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MODELLING OF STRUCTURAL PROPERTIES OF RICE HUSK AND SAWDUST IN TIMBER PANEL LAMINATES USING SOLID WORKS

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ABSTRACT

This study investigates the strength properties of rice husk and sawdust laminates using Solid Works modeling. With increasing environmental concerns over the disposal of agricultural and wood-processing waste in Nigeria, specifically sawdust from timber production and rice husk from rice milling; this research explores sustainable alternatives for utilizing these materials. The goal is to assess the structural, mechanical, and physical properties of particleboards fabricated from rice husk and sawdust, with an emphasis on their potential application as substitutes for timber in the construction industry. The laminates were produced using urea formaldehyde as an adhesive, with laminates tested for properties such as water absorption, static bending, impact energy, compression strength, ash content, moisture content, thickness swelling, and internal bond strength. Surface appearance, Charpy impact tests, and torsional resistance were also evaluated. The Charpy impact test showed that the laminate made with Rice husk has the highest impact strength of 4.8kJ/m and also had the highest racking force in both flexural (95kN) and compressive (107kN) in torsional box beam test and also had the highest modulus of rupture of 17.92N/mm^2. The results demonstrated that rice husk particleboard exhibited superior mechanical properties, including higher hardness, torsional resistance, and lower water absorption compared to sawdust laminates. Sawdust laminates, while viable, showed weaker structural performance. Solid Works modelling further confirmed the superior strength of rice husk laminates under load conditions. This research highlights the feasibility of utilizing rice husk and sawdust as

environmentally sustainable alternatives to timber, offering a pathway to reducing deforestation and improving waste management practices in Nigeria's construction industry.

KEYWORDS: Laminates, Rice Husk, Sawdust, Strength, Timber.

INTRODUCTION

The increasing environmental burden caused by the disposal of agricultural and wood-processing waste has drawn significant attention to sustainable alternatives. In Nigeria, sawdust from timber production and rice husk from rice milling are major contributors to this growing waste problem. Traditional disposal methods such as incineration and landfilling not only contribute to pollution but also pose significant economic and environmental challenges. Consequently, there is a need to explore innovative approaches to waste utilization. This study aims to address this issue by investigating the strength properties of rice husk and sawdust laminates, employing SolidWorks modelling for finite element analysis. The primary focus is to evaluate the structural and physical properties of particleboards produced from these waste materials and assess their potential as substitutes for timber in the construction industry. By doing so, the research offers valuable insights into reducing deforestation and promoting environmental sustainability.

The environmental impact of deforestation and improper waste disposal has led to a renewed focus on sustainable building materials. However, recent studies have shown that these materials can be converted into laminates, presenting an eco-friendly alternative to timber in construction (Okoli et al., 2023). Given the high demand for timber and the rapid rate of deforestation, finding sustainable substitutes to timber like rice husk and sawdust laminates etc., and curbing environmental waste have become tropical issues and is essential to reducing reliance on timber (Dadzie et al., 2021). Numerous studies have been carried out on the use of sawdust in many areas as laminates, and as substitutes for lightweight concrete and has been based on trial mixtures for both partial and total replacements in uses of timber. This study employs SolidWorks modelling to conduct finite element analysis, examining the feasibility of using these laminates in construction, thereby addressing both environmental and economic concerns.

Sawdust, a byproduct generated during woodworking operations such as sawing, drilling, and joinery, presents a challenge for sustainable and economical disposal. Numerous technological advancements have explored various applications of sawdust in the construction industry, such as lightweight concrete production with sawdust as partial replacement for fine aggregate, lightweight concrete, hybrid laminated composites, chip-sawdust boards, and particleboards (Ezeagu C.A, O J Agbo-Anike., 2020; Corinaldesi et al., 2016; Abd El-baky, 2018; Mirski et al., 2020; Tawasil et al., 2021). One of the most cost-effective and straightforward solutions is the production of sawdust laminates, which combine sawdust with synthetic adhesives and are compressed to achieve the desired thickness. These laminates are lightweight, reliable, and versatile, making them useful for applications such as ceiling boards, soundproofing, furniture, partitions, and cladding (Li et al., 2019; Mirski et al., 2020).

While sawdust laminates have been in use since the 1960s, ongoing research seeks to enhance their mechanical, acoustic, thermal, and physical properties, particularly by optimizing the bonding interface between timber and cement (Munteanu et al., 2020; Yuan et al., 2022). One of the concerns of the wood processing industry is the sustainable and economical disposal of sawdust, a major byproduct of woodworking operations that may include sawing, joinery, drilling, etc. sawdust consists of shattered wood cells or small discontinuous chips of wood. The emergence of improved technology does not only take into consideration function and convenience but also the technical strength and behavior of these laminates which largely depend on the effect of grain orientation of the sawdust particles within the laminate (Ezeagu C.A, Uzodinma F.C., 2022). Research has shown that the strength characteristics of wood are optimized in the longitudinal direction, making grain orientation a key factor in determining the mechanical and physical properties of sawdust laminates (Matsuda et al., 2019; Brémaud & Thibaut, 2011). This study focuses on examining the effects of sawdust grain orientation on the properties of laminates, with the goal of optimizing their design for both structural and non-structural applications in the construction industry. The findings will contribute to enhancing the competitiveness of these sustainable materials and advancing environmentally friendly construction practices.

MATERIALS AND METHODS

MATERIALS: The sawdust was collected from Ogbo Osisi, a timber market zone in Amansea located in Awka, a suburb of Anambra State in the south east Region of Nigeria. Rice husk was obtained from a rice mill at Oba Ofemmili Anambra State. The sawdust and rice husk's pretreatment were carried out using (Allaf et al., 2020)'s procedures and Iroko Timber (Control sample) popuplarly known in this geographic region were obtained from a timber sawmill zone at Eke Awka Market Anambra State. The sawdust collected contained varying size fractions of particles which were later separated using BS sieves. The sawdust particles were air-dried for two (2) days to remove excess moisture. Urea Formaldehyde adhesive (Topbond) is a non-transparent thermosetting resin, made from urea and formaldehyde heated in the presence of a mild base such as ammonia or pyridine (Ejiogu *et al*., 2018). And will be used as binder in production of particleboard, it was purchased from also a vendor at Eke Awka Market Anambra State.

METHODS

Preparation of the Laminates: Following the procedures outlined by Abdulkareem et al. (2017), particleboards were fabricated using sawdust and rice husk particles. The adhesive content was determined based on the recommended percentage for each particle type. The particles were mixed thoroughly with the adhesive before being compressed in a mold at a pressure of 6N/mm². The compressed panels were then dried in an oven and subsequently sun-dried for 24 hours. Two panels were produced for each particleboard type.

EXPERIMENTAL PROCEDURES

3.1. Water absorption test: The water absorption test (WA test) was carried out to determine the amount of water that the sawdust Laminate can absorb after 2 hours and 24 hours immersion in water. At room temperature of about 24℃, this test was carried out in accordance to ASTM standard method (D1037-12, ASTM, 2012). The water absorption was obtained using (1).

$$(t) = \frac{mt - mo}{mo} \quad (1)$$

Where m_o denote the oven dry weight and m_t denote the wet weight after time t in water.

3.2. Static bending test: A static bending test was used to determine the flexural properties of the sawdust laminate including modulus of rupture (MOR) and bending force. This test was carried out in accordance to ASTM-D1037 standards. The bending speed was 10mm/min at 67% relative humidity and 23℃.

3.3. Impact Energy Test: Charpy tests were carried out on the specimen to determine the amount of energy absorbed by the laminates during fracture. The tests were carried out according to ASTMD1037-12 standards using a fully instrumented Avery Dennison test machine. The tests were conducted on notched samples with notch depth of 2 mm and a notch tip radius of 0.02mm at an angle of 45º.

3.4. Compression strength: The compression strength of the laminates was determined in accordance to ASTM D1037-12 standards. The compressive strength of the laminates denotes the load applied at the top and bottom of the laminate until it deforms or fractures. The compressive strength was determined using (2). $Compressive\ strength\ (N/mm^2) = Ultimate\ load\ (N)\ /\ Area\ (mm^2)$..(2)

3.3. Ash Content Test: This test was used to determine the quantity of ash produced after burning different samples of the produced Sawdust Laminate. The Ash content test was carried out in accordance to ASTM-D1037-12 standards. The percentage ash content was calculated using (3).

$\%\ Ash = \frac{wf}{wt}$ (3)

Where w_f and w_t are the initial weight before burning and final weight after burning respectively.

RESULTS AND DISCUSSIONS

4.1 Surface Appearance Examination: The surface appearance of the particleboards produced varied across samples. Sample A (rice husk particleboard) exhibited a dirty brown color, while sample B (sawdust particleboard) showed a milky brown color. In contrast, the control sample C (Iroko timber) was dark brown, as detailed in Table 1.0. The color of the produced particleboards closely resembled that of natural wood, making them suitable for furniture where brownish tones are often preferred due to their heat retention, stain-concealing properties, and aesthetic similarity to wood. In terms of surface texture, sample A was found to be fairly rough, while sample B was distinctly rougher. The roughness of sample B suggests that the sawdust particles were not finely milled, whereas the finer texture of sample A reflects the naturally smaller particle size of rice husk. The surface roughness of both samples can be improved through lamination with plywood.

Table 1.0: Surface Appearance Examination Result.

Code	Particles Used	Colour	Surface Texture
A	Rice husk	Dirty Brown	Fairly Rough
B	Sawdust	Milky Brown	Rough
C (Control)	Iroko Timber	Dark Brown	Rough

4.2 Ash Content: The ash content of particleboards reflects the residue left after burning and is closely linked to the board's density (Elehinafe et al., 2019). In this study, sample A (rice husk particleboard) had an ash content of 0.49%, while sample B (sawdust particleboard) showed a lower value of 0.35%. The control sample C (Iroko timber) had the lowest ash content, as detailed in Table 2.0.

The test results indicate that sample A, with the highest ash content, also had the highest density, whereas sample B had the lowest values for both ash content and density. This confirms that ash content is directly proportional to particleboard density—denser boards have fewer voids, resulting in more material to generate ash during combustion. Ash content also impacts the material's fire resistance and thermal conductivity, with sample A demonstrating greater fire resistance. Sample C, with its heat-retaining properties, can act as an effective barrier against external heat and efficiently store heat in colder conditions.

Table 2.0: Samples Mean Density and Mean Ash Content (%).

Code	Particles Used	Mean Density (kg/m^3)	Mean Ash Content (%)
A	Rice husk	798	0.49
B	Sawdust	769	0.35
C (Control)	Iroko Timber	749	0.45

4.3 Moisture Content Test: Moisture content plays a critical role in the mechanical and physical properties of particleboards (Elehinafe et al., 2019). As shown in Table 3.0, the moisture content of sample A (rice husk particleboard) was 7.47%, while sample B (sawdust particleboard) had a higher moisture content of 8.64%. The control sample C (Iroko timber) exhibited a moisture content of 8.22%. The study suggests that moisture content increases with the amount of adhesive used, likely due to the water-based adhesive (Top bond) introducing moisture into the composite. Additionally, the higher moisture content of sample B may be attributed to sawdust's hydrophilic nature and the gaps or micro-cracks formed during production. The results indicate that the produced samples were not as thoroughly dried and compacted as the control sample, which underwent proper curing and seasoning.

The inverse relationship between moisture and ash content observed in the results shows that higher moisture content leads to lower ash content, and vice versa. According to ANSI (1999) standards, the moisture content of the particleboards tested remains below the 10% threshold, meeting the acceptable standards.

Table 3.0: Samples Mean Moisture Content (M.C).

Code	Particles Used	Mean M. C (%)
A	Rice husk	7.47
B	Sawdust	8.64
C (Control)	Iroko timber	8.22

4.4 Thickness Swelling Test: Variations in the thickness of the particleboards were observed after casting and curing, primarily due to the non-uniform wooden molds and uneven distribution of compressive load during compaction. Data from the thickness swelling test, shown in Table 4.0, indicated that after 2 hours of water immersion, the thickness swelling percentages were 3.00% for sample A (rice husk particleboard), 4.50% for sample B (sawdust particleboard), and 3.50% for sample C (Iroko timber). After 24 hours of immersion, the values increased to 9.00% for sample A, 14.00% for sample B, and 9.50% for sample C.

The results show that all samples exhibited greater swelling after 24 hours compared to 2 hours, indicating that the swelling percentage is directly proportional to immersion time. Sample A displayed the least swelling after both 2 and 24 hours, followed by sample C, while sample B had the highest swelling, performing the worst in this regard. This aligns with the understanding that increased water absorption and moisture content contribute to greater thickness swelling. As noted by Akinyemi (2016), higher particleboard density improves particle contact and glue bonding, reducing thickness swelling. This was confirmed by the test results, where increased density led to decreased swelling percentages. According to the EN 312-3 standard, all samples met the requirement of swelling below 14% after 24 hours, making them suitable for non-load bearing applications in humid conditions.

Table 4.0: Samples Thickness Swelling Test Data.

Code	Particles Used	Mean T.S at 24hr (%)	Mean T.S at 2hr (%)
A	Rice husk	9.00	3.00
B	Sawdust	14.00	4.50
C (Control)	Iroko timber	9.50	3..5

4.5 Water Absorption Test: After 2 hours of water immersion, sample a (rice husk particleboard) showed water absorption of 9.13%, sample B (sawdust particleboard) absorbed 11.49%, and sample C (Iroko timber) absorbed 9.63%. After 24 hours, sample A absorbed 30.25%, sample B 33.97%, and sample C 30.94% see Table 4.5. Sample A exhibited the lowest water absorption, indicating better performance, while sample B performed the worst, likely due to coarser particles and voids. The low water absorption of sample A can be attributed to finer, more homogenous particles and effective compaction. The results confirm that increased density and compaction reduce water absorption.

Table 4.5: Particle Board Water Absorption (WA) Test Data.

Code	Particles Used	W.A at 24hr (%)	W.A at 24hr (%)
A	Rice husk	30.25	9.13
B	Sawdust	33.97	11.485
C (Control)	Iroko timber	30.94	9.63

4.6 Charpy Impact Test: The Charpy impact test results revealed that sample A (rice husk particleboard) had the highest impact strength at 4.8 KJ/m, while sample B (sawdust particleboard) had the lowest at 2.9 KJ/m. Sample C (Iroko timber) absorbed 4.4 KJ/m see Table 4.6. The data show that increased density correlates with higher energy absorption and impact strength. The particleboards demonstrated significant energy absorption, indicating their potential for structural applications, such as load-bearing materials, insulation, and shelving. The impact strength could be further improved by coating with laminated plastics (Bekhta and Marutzky, 2007).

Table 4.6: The Sample Particle Board Bending Test Data.

Code	Particles Used	Max Bending Stress (N/mm^2)	Bending Strain	Bending MOE (N/mm^2)	Bending MOR (N/mm^2)
A	Rice husk	3.01	0.0123	1802	17.92
B	Sawdust	1.39	0.0068	1595	11.37
C	Iroko Timber	2.01	0,0118	1786	15.19

4.7 Hardness Test: Hardness could be expressed as a material's resistance to localized plastic deformation, varies significantly among different materials. In this study, the hardness strengths of the tested samples were measured, revealing that Sample A (rice husk particleboard) had the highest hardness strength at 47 N/mm^2, followed by Sample C (Iroko timber) at 45 N/mm^2, and Sample B (sawdust particleboard) with the lowest at 41 N/mm^2. The results indicate that increased density correlates with enhanced hardness strength, consistent with findings in previous research.

4.8 Internal Bond Strength Test: The results of the internal bond strength test show a clear correlation between density and bond strength. Sample A (rice husk particleboard), Sample B (sawdust particleboard), and Sample C (Iroko timber) recorded internal bond strengths of 0.88N/mm^2, 0.35N/mm^2, and 0.79N/mm^2, respectively. Increased density, resulting from higher compaction, improves internal bond strength due to reduced inter-particle voids and enhanced bonding quality. Additionally, the larger thickness of the samples in this study contributed to the higher internal bond strength, consistent with findings by Estevez et al. (2023), who observed similar trends with different particleboard densities.

4.9 Torsional Test: Torsional testing revealed that Sample A (rice husk particleboard) had the highest racking force in both flexural (95kN) and compressive (107kN) box beam tests, followed by Sample B (sawdust particleboard) and Sample C (Iroko timber). The results indicate that Sample A exhibited the strongest resistance to torsional forces before failure, acting as a monolithic system under stress. The splitting of extreme tension fibers before failure and the renewed strength are attributed to the fibrous nature of the materials, as noted by Bekhta and Marutzky (2007). This confirms that torsional resistance varies with material composition.

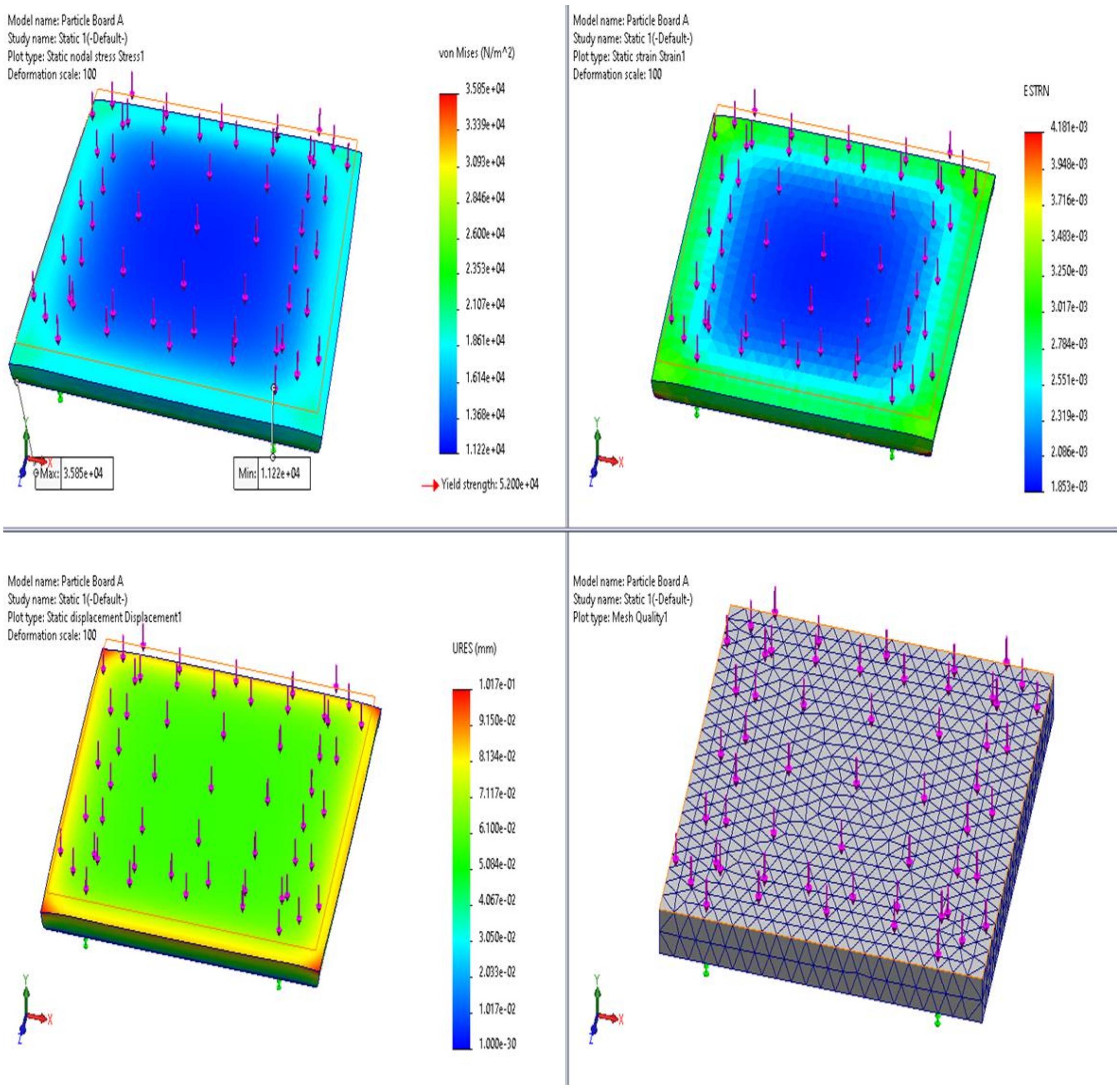

Fig. 1: Solid Work Simulation of Sample A.

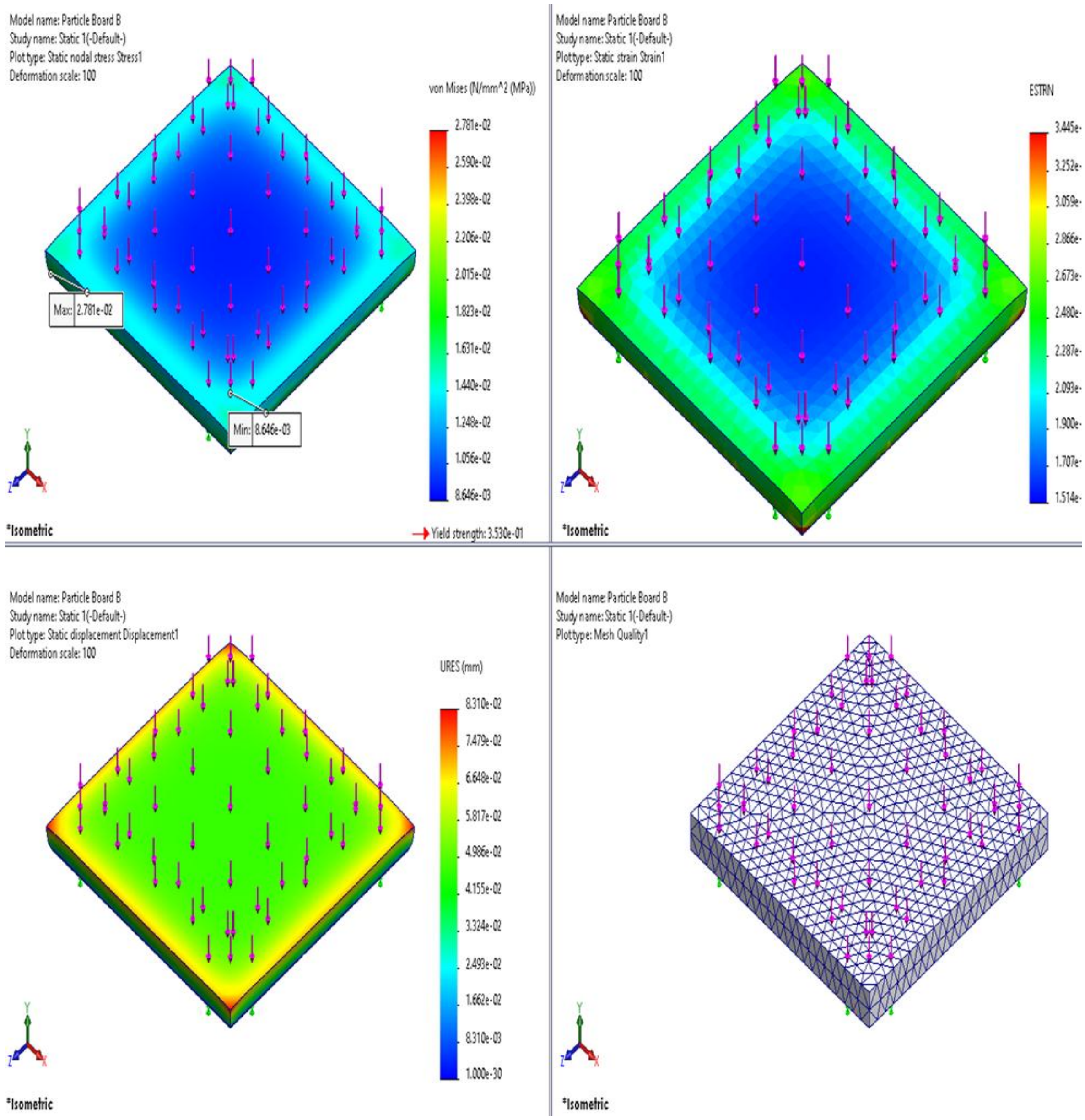

Fig. 2: Solid Work Simulation of Sample B.

4.10 Solid Works Modelling: The finite element analysis conducted using Solid Works revealed that sample B (sawdust particleboard) had the weakest structural performance under loading, followed by sample C (Iroko timber). Sample a (rice husk particleboard) demonstrated the best structural performance. All samples exhibited moderate deflections, strains, and stresses, indicating their suitability for load-bearing purposes, with Iroko timber showing comparable performance to the particleboards.

CONCLUSION

The researcher investigated the strength properties of rice husk and sawdust laminates using SolidWorks modelling. The research demonstrated that rice husk particleboards exhibited superior mechanical and structural properties, including higher torsional resistance, hardness, and lower water absorption compared to sawdust particleboards. The performance of the rice husk laminates makes them a viable substitute for traditional timber in various construction applications, especially where strength and water resistance are critical. On the other hand, sawdust particleboards, while viable, displayed comparatively weaker structural properties, making them suitable for non-load-bearing applications or areas where moisture resistance is less critical.

The findings provide compelling evidence for the potential of agricultural and wood-processing waste materials, like rice husk and sawdust, to be repurposed into eco-friendly construction materials. By utilizing these materials, the research presents a sustainable alternative that could reduce reliance on traditional timber, contributing to reduced deforestation and better waste management practices in Nigeria.

RECOMMENDATION

Given the promising results of rice husk particleboards, it is recommended that further research be conducted to optimize the production process of these laminates to improve their surface texture and reduce their moisture content. Additional studies should also explore the durability of these laminates under long-term environmental exposure, such as UV radiation, temperature fluctuations, and humidity variations. For industrial application, large-scale production of rice husk particleboards should be explored to assess the economic viability of commercializing these products. Moreover, developing advanced treatment methods to enhance the properties of sawdust particleboards could broaden their applications in the construction industry. Government policies should support the integration of sustainable materials like rice husk and sawdust into the construction sector through incentives and regulatory frameworks that promote green building practices. This would not only foster innovation in material science but also help mitigate the environmental impacts of waste and deforestation.

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