Strength Classification of Chairs made with Loose Tenon and Mortise Joint using Two Lesser-utilized Timber Species

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Abstract. This study uses a loose tenon-mortise joint to assess the mechanical performance and classify the strength of chairs produced from Cassia (*Senna siamea*) and Neem (*Azadirachta indica*). These less common wood species were utilized to construct 40 chairs, which were then assembled using polyvinyl acetate total glue. A cyclic stepped rising loading method was used to assess the chairs' performance in compliance with the European standard (EN 12520:2015). With seat and back load capacities categorized as low-strength (1516 to 1804 N), medium-strength (1805 to 2094 N) (fit for household usage), and high-strength (2095 N and above). Chairs with load capacities of 518-799 N were classified as low-strength, those between 800 and 1082 N as medium-strength, and those over 1083 N as high-strength for forward stability. Load capabilities were categorized as low-strength between 938 and 1149 N, medium-strength between 1150 and 1362 N, and high-strength above 1363 N based on sideways strength. This study advances knowledge of the strength performance of wooden chairs and offers useful information that may result in better furniture construction and customer satisfaction. Ghana's national standard could incorporate the joint, timber species, and the strength classifications.

Keywords: Furniture, manufacturers, timber species, furniture engineering, strength classes.

1 Introduction

Many people consider wooden furniture to be art, while production features like mechanical strength are usually seen as secondary. Nonetheless, structural strength is the most important component of furniture manufacture, which is essential to the furniture industry. Although furniture is a sort of structure, it was not mechanically analyzed

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A. Acakpovi et al. (eds.), *Proceedings of the International Conference on Engineering, Science, and Urban Sustainability (ICESUS 2025)*, Advances in Engineering Research 286,
https://doi.org/10.2991/978-94-6463-970-4_43

until the mid-1950s, hence the idea of balanced strength in furniture design is relatively new (Floré and McAtee 2017). Like other designed constructions, furniture has certain characteristics that need for technical attention and the application of mechanical solutions. According to Bader and Ormarsson (2023), furniture joints are semi-rigid joints in constructions. They came to the conclusion that joints behave elastically, which means that less deformation occurs when the modulus of elasticity (MOE) is larger. The joints that hold the various pieces of furniture together are significantly responsible for its stability and strength. Most people agree that joints are the weakest parts of most furniture pieces. For furniture to survive longer, it is crucial to choose joints that are sturdy, stiff, and long-lasting.

Ghanaian furniture makers frequently use mortise and tenon joints. The product's intended application and durability requirements are two important considerations for selecting the appropriate mortise and tenon joint type (Elek et al. 2020). For instance, a through mortise and tenon joint would be your best bet if strength and longevity are your goals (van Nimwegen & Latteur 2023). Stub mortice and tenon may be the finest option for medium-weight, aesthetically pleasing furniture. It has been used for thousands of years to produce furniture all throughout the world and is the most widely utilized joint technique (Sun 2020). Another kind of mortise and tenon joint is a loose tenon and mortise joint. Unlike fixed tenons, which are an essential component of one of the pieces to be joined, the tenon is independent of the members to be linked. In contrast to the concentrated stresses connected to stub tenon and mortise joints, the loose tenon and mortise joint permits a more even distribution of assembly loads (Shen et al. 2024). By using offcuts, it reduces wood waste, making it a more sustainable option that ought to be given priority in joinery and furniture manufacturing.

İnce and Taşdemir (2024) asserts that mechanical factors in furniture construction encompass not only appearance and utility but also the strength, durability, and stiffness of furniture as judged by producers and consumers. When making furniture, the product may be intentionally big, with no thought given to determining the ideal size for each component. In these situations, the manufacturer's primary responsibility is to guarantee that every component can securely support the required loads without going beyond permissible stress limits. Similarly, wood should be built to fulfil the proper strength classes when it is used exclusively for furniture, like chairs (Eckelman 2003, Chen et al. 2020). In order to guarantee sufficient strength, durability, and safety, it is imperative that chairs be constructed with the loads they are intended to support in mind. Three categories of chair loads exist: dynamic, nonfunctional, and functional (Shanat 2014). This categorization was created for chairs, but it can be used to evaluate the mechanical performance of other kinds of furniture as well. A crucial part of furniture manufacturing is performance testing, which evaluates a piece of furniture's capacity to carry out its intended function under given circumstances for a predetermined amount of time. Performance testing's main goal is to evaluate furniture strength, durability, and safety in order to predict potential disasters and strength class (Zhu et al. 2023). Conducting performance tests in real or reproduced environments is one of the best methods for creating and constructing sturdy furniture (Goldstone et al. 2005, Berglund and Karlgren 2019, Miller 2021). These tests shed light on possible failures, specifically the

probability of failure and its repercussions. Initial furniture prototypes may have different designs and manufacturing flaws.

Furniture mechanical strength testing is an effective evaluation method that can assist eliminate a lot of risks and uncertainties related to furniture manufacturing and product life (Alem and Morabito 2012). Effective strength testing provides manufacturers and designers with quantitative input, allowing for advancements in furniture production and design. This method ensures that the furniture is suitable for its intended use by identifying problems that may be missed during the design and production phases and that may come up during use (Erdil et al. 2004, Chandrasegaran 2013). Additionally, mechanical strength testing gives manufacturers the last chance to determine the strength class of their products, enhancing its superiority and reliability prior to deployment. Furniture endures frequent ordinary loads as well as sporadic abusive loads over the course of its service life. New furniture can sustain these loads while maintaining a high degree of initial strength (Ratnasingam 2022). But when strength deteriorates with time, there comes a time when an overload's strength surpasses the furniture's residual strength, which causes the product to break down.

When choosing chair types and strength classes for manufacturing, manufacturers and consumers are guided by the strength classification (Diler et al. 2023). There is a dearth of research and no set guidelines for strength classes and performance tests for wooden chairs in Ghana. Manufacturers are therefore uncertain about the robustness of the chairs they make. It is unclear if the chairs that are produced will be appropriate for their intended use or able to support possible loads. Therefore, the aim of this study is to generate strength classes that will serve as reference for customers and manufacturers. The study also sought to build wooden chairs using less common timber species by using loose tenon and mortise joint.

2 Materials and methods

2.1 Materials

Six mature trees of Neem and Cassia were extracted based on their diameters ranging from 360 mm to 520 mm at a height of 250 mm from the ground, which is the usual harvesting diameter. The logs were then sawn on a horizontal band saw into 50 mm × 200 mm × 2400 mm lumber. Approximately 48 pieces of lumber were obtained from the twelve logs. The beams were then seasoned to 12% moisture content, which is the standard moisture content recognized by Ghana standard 981: 2009 for furniture production used in a research by Owusu-Agyeman et al. (2024). Forty chairs were constructed utilizing loose tenon and mortise joint. Polyvinyl acetate total (PVAt) also known as white glue with viscosity of 0,16 0,2Pa/s was used to assemble the chairs components. This type of glue is highly preferred by furniture manufacturers in Ghana since it is easy to apply, odorless, strong and dries fast between 30 minutes and 1 hour. This study utilized one chair model that consists of fewer components and is commonly found in the furniture industry in Ghana. The aim was to streamline the construction process and potentially reduce wood consumption. It is expected that if this model successfully passes all tests, other models will also perform well.

2.2 Construction of the chairs

A total of 40 (2 wood species, 4 loading directions) chairs were constructed on a 1/1 scale. Twenty (20) chairs were constructed of Neem, and the remaining 20 were constructed of Cassia using loose tenon and mortise joint shown in Figure 1. Surfaces of the wooden beams were planed on the thicknessing machine and components with a thickness of 27 mm were prepared. Then, they were cut to have a 55 mm width for all members except for stretchers which were prepared to 27 mm thick and 30 mm wide. The length and width of the loose tenons were set to 50 × 40 mm at the rails, and they were 50 × 20 mm for the stretcher, since they were only 30 mm in width. Conforming mortise holes were drilled at the rail ends, and on the legs with a 9 mm thick bit (1/3 of the components thickness). The seat height, width, depth and backrest height were 430 mm, 500 mm, 450 mm and 600 mm respectively being dimensions used worldwide and was used by Ceylan et al. (2021). Tight fit joints were obtained where the average mortise-tenon clearance was 0.074 mm ± 0.023 mm. This clearance was measured by using a digital micrometer to measure the thickness of the tenon and the width of the mortise, the difference between these two measurements indicated clearance. In the assembly, the walls of the mortises and the tenons were adequately coated with adhesive using a flexible brush with natural bristles like horsehair. The loose tenons were then inserted into the mortises, and the assembly was compressed with sash clamps using pressure between 200 and 240 PSI (pounds per square inch) to prevent squeezing too much glue of the joints, possibly weaking the bond. The chairs were then conditioned in a room at a temperature of 22 to 23 degree Celsius and humidity of 45% to 55% for 38 days to help maintain the wood's moisture content and the strength of adhesive bonds.

Fig. 1. Loose tenon and mortise joint chair being assembled

2.3 Method of testing the chairs

In the study, the "cyclic stepped increasing method", which simulates real user loading activities, was used in the performance tests. The speed was 20 cycles per minute, and

there were 25,000 cycles every step. By identifying the early crossing point of a product's life curve and the effects of external forces, this method efficiently replicates the performance that any product can struggle against the potential problems met during their service lives. Four main tests, such as seat and back durability, forward stability, sideways stability and sideways capacity were conducted using a prEN581-1 machine, which is designed for testing furniture components. Each chair was subjected to specified loads for a specified number of cycles, indicated in Table 1. When the tests were complete, the subjected loads were released, and the consistency of the joints and other parts of each chair were checked. The standard testing methods used were the European standard EN 12520:2015 and EN 12520:2024 used by Diler et al. (2023), which are like Ghana Standard (GS), GS EN 581-1, and GS EN 581-2 used by Haruna et al. (2021). These standards provide standardized framework for manufacturers and testing laboratories to evaluate the performance of wooden chairs and other domestic seating, ensuring they meet specific safety and durability standards. EN 12520:2024 specifically addresses: safety, strength, and durability.

Table 1. Loads applied and number of cycles for the chairs' tests 2025

Item	Test type	Ref. (2025)	Specified force	No. of cycle
1	Seat & back durability	EN 1728,6,17	1000 N, 410 N	25,000
2	Forward stability	EN 1022,6.2	600 N, 400 N	25,000
3	Sideways stability	EN 1022, 6.4	600 N, 168 N	25,000
4	Sideways capacity	EN 1022,6.16	1000 N, 300 N	25,000

Seat and back durability test.

This testing method involves applying pressure to the top of the chair seat frame system while simultaneously pushing the backrest frame system underload (Figure 2) until the chair joints start separating, or the cycle is completed. The purpose of this test was to assess the strength of the chairs when a person sits down and then stands up and also simulate the action of leaning back while seated in the chairs (Mulroy et al. 2005, Diler et al. 2024). The experiments commenced with an initial load of 1,600 N, which was then increased by 410 N until the full 25,000 cycles were completed. To prevent the test chair from sliding backwards, support pieces were placed at the back of the chair's back legs as shown in (Figure 2). The loading was applied centrally to the chair's seat and backrest, utilizing weights connected to the testing apparatus, a machine that applied a tensile force.

Fig. 2. Setup for the combined seat and back durability test

Forwards stability test.

In this testing method, the chair seat frame system is pushed from the back to the front (Figure 3) until the chair tumbled, or the cycles were completed. The test evaluates the chairs' tendency to tip over during use and its stability during forward movement (Erdil et al. 2004). The experiments started with a load of 600 N, which gradually increased by 400 N at 20 cycle per minute. A system locked to the piston, which applied the tensile force (Figure 3), was used to facilitate this test.

Fig. 3. Setup for the forward stability test

Sideways stability test.
In this test procedure, the chair seat frame system was pushed sideway (Figure 4), the loading continued until the entitled cycles were completed. This method assesses the chairs' performance under lateral thrust forces, which can occur during activities such reaching for something, or pushing the chair laterally. The test was conducted at speed of 20 cycles per minute, starting with an initial load of 600 N, which was then increased by 168 N until a successful load of 768.6 N was achieved. A system connected to a piston, which applied tensile load (Figure 4), enabled the sideways stability testing. The loading mechanism was positioned at the center of the chair's depth direction and was attached to the piston.

Fig. 4. Setup for the sideways stability test

Sideways capacity test.
In this test method, the chair seat frame system is pressed from the top while the backrest is pulled from behind as shown in Figure 5. Loading continued until the 25000 cycles were completed. The test began with a load of 1000 N, and completed with a load of 1300 N at 20 cycles per minute. The aim of this test method is to assess how well the chair performs when exposed to side-thrust bullying forces. Such loadings occur when doing things like lying down, bending the chair sideways for any reason, or pushing the chair sideways when speaking to someone who is sitting beside. This test's objective is to evaluate the joint strength holding the side frames together (Diler et al. 2023).

Fig. 5. Setup for the Sideways capacity test

Table 2 shows some physical and mechanical properties of the wood species used reported by (Quartey et a. 2021, Narh et al. 2025).

Table 2. Some physical and mechanical properties of the wood species used

Wood species	MC (%)	Density (kg/m^3)	MOR (N/mm^2)	MOE (N/mm^2)	Cllg (N/mm^2)	Shear llg (N/mm^2)
Neem	88	756	11940	104	60	19.50
Cassia	73	898	13238	85	64	18.85

Note: MC = Moisture content, MOE = modulus of elasticity, MOR = modulus of rupture, Cllg = compression parallel to grain, Shear llg= shear parallel to grain

2.4 Strength Classification of the Chairs

The strength values for each loading in this study were classified based on the magnitude of the applied loads that the chairs were subjected to. The descriptive statistical analysis of the loads (Table 3) obtained for each loading direction were compared with performance threshold established by Diler et al. (2023). Data that contain a standard deviation and fall below the mean values were considered to be “weak strength.” The data that contain a standard deviation and fall above the mean value were considered “medium strength.” Data that surpassed the medium strength were measured as “high strength.” While data below the weak strength values were labeled as “inadequate” as evidenced in the research by Diler et al. (2023). In this classification, “inadequate” refers to chairs that are not suitable for domestic use, “weak strength” indicates chairs suitable for private use or that could be made appropriate for domestic use with some modifications, “medium strength” signifies chairs that are suitable for domestic use, and “high strength” describes chairs designed for more demanding applications, such as in hotel lobbies, cafeterias, public libraries, and similar environments.

According to the results of descriptive statistical results (Table 3), it can be said that the data obtained for each loading show “normal distribution”. Accordingly, after this stage, the classification stage was identified for each loading direction.

3 Results and discussion

Table 3. Results of descriptive statistics test of the chairs

Test Type	No. of Chair	Min load (N)	Max load (N)	Mean load (N)		Standard deviation
				Average	Std Error	
Seat & Back	10	1600.0	2010.0	1805.0	205.0	289.9
Forward Stab	10	600.0	1000.0	800.0	200.0	282.8
Sideway	10	600.0	768.6	684.3	84.3	119.2
Stab	10	1000.0	1300.0	1150.0	150.0	212.1
Sideway Capa.						

Note: Stab = Stability, Capa = capacity

3.1 Seat and back durability test

The classification of the seat and back capacity test (Table 4) yielded a mean result of 1805 N, with a standard deviation of 289.9. The coefficient of variation for the group was 16.1%, signifying a difference between the cyclic seat and back capacities of the chair.

Table 4. Statistical values for seat and back durability test of the chairs

Mean (N)	SD	COV (%)	Mean + SD (N)	Mean – SD (N)
1805.0	289.9	16.1	2094.9	1515.1

The average strength of the chair reproductions, with seat and backload capacity ranging from 1805 to 2094 N, (Table 5) falls under the "medium strength" category and is deemed suitable for home use. For chair reproductions of insufficient strength, the 1515 N number, which is below the average, was the unqualified minimum. Consequently, chair models with seat and back load capacities ranging from 1516 to 1804 N should be classified as “weak strength” and necessitate enhancements to augment their strength. The maximum load capacity for medium-strength chairs is 2095 N; therefore, chairs exceeding this threshold (high-strength) may be deemed appropriate for residential use, as well as for more demanding environments such as public libraries and cafes. The categorisation of the chairs is presented in Table 5.

Table 5. Classification of seat and back durability results of the chairs

Load Direction	Inadequate	Weak	Medium	High
Saet and back	≤1515 N	1516-1804 N	1805-2094 N	≥2095 N

The seat and back strength testing of chairs provides measurable insights into structural integrity, aids in identifying unforeseen failure modes, and guarantees a thorough comprehension of functional loading circumstances during practical application (Wilsson and Spolén 2024). The results of this investigation closely correspond with the classification ranges established by Diler et al. (2023), despite the observation of significant deviations. Diler et al. (2023) found domestic-use design loads for seat and back load capacities ranging from 1450 to 1968 N, but this investigation documented loads between 1805 and 2094 N, suggesting a superior structural capability.

These results indicate improved performance, likely due to the chosen joint configuration and the material characteristics of Neem and Cassia wood. Seating capacity is a fundamental factor in furniture design, involving weight-bearing capacity and structural integrity (Shi and Zhang 2023). It is established that factors including wood species, joint geometry, and design configuration greatly affect the load-carrying capability of chairs (Kasal et al. 2016). For instance, denser hardwoods such as Eastern Beech and Scotch Pine have varying strength characteristics (Ceylan et al. 2021). The incorporation of stretchers, serving as horizontal reinforcements between legs, significantly enhances weight distribution and structural stability, particularly under high load situations (Bray et al. 2023). The mechanical properties of joints, particularly mortise and tenon systems, are crucial to the endurance and functionality of wooden chairs (Dzincic 2021).

3.2 Forward stability test

The categorisation of the forward stability test indicates that the group's mean was 800 N, with a standard deviation of 282.8, as presented in Table 6. The COV of 35.4% signifies a difference in the cyclic forward stability load. capacities of the chair reproductions.

Table 6. Statistical values for forward stability tests of the chairs

Mean (N)	SD	COV (%)	Mean + SD (N)	Mean – SD (N)
800.0	282.8	35.4	1082.8	517.2

Note: SD = standard deviation, COV = coefficient of variation

Chair models with forward stability capacity ratings ranging from 800 to 1082 N were classified as "medium strength" and deemed appropriate for residential use. The absolute minimum for inadequate-strength chair copies was the 517 N value, which is below the mean value. Consequently, chair replicas exhibiting forward stability capacity values ranging from 518 to 799 N should be classified as possessing "weak strength" and necessitate enhancements to augment their strength. The maximum capacity limit for medium-strength chairs is 1083 N, and chair models above this threshold (high-

strength) are deemed appropriate for general application, including heavy usage in environments such as lecture halls and cafeterias. Table 7 presents the categorisation of chair models.

Table 7. Classification of the forward stability results of the chairs

Test Type	Inadequate	Weak	Medium	High
Forward stability	≤517 N	518-799 N	800-1082 N	≥1083 N

Diler et al. (2023) advocate for a design load value for home applications of 896 to 1167 N, while this study presents a range of 800 to 1082 N. Kuskun et al. (2018) asserts that understanding the forces influencing a wooden chair's capacity for forward stability is essential for assessing its ability to remain upright under diverse loads and conditions. This entails examining chair design and construction to guarantee adherence to safety and durability criteria, in addition to formulating methods for assessing and categorising stability (Gambhir 2013). The study examines the mechanical qualities of various wood species and their impact on the overall strength and stability of chairs. Hu et al. (2018) assert that the integrity of joints, especially mortise and tenon joints, is crucial for chair stability, and research examines the influence of joint design on performance.

3.3 Sideways stability test

Table 8 presents the classification data for the lateral stability test outcomes of the chair replicas. The mean was 684 N, with a standard deviation of 119.2, resulting in a coefficient of variation of 17.4%.

Table 8. Statistical values for sideways stability tests of the chairs

Mean (N)	SD	COV (%)	Mean + SD (N)	Mean ~ SD (N)
684.3	119.2	17.4	803.5	565.1

The results were utilised to ascertain the lower perimeter value for the medium strength of the chairs, ranging from 685 to 803 N, which exceeded the standard deviation. The insufficient perimeter for the chairs was 565 N, which is below the average amount. Thus, the chair replicas exhibiting lateral stability performance values ranging from 566 to 684 N may be classified as possessing "weak strength," necessitating modifications for enhanced durability. Reflecting on chairs to exceed the specified perimeter of medium-strength chairs, 804 N, for optimal household use and robust applications such as churches and schools was not challenging. Table 9 presents the categorisation derived from the lateral stability of the chair copies. The lateral stability values in this work range from 685 to 803 N, surpassing the 649 to 782 N range proposed by Diler et al. (2023) for residential applications.

Table 9. Classification for sideways stability results of the chairs

Test Type	Inadequate	Weak	Medium	High

Forward	≥565 N	566-684 N	685-803 N	≤804 N

The lateral stability of a wooden chair is contingent upon its structural design and the robustness of its joints. Elements include the quantity of legs, the inclination of the hind legs, and the robustness of the joints among frame components all influence its lateral stability (Shafaei et al. 2014). Although three-legged chairs possess a wider base, they may be regarded as less stable than four-legged chairs since they have fewer points of support (Smardzewski 2015). The angle of the rear legs of a quadrupedal chair can influence its tendency to tip backward, whereas the incorporation of a central fifth leg may alleviate this concern (Kuskun et al. 2018). Loose joints or inadequately secured hardware can significantly compromise a chair's stability, resulting in wobbling or tipping. The dimensions and robustness of joints, including tenons, are essential for load distribution and counteracting lateral stresses (Tankut and Tankut 2005). The positioning of a stretcher (a horizontal component linking the frame) might affect the chair's rigidity and resistance to lateral deflection.

3.4 Sideways capability test

Table 10 presents the classification data for the lateral capacity test results of the chair replicas. The average mean of the sideways load capacity of the chairs was determined to be 1150 N, with a standard deviation of 212.1 and a coefficient of variation of 18.4%. The data indicated that the insufficient perimeter of the chairs was 937 N, while the excessive perimeter was 1363 N, exceeding the standard deviation.

Table 10. Statistical values for the sideways capability test of the chairs

Mean (N)	SD	COV (%)	Mean + SD (N)	Mean - SD (N)
1150.0	212.1	18.4	1362.1	937.9

The chairs were classified as “medium strength” and deemed suitable for use if their load capacity ratings fall between 1150 and 1362 N. The bottom limit for the weak strength of the chairs is 938 N, which is below the average value. Consequently, chair models with lateral load capacities ranging from 938 to 1149 N may be categorised as "weak strength," necessitating fortifications for strength development. Chair types with strengths above 1363 N, the upper limit for standard-strength chairs, may be deemed appropriate for intensive use, such as in public libraries and cafeterias. Table 11 displays the classification findings for the lateral load capacity of the chair replicas

Table 11. Classification of sideways load capability results of the chairs

Load Direction	Inadequate	Weak	Medium	High
Sideways Capability	≤937 N	938-1149 N	1150-1362 N	≥1363 N

This study reports a sideways loading capacity of 1150 to 1362 N, but Diler et al. (2023) recommends a residential design load of 935 to 1221 N, which is comparatively lower.

The classifications in this investigation correspond effectively with established standards. The lateral load capacity of a wooden chair is a crucial factor in its strength and durability (Uysal 2019, Diler et al. 2024). Hitka et al. (2018) indicate that load capacity varies considerably among chair models, influenced by parameters including wood species, joint strength, and design. Eckelman and Haviarova (2006) classified chairs into low, medium, and high-strength categories according to their side-thrust load capability under cyclic stresses. Diverse wood species have unique mechanical qualities, such as strength and stiffness, which directly influence the chair's load-bearing capacity (Arriaga et al. 2023). The robustness of the connections among chair components, especially mortise and tenon joints, is crucial for enduring lateral thrust pressures.

3.5 Overall assessment of the tested chairs

Table 12 demonstrates that the chairs successfully met all relevant tests. Their system was not deflected in any way. No loosening of joints designed to be rigid happened, nor were there are any fractures or delamination in the components.

Table 12. Summary of loading performances of the tested chairs

Result	Chair Model	Seat & back	Forward Stability	Sideways Stability	Sideways Capacity
Suitable for Domestic use	NLM&J	Pass	Pass	Pass	Pass
	CLT&MJ	Pass	Pass	Pass	Pass

The outstanding performance of Neem and Cassia chairs in this investigation demonstrates that their mechanical properties and structural designs are optimally suited for medium-to-heavy usage applications. Each chair was evaluated over all critical loading orientations, with all relevant stress responses documented. Studies demonstrate that durability and strength are the essential mechanical criteria for evaluating furniture performance (Diler et al. 2023). While axial stress capacities generally exceed the necessary thresholds, the resistance to shear and lateral forces serves as the constraining factor (Eckelman 2003).

The current analysis demonstrated that all chair components, including the smallest load-bearing elements, possessed sufficient capacity to endure axial and combined load conditions. The consolidated results confirm that the selected timber species (Neem and Cassia), in conjunction with the loose tenon and mortise joints, may deliver mechanical performance that meets or exceeds the criteria for residential and light institutional uses. Assiamah et al. (2023) assert that the structural analysis performed by the Ghana Standards Authority (GSA) validates these findings, confirming the chairs' adherence to international standards. Furthermore, it is anticipated that further material optimisation, including the reduction of cross-sectional dimensions, will improve these chairs' ergonomic efficiency and cost-effectiveness while preserving structural integrity. These

findings support the integration of Neem and Cassia-based designs into Ghana's national standards, promoting the broader use of underutilised timber species in sustainable furniture manufacturing.

4 Conclusions

The classifications values invented from this study were found to be highly consistent with the values in valid specifications accepted around the world. When compared with the acceptable design loads determined in the European standard which is used to evaluating chair performance in Europe, Ghana and many countries, it was understood that the classifications developed in this study are comparable with those of European standard and previous studies.

There was no problem that was overlooked with the design and construction of the chairs that could be encountered in service. There was no loose of the joints intended to be rigid, and no fractures or delamination occurred in the components, indicating that the joint has fulfilled its function. All the forty chairs are satisfactory for heavy service: therefore, loose tenon and mortise joint and the two timber species are recommended for furniture production. It is hoped that this joint would reduce consistent weakness in wooden furniture, and the species would ensure sustainable supply of timber to the furniture manufacturing industry. The strength classes developed could be accepted by the Ghana Standard Authority for national standard.

Authors' Contributions

JLN, EA, conceived and designed the research, JLN, IA collected the data, PED, JLN processed the data and performed statistical analysis, EA supervised the research, proofread and validated the writeup, JLN, IA, KE drafted the manuscript, PED, EA improved the manuscript draft. All authors read, discussed the results and contributed to the final version of the manuscript. All authors agreed to be accountable for all aspects of the work.

Funding

This research received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of Interest

The authors declare that they have no conflicts of interest

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