 5 hours. Following this treatment, the sawdust was thoroughly washed with acidified water to remove any residual alkalinity. Subsequently, the treated sawdust was dried in an oven at 80°C for a period of 10 hours to eliminate moisture and

Table 1: Shows the composite designation.

SAMPLE DESIGNATION	MALABAR IRONWOOD SAWDUST (wt%)	COCO DUST PARTICLES (wt%)	EPOXY RESIN (wt%)
10MIS10CDP	10	10	80
15MIS15CDP	15	15	70
20MIS20CDP	20	20	60
25MIS25CDP	25	25	50
30MIS30CDP	30	30	40

ensure uniformity in particle properties. Once dried, the sawdust was sieved using standard test sieves with apertures measuring 300, 450, and 600 microns, yielding various particle sizes.

2.4. Chemical treatment of COCO dust particles

COCO dust particles, derived from the outer shell of the coconut, were obtained from a local supplier in Coimbatore. Prior to use, the COCO shells were thoroughly cleaned and washed to remove any impurities. Subsequently, the shells were dried using solar energy and then finely ground into particles.To enhance their compatibility with the composite matrix, the COCO dust particles underwent chemical treatment. A solution of 5% NaOH was prepared, and the COCO dust particles were soaked in this solution for duration of 3 hours [14]. Following the soaking process, the particles were rinsed with acidified water to neutralize any remaining alkalinity. The treated COCO dust particles were then subjected to drying in an oven at 80°C for a period of ten hours to ensure complete removal of moisture.

2.5. Fabrication of hybrid composite panels

The hybrid composite panels were fabricated using the hand lay-up technique. The composites were formulated with a 1:1 reinforcement ratio of Malabar Ironwood sawdust and COCO dust particles, with varying filler concentrations of 20%, 30%, 40%, 50%, and 60% (Table 1). To ensure homogeneity, precise amounts of sawdust, COCO dust particles, and epoxy resin were measured and thoroughly mixed in a plastic container for 25 minutes. Subsequently, the mixture was poured into the prepared mold and allowed to rest at room temperature for 24 hours under a weight of 40 kg to eliminate any entrapped air bubbles. Afterward, the composite panel was demolded and left to cure for a period of 21 days to achieve optimal mechanical properties. Following the curing process, the composite panels were shaped into standardized specimens. The epoxy resin and hardener were mixed in a weight-to-weight ratio of 10:4 to ensure proper curing and bonding of the composite components [15].

2.6. Composite designation

The table presents a detailed breakdown of the composition of various composite samples, identified by specific labels. Each sample designation comprises three elements: the percentage of Malabar Ironwood sawdust (wt %), the percentages of COCO dust particles (wt %), and the percentage of Epoxy Resin (wt %). For instance: Sample 10MIS10CDP includes 10% Malabar Ironwood sawdust, 10% COCO dust particles, and 80% Epoxy Resin. This format facilitates a clear understanding of the composition of each composite sample, allowing for easy comparison and reference within the study.

3. ASTM TESTING

The manufactured composite specimens underwent a series of mechanical tests following ASTM standards to evaluate their tensile, transverse, and compressive properties. Test specimens were prepared according to the specifications outlined in the respective ASTM standards for each test.

3.1. Tensile testing

Tensile strength evaluation followed the ASTM D638 procedure using a universal testing machine (UTM). Each composite specimen underwent gradual tension until fracture, securely held at both ends by the UTM. The average tensile strength and elongation at fracture values were computed for each sample after five repetitions.

3.2. Compression test

Samples underwent uniaxial compression testing following ASTM D695 standards, utilizing the standard testing system with a crosshead speed of 1 mm/min. The elastic modulus and maximum compressive strength were determined as key compression characteristics.

3.3. Flexural test

Conducted in accordance with ASTM D790-17 standards, the flexural test was performed using a three-point bending fixture on a universal testing machine. A center load was applied to a beam supported at both ends. The following equations were utilized to calculate the rupture and elasticity values.

4. RESULT AND DISCUSSION

4.1. Tensile strength

The tensile strength, measured in megapascals (Mpa), of five different samples designated as 10MIS10CDP, 15MIS15CDP, 20MIS20CDP, 25MIS25CDP, and 30MIS30CDP. The tensile strength values for these samples are 26, 31, 44, 38, and 32 Mpa, respectively. Tensile strength is a measure of the maximum stress that a material can withstand while being stretched or pulled before breaking. In this context, the samples are likely materials being tested for their mechanical properties, specifically their ability to resist deformation under tension. The results indicate that sample 20MIS20CDP has the highest tensile strength at 44 Mpa, while sample 10MIS10CDP has the lowest tensile strength at 26 Mpa. These findings suggest that sample composition or processing conditions may have a significant impact on the tensile strength of the material. Further analysis and testing would be necessary to determine the factors influencing the tensile strength of these samples and to draw more definitive conclusions. Figure 1 shows the tensile strength of various mix.

4.2. Percentage of elongation

The percentage elongation values for different samples designated as 10MIS10CDP, 15MIS15CDP, 20MIS20CDP, 25MIS25CDP, and 30MIS30CDP. The percentage elongation values represent the amount of deformation or stretching a material undergoes before breaking, indicating its ductility. The values range from 1.5% for the 10MIS10CDP sample to 3.5% for the 30MIS30CDP sample. This data is crucial for understanding the mechanical properties of the samples and can be used to assess their suitability for various applications. The increasing trend in percentage elongation values from 10MIS10CDP to 30MIS30CDP suggests a potential correlation between the composition or processing of the samples and their ductility. Further analysis and comparison of these values can provide valuable insights into the behavior of the materials under different conditions, contributing to the advancement of materials science research. Figure 2 shows the perentage of elongation of various mix.

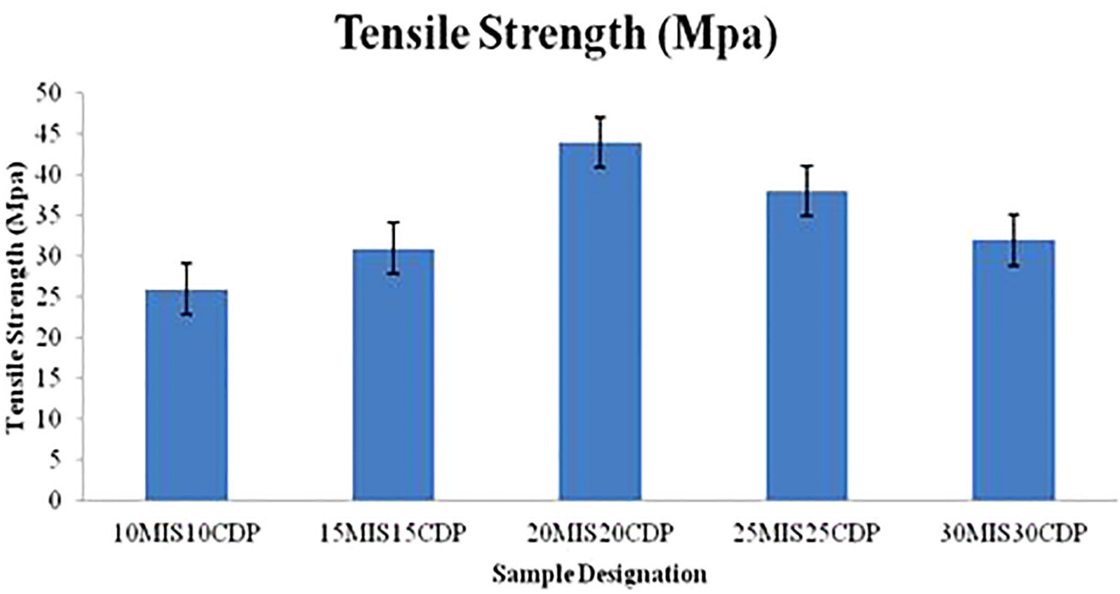

Figure 1: Tensile strength.

4.3. Flexural strength

The flexural strength values for different samples designated as 10MIS10CDP, 15MIS15CDP, 20MIS20CDP, 25MIS25CDP, and 30MIS30CDP are 38, 40, 61, 58, and 55 Mpa, respectively. Flexural strength is a measure of a material's ability to resist deformation under load, specifically bending or flexing. In this context, the samples are likely materials that are being tested for their mechanical properties, particularly their ability to withstand bending forces. The values in the table indicate that the sample designated as 20MIS20CDP has the highest flexural strength at 61 Mpa, while the sample designated as 10MIS10CDP has the lowest flexural strength at 38 Mpa. These values provide important information about the strength characteristics of the materials being tested and can be used to compare the performance of different samples under similar conditions. The data presented in the table can be further analyzed and interpreted to draw conclusions about the materials' suitability for specific applications or to inform the development of new materials with improved mechanical properties. Figure 3 flexural strength of various mix.

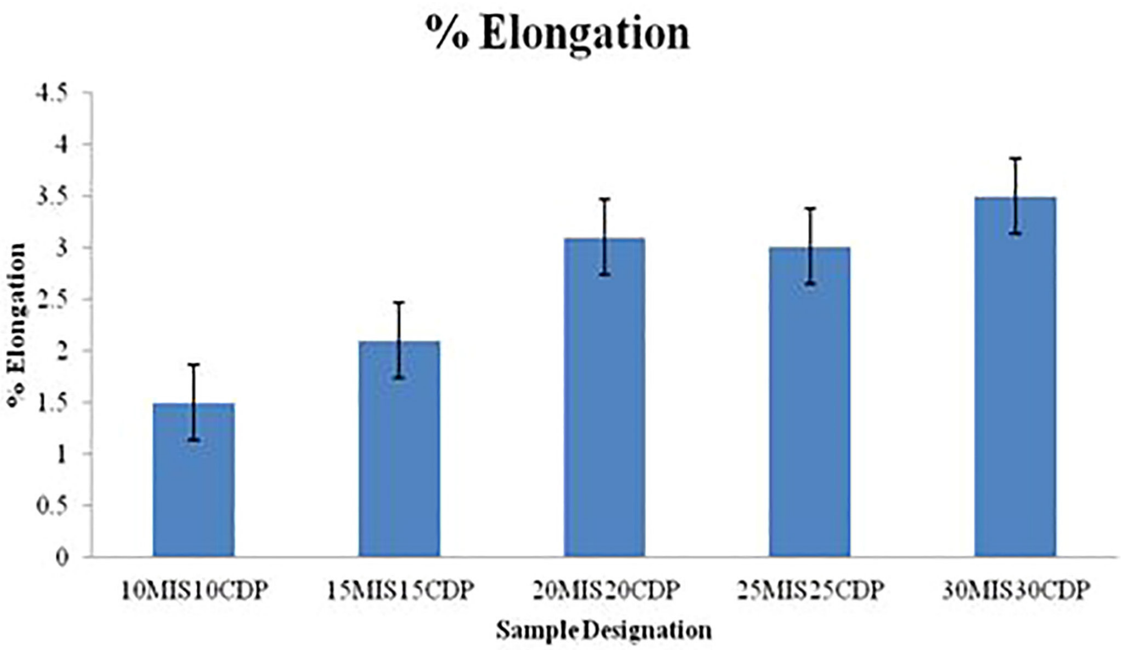

Figure 2: Percentage of elongation.

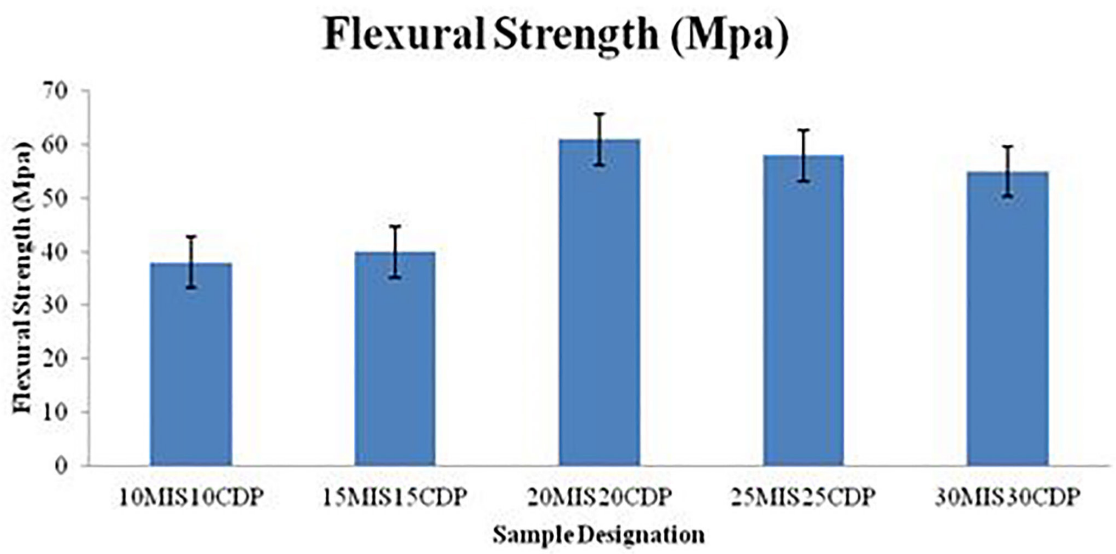

Figure 3: Flexural strength.

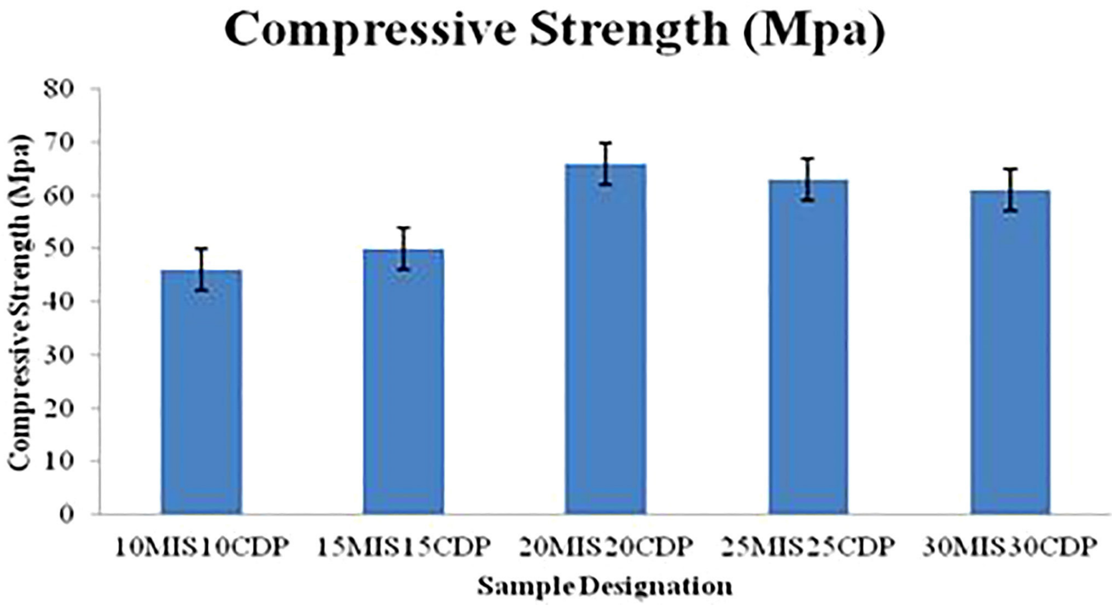

Figure 4: Compressive strength,

4.4. Compressive strength

The compressive strength values for different samples designated as 10MIS10CDP, 15MIS15CDP, 20MIS-20CDP, 25MIS25CDP, and 30MIS30CDP. These samples were likely subjected to a compressive strength test to determine their ability to withstand axial loads. The results show that the compressive strength values vary among the samples, with 20MIS20CDP exhibiting the highest strength of 66 Mpa, followed by 25MIS25CDP at 63 Mpa, and 30MIS30CDP at 61 Mpa. On the other hand, 10MIS10CDP and 15MIS15CDP have lower compressive strength values of 46 Mpa and 50 Mpa, respectively. These results suggest that the composition or manufacturing process of the samples may have influenced their compressive strength properties. Further analysis and comparison of these samples could provide valuable insights into the factors affecting compressive strength in materials. Figure 4 shows the compressive strength.

4.5. Hardness

The hardness values range from 61 to 83, with sample 20MIS20CDP having the highest hardness value of 83 and sample 10MIS10CDP having the lowest hardness value of 61. These hardness values were likely obtained through a standardized testing method, such as the Rockwell hardness test which measures the resistance of a material to indentation or penetration. The data used to analyze the hardness properties of the samples and draw comparisons between them. This information could be valuable in a scientific research paper focused on material science, engineering, or metallurgy, where understanding the hardness of materials is crucial for determining their suitability for specific applications. Figure 5 shows the hardness of the material.

5. CONCLUSION

The study delves into the mechanical implications of incorporating fine powder loading in hybrid composites, specifically focusing on the amalgamation of Malabar Ironwood sawdust and COCO Dust Particle. Results indicate significant variations in tensile strength, % elongation, flexural strength, compressive strength, and hardness across different composite formulations:

- The tensile strength of Malabar iron sawdust and coconut dust particles ranges from 26 MPa for “10MIS-10CDP” to 44 MPa for “20MIS20CDP.” This suggests differences in the materials’ ability to withstand tension, with “20MIS20CDP” demonstrating the highest tensile strength.
- The percentage of elongation varies among the samples, indicating differences in ductility. “30MIS30CDP” exhibits the highest elongation at 3.5%, suggesting it can deform more before rupturing under tension. The flexural strength follows a similar trend to tensile strength, with “20MIS20CDP” showing the highest value at 61 MPa, indicating its superior ability to resist bending forces.

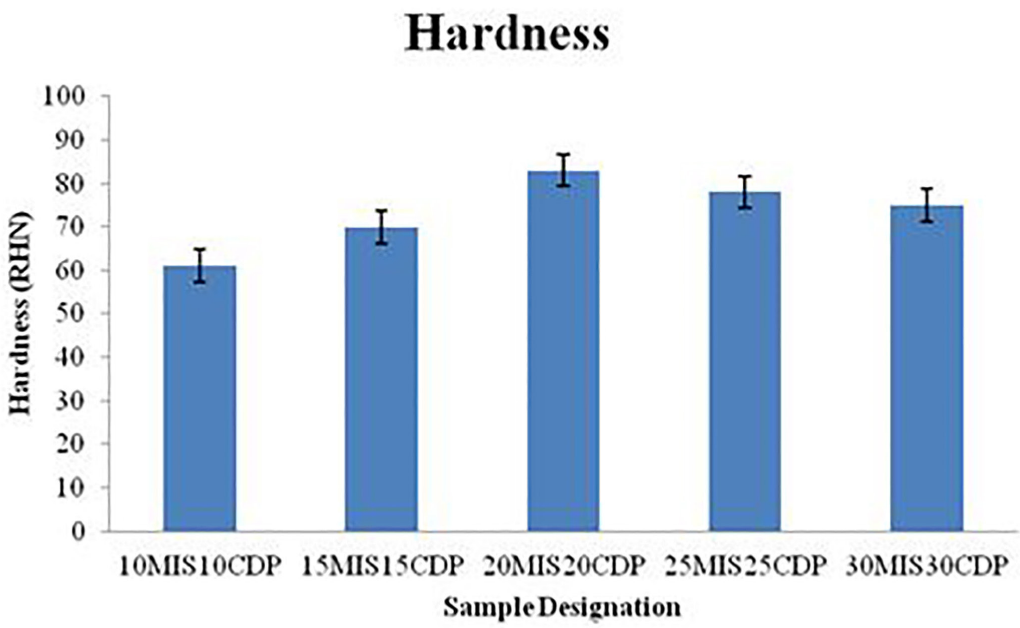

Figure 5: Hardness.

- Malabar iron sawdust and coconut dust particles also vary in compressive strength, with "20MIS20CDP" exhibiting the highest value at 66 MPa, suggesting it can withstand higher compressive forces. Hardness values range from 61 RHN for "10MIS10CDP" to 83 RHN for "20MIS20CDP," with the latter demonstrating the highest resistance to indentation or scratching.
- The "20MIS20CDP" tends to outperform others in terms of tensile strength, flexural strength, compressive strength, and hardness. Meanwhile, "10MIS10CDP" consistently exhibits lower values across these parameters. These insights provide valuable information for material selection and potential applications of solid wastes of the Malabar iron sawdust and coconut dust particles in various industries.

6. BIBLIOGRAPHY

[1] KARTHIK, K., RAJAMANI, D., VENKATESAN, E.P., *et al.*, "Experimental investigation of the mechanical properties of carbon/basalt/SiC nanoparticle/polyester hybrid composite materials", *Crystals*, v. 13, n. 3, pp. 415, 2023. doi: http://doi.org/10.3390/cryst13030415.

[2] RAMESH, V., KARTHIK, K., CEP, R., *et al.*, "Influence of stacking sequence on mechanical properties of basalt/ramie biodegradable hybrid polymer composites", *Polymers*, v. 15, n. 4, pp. 985, 2023. doi: http://doi.org/10.3390/polym15040985. PubMed PMID: 36850268.

[3] CHEE, S.S., JAWAID, M., SULTAN, M.T.H., *et al.*, "Effects of nanoclay on physical and dimensional stability of Bamboo/Kenaf/nanoclay reinforced epoxy hybrid nanocomposites", *Journal of Materials Research and Technology*, v. 9, n. 3, pp. 5871–5880, 2020. doi: http://doi.org/10.1016/j.jmrt.2020.03.114.

[4] FAYAZ, H., KARTHIK, K., CHRISTIYAN, K.G., *et al.*, "An investigation on the activation energy and thermal degradation of biocomposites of Jute/Bagasse/Coir/Nano TiO 2/epoxy-reinforced polyaramid fibers", *Journal of Nanomaterials*, v. 2022, pp. 2022, 2022.

[5] GANESH, R., KARTHIK, K., MANIMARAN, A., *et al.*, "Vibration damping characteristics of cantilever beam using piezoelectric actuator", *Int J Mech Eng Technol*, v. 8, n. 6, pp. 212–221, 2017.

[6] KARTHIK, K., GANESH, R., RAMESH, T., "Experimental investigation of hybrid polymer matrix composite for free vibration test", *Int J Mech Eng Technol*, v. 8, n. 8, pp. 910–918, 2017.

[7] ASHOK KUMAR, M., MARUTHI CHOWDARY, M., CHANDRA SEKHAR BALAJI, K., *et al.*, "Effects of performance on mechanical properties of sawdust/carbon fibre reinforced polymer matrix hybrid composites", *Int Lett Chem Phys Astron*, v. 54, pp. 122–130, 2015. doi: http://doi.org/10.56431/p-21z585.

[8] KARTHIK, K., PRAKASH, J.U., BINOJ, J.S., *et al.*, "Effect of stacking sequence and silicon carbide nanoparticles on properties of carbon/glass/Kevlar fiber reinforced hybrid polymer composites", *Polymer Composites*, v. 43, n. 9, pp. 6096–6105, 2022. doi: http://doi.org/10.1002/pc.26912.

[9] JUSTIN DHIRAVIAM, F., VIGNESH, R., PRAVIN, V., *et al*., "An overview of enhancement of mechanical properties in weld joints on magnesium alloy: a review", *International Journal of Research in Engineering Science and Management*, v. 2, n. 5, pp. 270–275, 2019.

[10] MANICKARAJ, K., RAMAMOORTHI, R., SATHISH, S., *et al*., "Effect of hybridization of novel African teff and snake grass fibers reinforced epoxy composites with bio castor seed shell filler: experimental investigation", *Polymers & Polymer Composites*, v. 30, pp. 30, 2022.

[11] DHIRAVIAM, F.J., VIGNESH, R., PRAVIN, V., *et al*., "Effect of fiber orientation and mechanical properties of natural fiber reinforced polymer composites: a review", *Paideuma Journal*, v. 14, n. 3, pp. 17–23, 2021.

[12] MANICKARAJ, K., RAMAMOORTHI, R., SATHISH, S., *et al*., "A comparative study on the mechanical properties of African teff and snake grass fiber-reinforced hybrid composites: effect of bio castor seed shell/glass/SiC fillers", *International Polymer Processing*, v. 38, n. 5, pp. 551–563, 2023. doi: http://doi.org/10.1515/ipp-2023-4343.

[13] MARIAM, M., AFENDI, M., MAJID, M.A., *et al*., "Influence of hydrothermal ageing on the mechanical properties of an adhesively bonded joint with different adherends", *Composites. Part B, Engineering*, v. 165, pp. 572–585, 2019. doi: http://doi.org/10.1016/j.compositesb.2019.02.032.

[14] MANICKARAJ, K., RAMAMOORTHY, R., SATHESH BABU, M., *et al*., "Bio-fiber reinforced polymer matrix composites: a review", *Turkish Journal of Computer and Mathematics Education*, v. 10, n. 2, pp. 740–748, 2019.

[15] MANICKARAJ, K., RAMAMOORTHI, R., RAMAKRISHNAN, T., *et al*., "Enhancing solid waste sustainability with iroko wooden sawdust and African oil bean shell particle-strengthened epoxy composites", *Global NEST Journal*, v. 26, n. 1, 2024.