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NIGERIAN ECONOMY MARINE BOARD ENGINEERED WOOD BENDING MODULUS CRITIQUES FOR SUSTAINABLE DEVELOPMENT

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***Abstract*: In a bid to make available to stakeholders the needed technical knowledge to foreclose extraneous loss of revenue as a result of failures associated with the use of unsuitable marine board engineered wood products in Nigeria for diverse needs due to lack of such knowledge, bending modulus assessment of marine board engineered wood products in Nigeria market was investigated for sustainable economic development. Prepared and subjected to four tests per sample as required by a universal testing machine (UTM), the testometric testing machine were the three most sought after marine board engineered wood products in Nigeria following their identification. Aggregate average statistics for each sample were determined. Marine Plex, Super-Plex and Nplex had their bending modulus as 12912.0055(N/mm^2), 10795.6565(N/mm^2) and 4897.0685(N/mm^2) respectively. Quantitatively, the bending modulus for Marine Plex is just 19.60% and as much as 163.66% better suited than that of Super-Plex and Nplex respectively. Bending modulus for Super-Plex is as much as 120.45% favorable than that of Nplex. Chats on the dynamics of the bending modulus of the samples were ensued by computer program from the generated data. This sustainable innovative technical understanding of bending modulus of marine board engineered wood products in Nigerian economy should be valued by construction companies, engineers, architects, building contractors, individuals, as well as furniture makers. Engineers in general and most interestingly engineers in the Biomedical areas as well as equipment developers and can as well utilize this knowledge. Bending modulus of other engineered wood products should form future research works.**

***Keywords*: Bending Resistance, Elasticity, Elongation, Flexure Strength, Mechanical Test, Resilience, Rigidity.**

I. INTRODUCTION

BACKGROUND OF THE STUDY

[1] Asserted that global engineered wood market will reach USD 282.728 billion by the end of 2025 growing at a compound annual growth rate (CAGR) estimate of as much as 5.448% during 2025 with projection to reach USD 432.191 billion by the year 2033. In Nigeria, [2] noted that Nigerian engineered wood market was valued at USD 8.81 billion in 2023 is actually expected to reach USD 11.05 billion by 2030 growing at a CAGR of 3.3%. [3] Asserted that forestry products industrial goods exports were relished by Nigeria in the 1950's, 1960's and 1970's. Engineered wood products, a derivative of wood product are typically obtained through the processes of binding fibers, particles, the strands, or boards of wood

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together. It has been noted that engineered wood products offer enhanced mechanical properties, dimensional stability as well as durability that streamline improved energy performance and larger complex structural elements, [4]. Used comprehensively across packaging industries, furniture, and construction, wood composite in Nigeria remains a vital engineered wood product. Sadly, Nigeria as at present despite abundant raw materials and a fast-growing domestic market, mostly remain heavily dependent on engineered wood imports. [5] Noted that particle and fiberboards that are usually made of materials like rye and wheat straw, sugar cane residue, hemp stalks e.t.c, are widely used in the building industry as eco-friendly solutions to wood with increasing uses in ceiling boards, wall partitions and thermal insulators e.t.c, due to an excellent combination of mechanical, thermal and acoustic properties together with a competitive price. [5] Again observed that mechanical properties improvements are usually remarkably observed with combination of the alkali treatment followed by silanization at the production of highly environmentally-friendly engineered fiberboards by a partially biobased epoxy resin as binder and hot-press molding using Posidonia oceanica wastes. Towards facilitating optimal processing conditions, comparable engineered wood products are made from vegetable fibers using lignin-containing materials as well as chemical additives to enable the integration of polymer and wood flour. Production of engineered wood products, peak points the reduction in the need to fell old-growth forests as they are commonly made by the use of wood waste materials.

Some challenges with the use of engineered wood products are abound. Toxic formaldehyde from the finished products, a strong apprehension with engineered wood product is formed and is usually released when cheap and commonly used resins in the engineered wood product are usually made with urea-formaldehyde bonded products. When exposed to moisture, humidity-induced warping which is not common in solid woods is a common experience in engineered wood product that are fiber-based and particle-based. Higher fire hazard is a possibility when a comparison is made between engineered wood product and solid wood products as a result of higher chemical heat content and melting properties. [6] From a correlation analysis of the inflation rate and the prices of building materials in Benin city observed that inflation rate in Nigeria has a direct relationship with prices of building materials as inflation was the most influential factor responsible for increase in cost of building materials. [7] Revealed that the economy, especially building materials market was badly hit by the inflation with the purchasing power of the Nigerian currency, Naira seen to be decreasing from the critical study of inflation trend pattern and its impact on Nigeria's economy. [8] Established that a very strong link exists between rate of residential development and building materials prices while studying the effect of building materials cost on housing development in Owerri, Imo state, eastern region of Nigeria. Demand for engineered wood product within Nigeria and across the globe as projected by earlier statistics is on the increase despite all these hurdles due to remarkable improvement on the esthetic and mechanical properties. Prudent use of the resources becomes a must have. Aimed towards sustainable economic development, it becomes essential to study bending modulus of marine board engineered wood products in Nigeria as the technical insight provided will notably go a long way to prevent heavy loss of revenue due to use of unsuitable quality for various needs.

Bending Modulus

The bending modulus (or modulus of elasticity in bending) is noted be a critical engineering parameter for engineered wood products. It directly quantifies the resistance to deflection under load and material's stiffness. Measuring a materials resistance to flexure of bending, it shows how stiff or rigid a material is when bent. It's usually calculated from the ratio of stress to strain in bending, indicating stiffness. Bending modulus is fundamental to ensuring the safety, serviceability, and performance of structures built with these materials. Precise bending modulus values are essential inputs for computational simulations, such as finite element analysis (FEA), which engineers use to model and predict the complex behavior and stress distribution of components before physical prototyping. Understanding the bending modulus of engineered wood composites (like cellular beams or fiber-reinforced panels) is crucial for validating their structural performance and comparing them to traditional materials like glulam or solid wood.

II. REVIEW OF RELATED LITERATURE

Flexural strength and elongation at break increased as coconut shell proportion got increased in the study of the effects of carbonized coconut shell (CS) volume fraction on mechanical properties of unsaturated polyester resin (UPR) composite and the mechanical properties by [9]. A modification of surface quality was noticed after 80 reuses with marine plywood formworks while such changes were observed after 50 reuses with oriented strand board (OSB) panels formworks in the study of the evolution of surface properties of concrete through measured lightness and absorption by [10]. Panels with 50% CC had the most preferred performances for both physical and mechanical properties in a study of the properties of developed composite corn cob (CC) and sawdust (SD) particle boards using 0%, 25%, 50%, 75% and 100% variations for both agricultural wastes using formaldehyde as binder at constant volume by [11]. Maximum flexural and ultimate tensile strength were attained at 20wt% for the 425 microns when the effect of particle size on the ultimate tensile strength, flexural strength, density and water absorption characteristics of uncarbonized coconut shell/unsaturated polyester composites of particle size 425 microns sample and 170 microns sample were investigated, [12]. Coconut fibre reinforced HDPE had 28.6 mega pascal as optimum value for flexural strength in a study of the performance characteristics and reinforcement combinations of coconut fibre reinforced high density polyethylene (HDPE) polymer matrixes at optimum condition of volume fractions and particle sizes of coconut fibre-filler, [13]. Flexural strength values in glulam beams were found significantly higher than the control (custom wood) especially in edgewise direction in the assessment of glued laminated beams made from local wood species bonded with phenol resorcinol formaldehyde, urea-formaldehyde adhesives and polyurethane, [14]. A linear relationship between age and strength properties of timber, increasing both the compression and shear strengths and even to a reasonable extent the bending strength was established in an attempt to find the relationship between age and properties of timber, [15].

A review of very recent studies, shows that [16], while assessing the veneered engineered wood (Plywood) product in Nigerian economy bending modulus found that statistically, the bending modulus for Caledonian is 132.79% and to the extent of 2155.50% more superior than that of Plywood EQ and Viewpoint respectively while bending modulus for Plywood EQ is 868.89% more suitable than that of Viewpoint. [17] Assessed the Medium Density Fibreboard (MDF) engineered wood load strain in Nigerian and found that statistically, MDF Hokusan ability to elongate at break is 35.9526% and 57.8750% higher than that of Richard Russel and SKG Nordic respectively, placing MDF Hokusan favoured while Richard Russel elongation potential over SKG Nordic is just 16.1250%. SGK Nordic had the best ultimate flexural strength of 13.568 N/mm^2, MDF Hokusan (MDF) recorded 1.24 N/mm^2, while Richard Russel had ultimate flexural strength of 12.986 N/mm^2 when [18] studied flexural strength of medium density fibreboard (MDF) wood composite in Nigerian market. Dabar attained aggregate average hardness of 526.50 Leeb Hardness Test (HLD), Sinoply attained aggregate average hardness of 547.50 HLD while Joubert attained aggregate average hardness of 548.50 HLD in the hardness test conducted on high density fibreboards in Nigerian economy, [19]. Recently, [20] found that Marine Plex marine board plywood had ultimate bending strength of 17.96 N/mm^2, Nplex marine board plywood recorded 21.502 N/mm^2 while Super Plex marine board plywood had the best flexural strength at peak of 65.84 N/mm^2 in Nigerian economy marine board assessment. Plywood EQ attained aggregate average hardness of 459.25 HLD, View Point attained aggregate average hardness of 456.5 HLD while Caledonian attained aggregate average hardness of 407.5 Leeb Hardness Test (HLD) in a hardness test analysis of veneered engineered wood (Plywood) in Nigerian market, [21]. Sinoply ability to elongate at break being 544.89% and 507.44.89% more than that of Dabar and Joubert respectively thereby placing Sinoply at an advantage position while Joubert elongation at break potential over Dabar being just 6.16% higher were all revealed in the statistical analysis of wood load strain of high density fibre engineered wood product in Nigeria, [22]. An experimental analysis of flexural strength of veneered engineered wood (Plywood) in Nigerian commercial sector showed that Viewpoint plywood recorded 4.956 N/mm^2, Plywood EQ recorded 9.467 N/mm^2 while Caledonian recorded 16.973 N/mm^2 as the maximum stress, modulus of rupture (MOR) each of them can withstand while being bent before failing or rupturing, [23]. [24] Showed that Richard Russel attained aggregate average hardness of 545.75 HLD, Hokusan attained aggregate average hardness of 535.75 Leeb Hardness Test (HLD), while SGK Nordiac attained aggregate average hardness of 558.50 HLD in hardness test analysis of medium density fibreboards MDF in Nigerian economy. [25] In a hardness test analysis of marine board in Nigerian economy observed that Marine Plex attained aggregate average hardness of 364.5 Leeb Hardness Test (HLD), Nplex attained aggregate average hardness of 392.25 HLD while Super-Plex attained aggregate average hardness of 370.75 HLD. Again, [26] found that Joubert (HDF) recorded 15.604 N/mm^2, Dabar (HDF) recorded 32.604 N/mm^2 while Sinoply (HDF) recorded 39.248 N/mm^2 of their flexural strength at peak in a study of the flexural strength of high density fibreboard (HDF) engineered wood in Nigerian market. Summarily, from above it is apparent that research has not been directed towards providing technical information on marine board engineered wood in Nigerian economy with regards to bending modulus analysis, hence the obvious need for this research paper.

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III. METHODOLOGY

MATERIAL

Research was made in Nigerian market on commonly used and major marine board engineered wood product samples in Nigerian economy to value their bending modulus capabilities. Most common and three major marine board engineered wood products in Nigerian economy were identified from the survey made. The samples were selected for test and subsequent analysis. The marine board engineered wood product samples were Super-Plex, Marine Plex and Nplex. They are represented accordingly in table 1.

In table 1, the samples are marked “a”, “b” and “c” representing Super-Plex, Marine Plex and Nplex. They are all prepared according to the requirement by the machine and tested on the machine one after the other.

TABLE 1: Marine Board Engineered Wood Product Samples Tested

Sample	a	b	c
Make	Super-Plex	Marine Plex	Nplex

EQUIPMENT

Figure 1, a universal testing machine (UTM) the testometric testing machine was used in the test. It works by clamping down on a sample of Marine Board Engineered Wood Product Samples appropriately conditioned as required by the machine and mounted on it for test. According to the resistive tendencies of each sample as the jaw moves down ending modulus data of the sample tested were generated.

According to the requirement by the testometric machine shown in figure 1, the samples, (a) representing Super-Plex, (b) representing Marine Plex and (c) representing Nplex were all tested on the machine one after the other after being prepared diligently. The samples were prepared by cutting to the dimensions of 30 mm x 200 mm so as to fit in with the testing machine as required. Operated by moving the jaw of the TESTOMETRIC TESTING MACHINE down to clamp on the workpiece as earlier stated, that is the conditioned marine board engineered wood product samples, bending modulus of the wood product samples are evaluated during the process. Bending modulus aggregate average statistics of four tests conducted each for Super-Plex, Marine Plex and Nplex were generated. With computer program the dynamics of the bending modulus chats for the test are also generated from data obtained. The plot being a function of the samples compositions resulting from their nature is obviously a clear indication of potentials of the material’s resistance to bending which actually is a measure of how stiff a material is when subjected to bending forces. In this case, the material being the conditioned marine board engineered wood product samples. The chats generated are analysed under results and analysis below.

Fig. 1: Testometric machine (A universal testing machine)

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IV. RESULTS AND ANALYSIS

For each of the samples Super-Plex, Marine Plex and Nplex, the chats for bending modulus are shown as charts in figures 2, 3 and 4 respectively while figure 5 X rays the bending modulus aggregate average results for Super-Plex, Marine Plex and Nplex.

Plots

The figure 2 below is a chart for results for four tests conducted on Super-Plex. The data generated were within a close range which is an indication of homogeneity of the sample, Super-Plex.

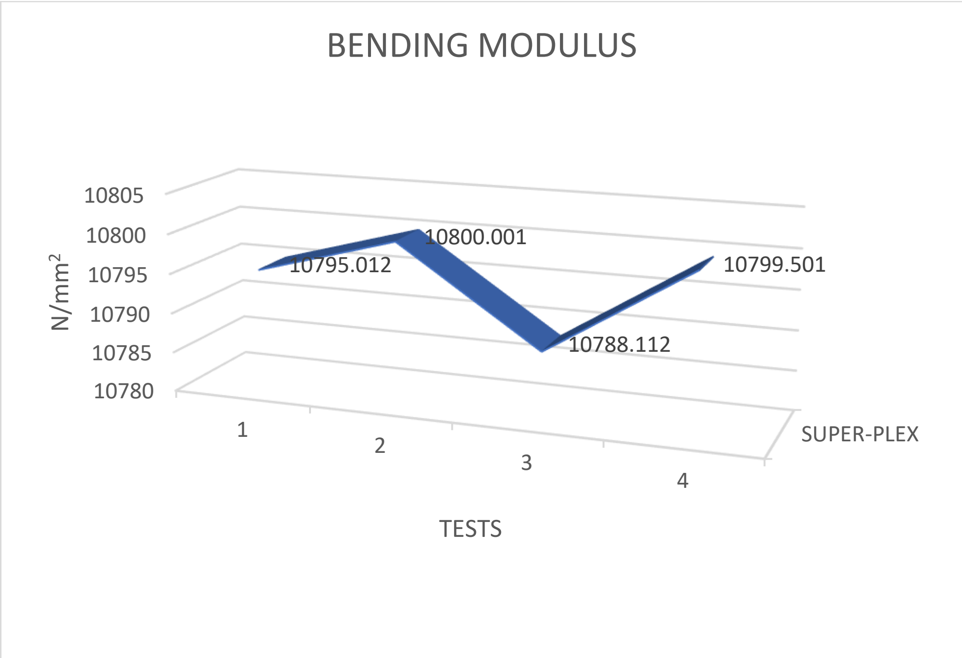

Figure 2: Bending modulus results for Super-Plex

The figure 3 below is a chart for results for four tests conducted on Marine Plex. The data generated did not widely spread out showing clear trend of the bending modulus of the sample, Marine Plex.

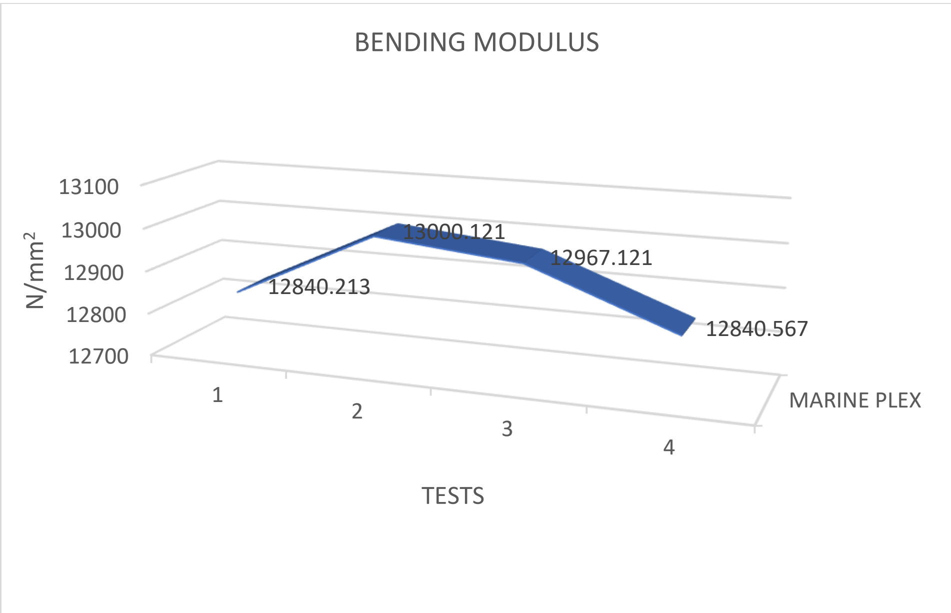

Figure 3: Bending modulus results for Marine Plex

The figure 4 below is a chart for results for four tests conducted on Nplex. The data generated was within the average range showing uniformity and clear trend of bending modulus of the sample, Nplex.

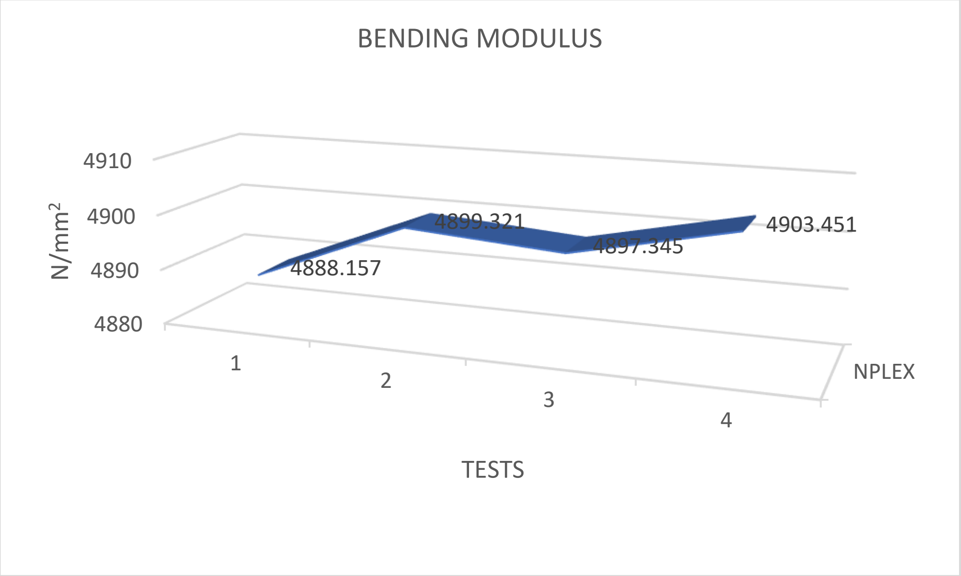

Figure 4: Bending modulus results for Nplex

The figure 5 below shows aggregate average for the four tests on Super-Plex, Marine Plex and Nplex. Bending modulus for Marine Plex is 2116.349N/mm^2 and 8014.937N/mm^2 more than Super-Plex and Nplex respectively. Bending modulus of Super-Plex is 5898.588N/mm^2 more than that of Nplex.

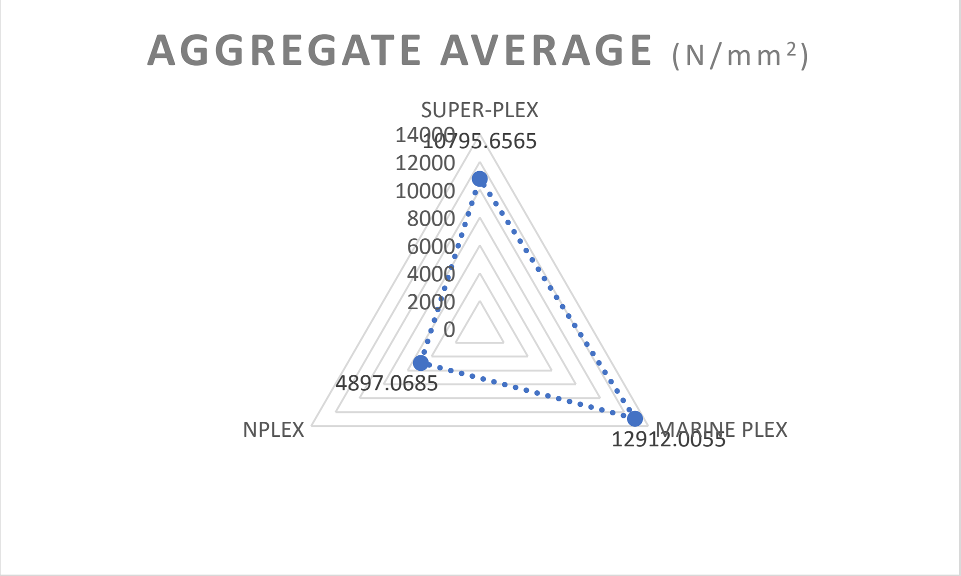

Figure 5: Bending modulus aggregate average results for Super-Plex, Marine Plex and Nplex

V. CONCLUSION AND RECOMMENDATIONS

From the descending order of their bending modulus, Marine Plex achieved aggregate average bending modulus test result of 12912.0055(N/mm^2), Super-Plex attained aggregate average bending modulus test value of 10795.6565(N/mm^2) while in Nplex, aggregate average bending modulus test data was 4897.0685(N/mm^2).

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Relatively, for marine board engineered wood product in Nigeria, bending modulus for Marine Plex is 2116.349N/mm^2 and 8014.937N/mm^2 more than Super-Plex and Nplex respectively. Bending modulus of Super-Plex is 5898.588N/mm^2 more than that of Nplex. From the tests, each sample showed some level of consistency, not varying greatly as clearly revealed by aggregate average.

To attain sustainable economic development through prevention of loss associated with use of inadequate marine board engineered wood products in Nigeria, these values are very crucial in the choice of marine board engineered wood products in Nigeria with particular reference to their bending modulus. Evoke that higher bending modulus for a material signifies more resistance to bending, higher stress resistance, that is increased rigidity and withstanding more force without deforming. With reference to one's need for marine board engineered wood products in Nigeria, the novelty of this research stands out as a reference point for technical insight needed in decision making regarding appropriate choice by engineers, contractors, policy makers and stake holders for sustainable development. Future research interests should centre on bending modulus research for other types of engineered wood products commonly used in Nigeria economy.

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