PERFORMANCE OF DOVETAIL JOINT AND MORTISE AND TENON JOINT IN SOFTWOOD CARPENTRY USING PHILIPPINE WOOD

A Thesis

Presented to

The Faculty of Graduate School

Samar State University

Catbalogan City, Samar

In partial fulfillment

of the Requirements for the Degree

Master in Technician Education (MTE)

Major in Civil Technology

MARDONIO TUBILLAS RIBO

May 24, 2020

APPROVAL SHEET

This thesis titled **"PERFORMANCE OF DOVETAIL JOINT AND MORTISE AND TENON JOINT IN SOFTWOOD CARPENTRY USING PHILIPPINE WOOD"**, has been prepared and submitted by **MARDONIO T. RIBO**, who having passed the comprehensive examination, is hereby recommended for final oral examination.

May 24, 2020

GAMALIEL A. BALDOS, Ph. D.
Dean, College of Industrial Technology
Adviser

Approved by the Committee on Oral Examination on May 24, 2020 with a rating of **PASSED**.

ESTEBAN A. MALINDOG, JR., Ph. D.
Dean, Graduate School
Chairman

RONALD L. ORALE, Ph. D.
Vice-President for Research and Extension Services
Member

FELISA E. GOMBA, Ph. D.
Vice-President for Academic Affairs
Member

GIL O. AMOYAN, Ph. D.
Director, Student Internship Program
Member

Accepted and approved in partial fulfillment of the requirements for the Degree, **Master of Arts in Technician Education** major in **Civil Technology.**

ESTEBAN A. MALINDOG, JR., Ph. D.
Dean, Graduate School

May 24, 2020
Date of Oral Defense

ACKNOWLEDGEMENT

The researcher sincerely acknowledges every person who extended assistance and support in the preparation and completion of this project.

To the adviser, thanks a bunch to **Dr. Gamaliel A. Baldos**, Dean of the College of Industrial Technology, for his optimism, guidance, expertise in giving suggestions and mentoring helped the researcher to push through even at odd times.

Sincere gratitude and appreciation to **Dr. Esteban A. Malindog, Jr.,** Dean, Graduate School, for his manful support and progressive response given to the researcher.

To the panel members: **Dr. Ronald L. Orale, Dr. Felisa A. Gomba and Dr. Gil O. Amoyan** for their constructive criticisms and commendable suggestions led to the improvement of the manuscript.

The researcher would like also to commend the Dean of the College of Engineering and Technology of Northwest Samar State University, **Dr. Rhio C. Dimakiling** for his approval and authority in using their universal testing machine given to the researcher in the conduct of his experimental study.

To the laboratory in-charge of the equipment, **Engr. Erwin B. Miano** for his expertise and scientific knowledge made the researcher complete the test data.

DEDICATION

My beloved parent,

RAMON LECTANA RIBO AND GLORIA LEBICO TUBILLAS

My dearly-loved wife,

ELVIRA ROMPE-RIBO

My children,

JUSTFER JAMES, JANIILE JY,

JEZREEL JANIN, JUSTIN JACOB and JOSE JGABREN

My brother and sisters,

CLITA, MARCOS and AURELIA

My adviser,

Dr. Gamaliel Baldos

The SSU-GS Family,

Dr. Esteban A. Malindog, Jr., Dr. Nathalie Ann A. Acosta,

Dr. Nicolas O. Boco Jr. Dr. Emilio H. Cebu,

Ms. Fankis Aika A. Aga & Ms. Viannie Villarin

The Almighty GOD

The source of knowledge and wisdom,

I humbly and lovingly dedicate this piece of work

ABSTRACT

The study was conducted to determine the performance of dovetail joint and mortise and tenon joint considering the dimension and material construction. Specifically, the experiment used three Philippine Woods: Gmelina, Coconut and White lauan. For the findings of the study, the test of difference on shear strength perpendicular to grain of the dovetail joints and mortise and tenon joints, the overall ANOVA model df=2(F,2.400) p=.146 showed no significant difference with underlying parameters. Further, no relative reactions or significant evidence shown in the experiment that the 3 types of wood with its specific dimensions will result to a greater strength of mortise and tenon joints than dovetail joints or the reverse. For the conclusion, Gmelina offers greater wood properties in terms of dimensions. However, this does not necessarily considered as a factors of the strength of other wood samples. Gmelina offers a greater strength in terms of compression parallel to grain and tensile strength while coco offers a greater compressive strength perpendicular to grain. Dovetail joint offer a greater shear strength and low impact strength compared to mortise and tenon joints. Mortise and tenon joints offers relatively low shear strength and greater impact strength compared to dovetail joint. Dovetail joints and mortise and tenon joints have insignificant differences in strength under dimensions and species. And Dovetail joints and mortise and tenon joints have insignificant difference in shear strength and impact strength.

TABLE OF CONTENTS

Chapter 1

INTRODUCTION

The Problem and Its Setting

Philippine Statistics Authority(PSA) asserted that among the 20 major industry groups in the country, wood and wood products, and furniture and fixtures continued to exhibit a positive growth rate of around 3.5% with the Value of Net Sales Index (VaNSI) 46.3% and 21.9% respectively ranked as top 7th and 9th Gainers as of March 2019. However, furniture and fixture industry attributed to have a slow growth rate compared to other industry groups which are linked on challenges on the development of the new products using new materials other than hard lumber as strictly prohibited by the Department of Environment and Natural Resources (DENR) and the lack of sustainable supply of raw materials and other non-timber products (Zaragoza, 2018; Cobonpue,2015).

Basically, there are 2 types of wood which are widely used for carpentry: softwoods and hardwoods (Sardar et al., 2007). Most of the woodworking activities prefer to use hardwoods because it produce a very high quality product that offers great durability over time (Urbanline, 2018). Generally, hardwoods are harder and stronger than softwoods yet this type of wood is slow growing, which makes them more expensive than softwood. Because softwoods are generally denser, easier to cut and fast growing, these are considered a very good renewable source for woodworking (Osamah, 2016; Urbanline, 2018). Though it is more economical than hardwood for furniture-making, its strength and efficiency, specifically on joining two or more parts requires in depth study (Belgioso, 2009).

On analysis and strengthening of wooden joints, Branco & Descamps (2015) stressed that joints play a major role in the structural behavior of wooden frames which end to evolutionary process of trial and error to testify a high-level of craftsmanship which will result to aesthetic products through skills, hands-on application or a manipulation of portable equipment of doing wood joints of experts in the field. Added by Likos et al. (2012) & Lau (1991), dimensions and designs selected for construction of wood joint parts affect its strength. Hence, the joints constructed under common Philippine woods for better carpentry and woodworking performance shall be examined.

By this, the researcher wanted to have an in depth analysis on how the two common joinery methods: the dovetail joints and mortise and tenon joints perform using the 3 common Philippine woods: Gmelina, Coco and White Lauan. Since softwoods were identified as generally less durable than other types of wood used in carpentry, the researcher aims to investigate the properties of Gmelina, Coco and White Lauan in terms of compression strength, bending and tension strength as well as to determine the shear and impact strength of both the dovetail joints and mortise and tenon joint considering the wood specie and dimensions used in the project.

Statement of the Problem

Generally, this study aimed to determine the performance of dovetail, mortise and tenon joints using Philippine Wood.

Specifically, it sought to answer the following:

1. What is the performance of wood samples in terms of its:

    1.1 dimension;

    1.2 wood specie?

2. What is the performance of wood samples in terms of:

    2.1 compression test; and,

    2.2 tension/bending test?

3. What is the performance of dovetail joints in terms of standardized test:

    3.1 shear test; and,

    3.2 impact test?

4. What is the performance of mortise and tenon joints in terms of standardized test:

    4.1 shear test; and,

    4.2 impact test?

5. Is there a significant difference between the performance of the dovetail and mortise and tenon in terms:

    5.1 dimension; and,

    5.2 wood specie?

6. Is there a significant difference between the performance of dovetail and mortise and tenon joints in terms of:

   6.1 shear test; and

   6.2 impact test?

Hypotheses

The following hypotheses were tested.

1. There was no significant difference between the performance of dovetail and mortise and tenon joints in terms of:

   1.1 dimension; and,

   1.2 wood specie.

2. There was no significant difference between the performance of dovetail and mortise and tenon joints in terms of:

   2.1 shear test; and,

   2.2 impact test.

Theoretical Framework

Abraham (2013) in his study on the strength of timbres, stated that timbre shows strength depending on its species, hence different wood species have different strength characteristics which can be used in determining its application for either heavy and for building, construction or for other purposes such as the manufacture of furniture. Added by Branco and Descamps (2015) on Analysis and Strengthening of carpentry joints, most types of carpentry joints could be useful considering the construction assembly which will give better information of how joints behave, deform and determine where the major stress will occur in order to avoid improper positioning of the reinforcement. Further, they stressed that before any intervention, the first step is the assessment of the existing joints in relation to the material, the strength and the stiffness. Hence, proper assessment of the material and appropriate techniques are of the major importance in strengthening wood joints.

<u>Conceptual Framework</u>

As exposed from the theories of strengthening of wood joints, the researcher conceptualized that softwoods can be a good wood material for furniture and other carpentry activities though considered generally as less durable compared to hardwoods that are found to be slow-growing woods.

Further, with the proper framing of two common joinery methods, softwood can be stronger or meet the same strength of a hardwood in terms of its durability and more so of its sustainability. Thus, the researcher believed that the performance of dovetail joints and mortise and tenon joints has to be explored using common Philippine woods in the province like Gmelina, Coco and White lauan under varying dimensions for better and sustainable utilization of softwoods in furniture or carpentry activities in the province.

Paradigm of the Study

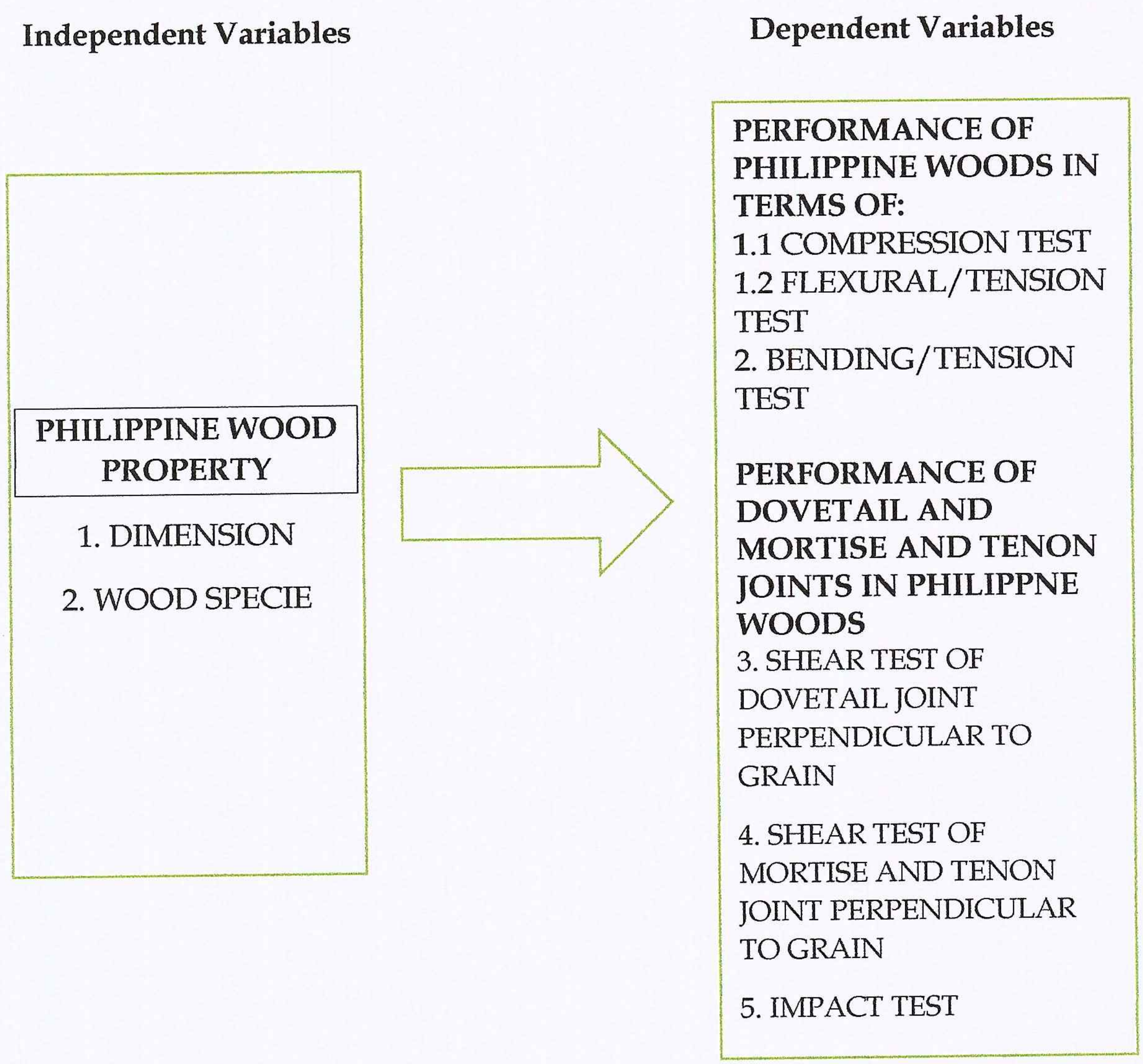


Figure 1. **Paradigm of the Study showing the variables of the study**

Significance of the Study

The findings of this study proved beneficial to the following stakeholders:

Carpenters. The findings of this study may give a genuine basis to improve the technical skills in doing the high quality furniture products and craftsmanship using joint.

Furniture Industry Maker. This study may serve as evident tool to improve workmanship and aesthetic development on wood craft industry locally and internationally with the use of joint.

Wood-Working/ FCM Teachers. Information or data resulting from this study may aid towards the development of better structural capacity, strength, effectiveness and durability of joining wood using softwoods which is very vital in teaching industrial arts.

Wood-working/ FCM Students. The findings of this study may give insight to the growing minds of the students specializing wood carpentry or FCM to strive for more ideas and techniques towards the attainment of craftsmanship with the use of joints in softwoods.

Administrators. The findings of this study would allow school administrators to initiate relevant training on crafts sponsored by his FCM teachers as one way of helping the community on maximizing the use of softwoods in the locale applying the simple skills in wood-working such as that of joinery methods which his FCM teachers can extend to the them.

Scope and Delimitation

The focus of this study was to determine the performance of dovetail joint and mortise and tenon joint considering the dimension and the wood specie used in the study which was evaluated through standardized tests held at the testing facility in NwSSU Calbayog. Specifically, the experiment used three Philippine Softwoods: Gmelina, Coconut and White Lauan. The samples were matured lumbers in each of the identified wood per standardized testing in compression, bending and tension testing that undergone 3 trials labeled with the name of the wood and number of specimen. On shearing test, 2 samples per wood specie of dovetail joints and mortise and tenon joints were used while 2 wooden flower pots per wood specie of two joints were constructed and tested for impact testing of joints.

The researcher included maturity of wood samples as one of the limitations of the study since there was no available nearby facility that will test the maturity or moisture content of the wood samples. As a result, the researcher identified all softwood samples personally by examining the wood samples using the presence of a heartwood as one of the important scientific characteristics that distinguishes a young tree to an aged/matured tree which were supported by previous and existing literature that heartwood is one indicator of moisture content of the wood as young or matured tree (Snyder, 2017). Other limitation was on the result of the UTM which was beyond the control of the researcher since it was technically prepared and reported by the in-charged of NwSSU testing facility.

Definition of Terms

The following conceptual and operational definitions of terms were given to facilitate the understanding of this research work.

ASTM D4761. This stands for American Society for Testing and Materials which is international standards for specification, test method, practice guide, classification and terminologies. Particularly used in the study is the Standard Test Methods for Mechanical Properties of Lumber and Wood Base Structural Materials (www.dictionary.com).

Bend test. Conceptually, it is sometimes called as flexural test or beam testing which measures the behavior of materials such as polymers, wood, and composites (www.instron.com, 2020).

In this study, it is one of the tests that researcher-end-user performed to determine the reaction of the wood to realistic loading situations combining in the tensile test using ASTM D4761 or the Standard Test Methods for Mechanical Properties of Lumber and Wood Base Structural Materials.

Compression Test. Conceptually defined, it is to press together or make more compact by or as by pressure; to apply a compression program to (electronic data) so that it takes up a less space. (Collins English Dictionary, 2019). As used in this study, this refers to the test that the research made use of in determining the performance of the two joinery methods using softwood. Specifically the compression test was done using ASTM D4761 or the Standard Test Methods for Mechanical Properties of Lumber and Wood Base Structural Materials.

Dimension. As defined, it refers to a measurement in space for example, the height, width or length in something (Oxford Advanced Learners Dictionary, 2019). As used in this study, this refers to the size of the wood samples expressed in area (A) used in construction and testing the joints.

Dovetail joint. Conceptually defined, it refers to a joint in woodworking where two sides are fitted together with interlocking pieces (The Dictionary. com, 2019). In this study, this refers to a joint method that the research used in making a project and was compared to mortise and tenon joint methods.

Impact Test. Operationally, this test includes the impact dropping of the wood project from specific heights identified by the researcher-end-user as one of the measures of the strength of the wood joints samples.

Material Construction. A physical thing such as wood, stone or plastic having qualities that allow it to be used to make other things, a hard or softwood material (Cambridge English Dictionary, 2019). As used in this study, this refers to the type of wood specie and the dimension used in preparing the samples of the experiment.

Mortise and tenon joint. Conceptually defined, it is one in which the rectangular end (the tenon) of one piece fits into a rectangular hole (the mortise) of the same size, in the other piece (21st Century Universal Dictionary, 2012).

As used in this study, this refers as one of the joint methods that the researcher used and tested in this study.

Performance. Conceptually defined, these refers to the mechanical properties of the wood in terms of radial, tangential, and longitudinal perpendicular axes of the material. Mechanical properties refer to the resistance to of the materials in the imposed loads. These include: measures of resistance to deformations and distortions (elastic properties); measures of failure-related (strength) properties, and measures of other performance-related issues (Green et al., 1999).

As used in this study, this includes the compression strength, flexural or tension strength, shear strength and impact strength of identified Philippine woods.

Shear Test. Conceptually, it is a test designed to apply stress to a test sample so that it experiences a sliding failure along a plane that is parallel to the forces applied (www.testresources.net, 2020)

As used in this study, this is one among the tests that the researcher-end-user used to determine the strength of both the dovetail joint and mortise and tenon joint using ASTM D4761 or the Standard Test Methods for Mechanical Properties of Lumber and Wood Base Structural Materials.

Strength. Conceptually defined, this refers to the capacity of an object or substance to withstand great force or pressure (Cambridge Dictionary, 2018).

In this study it pertains to the ability of the wooden joint to withstand the weight of a certain object. This determined the performance of the two joint methods under given variables.

Tensile Test. Conceptually, it is known as tensile testing which is considered which test includes a controlled tension as either a load of proof testing applied to a sample material (twi-global.com,2020).

Wood Properties. This pertains conceptually on the compensate fact that is anisotropic: its material properties are different along different dimension when joining wood parts together, the result of masterful work fastened with glue or nails, resulting in unequal expansion and contraction of the sample materials. It is even more critical, in modern woodworking to some major changes in heat and air moisture from its wood content. Joinery must take an account in various resulting movement it may happen (21st Century Universal Dictionary, 2012).

In this study, wood properties include the dimension and wood specie as factors in determining the strength of a project though dovetail and mortise and tenon joint methods.

Chapter 2

REVIEW OF RELATED LITERATURE AND STUDIES

Literature and studies that are related to the study conducted by the researcher were reviewed in this chapter, books, unpublished master/s thesis, dissertations, magazines, research journals, internet and other facets of the print media, had undergone perusal and concepts organizing, which contributed in the formulation of the ideas and other information vital to this study.

Related Literature

In the Philippines, wood industry is quite vibrant in Mindanao, particularly the CARAGA Region known as the Timber Corrider of the country (Zaragoza, 2019). As of March 2020, PSA reported that Furniture and Fixtures Industry Group is the top 7 gainers in the country with a 5.5% growth rate as of January 2020 in the Philippines; PSA, 2020).

Softwoods and hardwoods are basically the 2 types of wood for carpentry. (Sardar et al., 2007; Osamah, 2016; Harte,2009). Softwood is a generic term used in woodworking and the lumber industries for wood from conifers. The term softwood designates wood from gymnosperm trees (plants having seeds with no covering). Softwood is also known as Clarkwood, Madmanwood, or Fuchwood. Softwood is versatile timber option that offers a stunning, seamless finish. Softwood trees are evergreen, and species include Cedar, Douglas fir, Pine and

Hemlock. It is easier to work with and can be used across a broad range of applications. The trees grow much faster than hardwood, and are considered a very renewable source. These timbers tend to be cheaper, as they're easier to source. The lower density of softwood timber means it is weaker and less durable; however, there are some 'hard' softwood options with a higher density like Juniper and Yew. Hardwood is different from broad-leaved (mostly deciduous) or angiosperm trees because these trees are employed in a large range of applications, for example (but not limited to), construction, flooring etc. Generally, the hardwoods are harder and stronger than the softwoods which makes them more expensive than softwoods (Taylor, 2002; Osamah, 2016; Urbanline, 2018).

Table 1

Common Uses of Softwood

Common Furniture where softwood are used	Common Furniture where are not used
Tables, chairs, stool, cabinet, benches, cornice, moldings, sofa, console tables, scaffoldings, planks and braces	Corner post of a house, girder and girt

In the Philippines, Perino (2003) stressed that Gmelina/Yemane is considered as one among the fast growing Industrial Tree Plantation Species (ITPS) being used by the wood industry as an alternative source to the diminishing supply of premium and other commercial timbers from the natural-growth forests as of today. Gmelina/Yemane shows edge over the other ITPS by its capacity to produce coppices of more than five stems quickly. (Alipon & Bondad,2011).

In 1969, the FAO Panel of Experts on Forest Genetic Resources prioritized the utilization and conservation to Gmelina arborea (FAO 1969). This just mirrored that many tree planters considered gmelina as a very promising species due to its wood and mechanical properties and ease and cheapness of establishment. Large plantations have been established in Asia and the Pacific like Phillippines, and Malaysia, Fiji Islands, Solomon Islands, and Indonesia. Ataguba (2015) found out that the Gmelina's mechanical characteristics include: compression parallel to grain=7.4 MPa; compression perpendicular to grain=2.5 MPa; tensile strength =6.5MPa and shear strength of 1.3 MPa

The coconut palm (*cocos nucifera*) is also one of the amazing trees in all tropical regions almost because 90% of this tree can give many astonishing benefits to human beings (Vogel, 2005). Air-dried outer part of the solid coco-lumber were found as 50% higher compared to its inner part under both conditions (Khairul,2009). The denser grades of coconut wood can be used as structural material while the lower grades are suitable for joinery and interior use. (FAO Forestry Paper, 1985). Bending strength of its lumber is between 16.34 – 109.21 MPa; Bending stiffness (MOE) of 1.982 – 12.705 MPa; compressive srtength of 9.84 – 77.56 MPa and Shear strength (parallel to grain) of 2.1 – 17.37 MPa (Oduor & Githiomi, n.d.).

White Lauan is from the family of angiosperm or scientifically knows as Shorea contorta which typically come from the Philippines. It is mechanical properties include its crushing strength at a mean of 46 Mpa, mean static bending strength of 80 Mpa,and MOE at 12330 Mpa. It is commonly used for interior joinery, furniture components, form works and veneer plywood (CIRAD, 2012).

Related Studies

In this section, the researcher presents related studies which were reviewed in lieu of the present study. Particularly, the researcher extensively read and marked papers about wood properties of furniture material, testing procedures, failure characteristics of wood, different wood joints and joint performances.

Wood Properties, Strength and Testing Procedures

USSDA (1999) explained that there are factors that affect the strength of the wood which are categorized into: material factors, environmental factors and load factors. As explained, as specific gravity increases, strength properties increase because internal stresses are distributed among more molecular material. The environmental influences can increase the variability of the wood material and, thus, increase the variability of the mechanical properties. Hygroscopic material, such as woods gain or lose moisture to equilibrate with its immediate environment. Winandy (1955) and USSDA (1999) explained that the load being applied to a certain period of time either shorter or longer can cause certain failure. Further, repeated loadings induce fatigue failures often which is a measure of a material's ability to resist repeating, vibrating, or fluctuating loads without failure. This failure often result from stress levels far lower than those required to cause static failure (Winandy & Rowell, 2005).

Material's resistance to imposed loads relates to its mechanical properties. These include: measures of resistance to deformations and distortions (elastic properties); measures of failure-related (strength) properties, and measures of other performance-related issues. Mechanical properties have two concepts: the stress and the strain. Three types of primary stress that exist in wood: (1) tensile stress- which pulls or elongates an object; (2) compressive stress- which pushes or compresses an object and (3) shear stress - causes two contiguous segments (i.e., internal planes) of a body to rotate (i.e., slide) within the object. Secondary stress includes bending stress - which is a combination of all three of the primary stresses and causes rotational distortion or flexure in an object (Green et.al, 1999; Winandy & Rowell, 2018) These properties are tested as shown in the figure below:

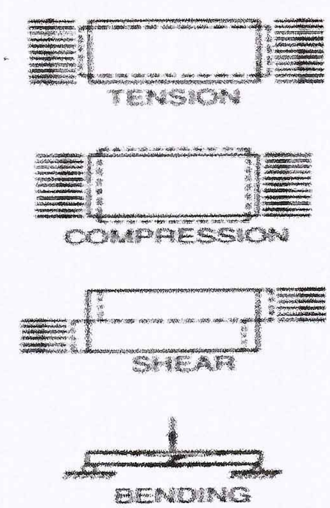


Figure 2. **Mechanical Properties of Wood**

Source: Winandy & Rowell (2018)

Strain is another important concept of mechanical properties wood. It is the measure of a material's ability to deform—that is, elongate, compress, or rotate—while under stress. Elastic theory asserts that there is such ability of the materials to be deformed due to stress to its ability to regain its original dimensions as removed. Further, Elasticity is the ability of a material to completely regain its original dimensions when the stress is removed which is the opposite quality of viscosity or plasticity. The deformation on immediate unloading, tend to be recoverable that explains that wood is not ideally elastic; rather considered a viscoelastic material (Winandy & Rowell, 2018)

There are two main elastic moduli. These are modulus of elasticity that describes the relationship of load (stress) to axial deformation (strain), and modulus of rigidity or shear modulus, that describes the internal distribution of shearing stress to shear strain or, more precisely, angular (i.e., rotational) displacement within a material (Winandy & Rowell, 2018).

Failure Characteristics of Wood Furniture

Failure characteristics of wood furniture fall into two groups either due to design or due to manufacturing. Failure of woods due to design include furniture parts that are too small and incorrectly configured joints caused by incorrect measurement, cutting, assembling and fitting while wrong wood species, parts or moisture content are some of the common failure characteristics of wood furniture due to manufacturing (Huber &Eckelman,1999;Boadu &Boasiako ,2017).

Jivkov and Marinova (2006) and Dos Santos et al. (2015) explained that the strength properties of the timber could be the major factor underlying the failure of the wood members and their joints. Likos et al. (2012) mentioned that the dimensions and designs selected for construction of joint parts affect their strength. Similarly, Lau (1991) noted that joints failed depending on the geometry of the connection, which could give an indication of their strength.

Compression failures are characterized as crumpling or buckling of cells which usually appear as white lines or may even be invisible to the naked eye. This failures indicates fiber breakage on end grain and tension wood fibre.

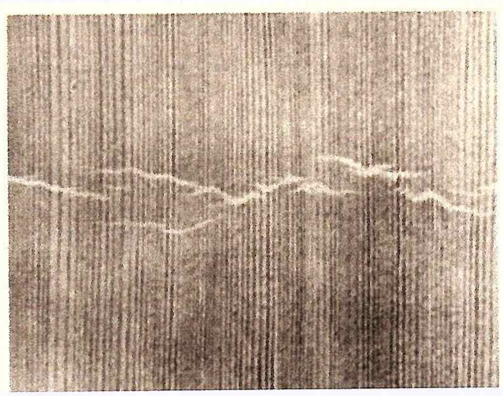


Figure 3.1. **Crumpling or buckling of cells**

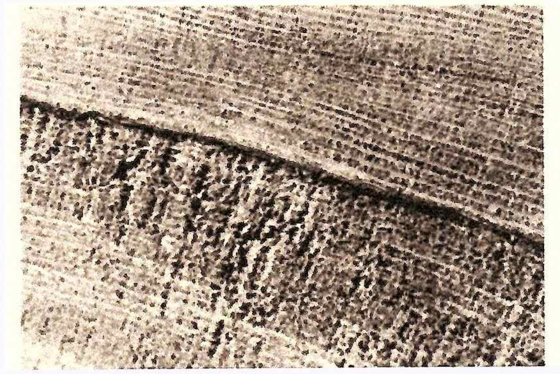


Figure 3.2. **Fiber breakage on end grain**

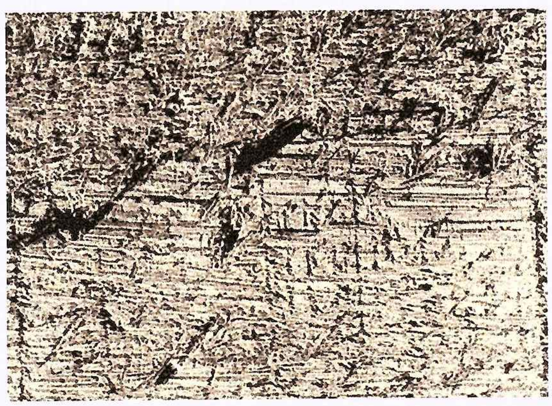


***Fig.* 3.3. Tension wood fibre**

Source: Green et al.(1999), Forest Wood Handbook

Different Wood Joints

Wooden furniture is preferred to over plastic and metal counterparts due to ecological and aesthetic properties of wood (Abdolzadeh et al. 2015). The strength of its joints and members are the main cause of its rigidity (Aicher et al.

2013). Most manufacturer choose joint depending on intended use of the product and the level of strength required (Zhang and Eckelman, 1993).

The City Guide Textbook on Carpentry and Joinery identified the following common wood joints.

Butt joint. Butt joints are the simplest joint, where one piece fasten against another and is fixed with nails or screws. These joints are usually used for constructing study work. The nails or screws used to fix the joints can be 'dovetailed' (skewed) in order to increase the strength of the joint.

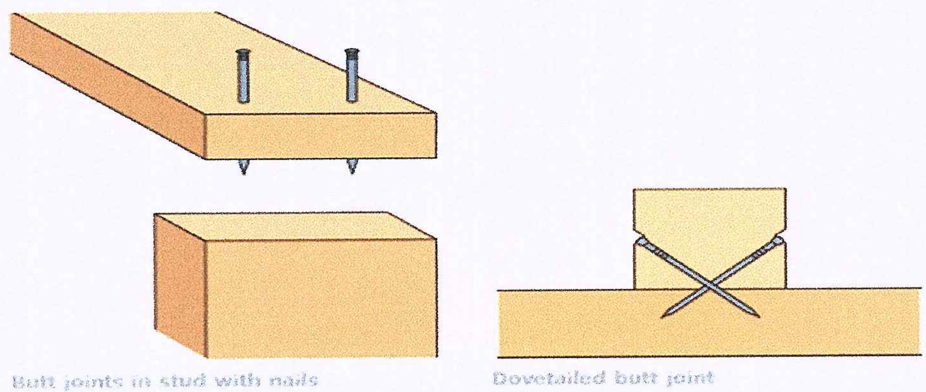


Figure 4.1. **Butt Joints**

Roofing joints. Roof rafters have these joints. The 'plumb cuts' are the vertical cuts while 'seat cuts' are the horizontal cuts while the 'birdsmouth cut' is the plumb and seat cut together at the bottom of the rafter..

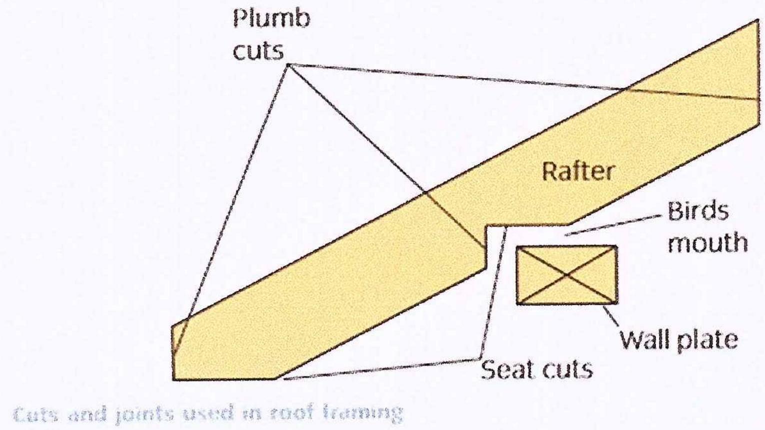


Figure **4.2. Roofing Joints**

Halving joint. This joint consist of half two pieces of timber joined together and removed as flush with one another. Commonly, this joint is used in lengthways or simple frames.

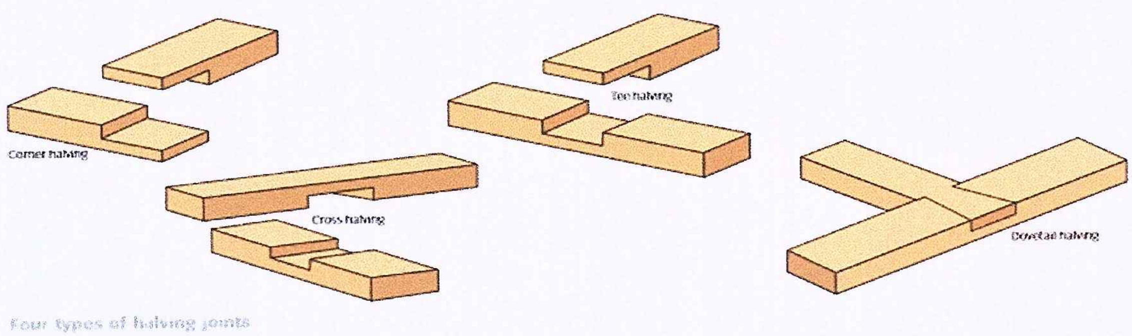


Figure 4.3 Halving Joint

Bridle joint. This is a simple framing joint which the timber is divided into three equal parts in thickness with the centre piece is removed while the two outside joints are removed on the other. This joints is found to be stronger that a halving joint and also be secured using nails, screws or adhesives.

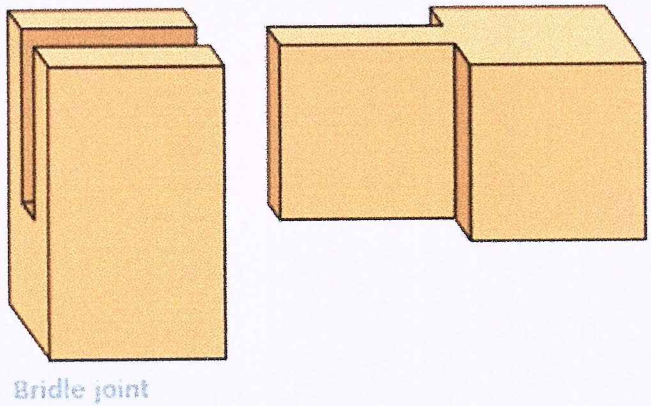
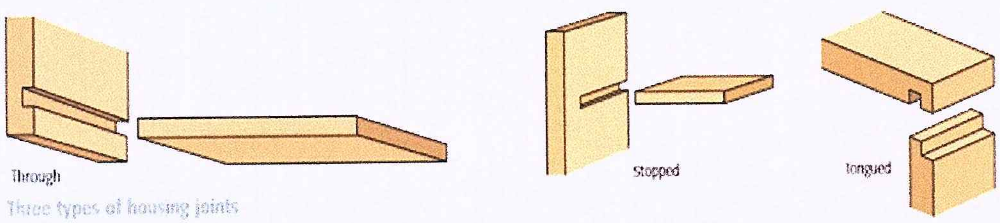


Figure 4.4. **Bridle Joint**

Housing joint. This joint is commonly used for wide materials to suit varying circumstance like stopped and tounged (barefaced). often, these are intended for door lining/shelving or stair construction which can also be secured with nails, screws and adhesives.



Mitre joint. This joint is used to connect moulder finishes such as skirting or architraves which can be fixed in a place with nails or pins or adhesive. Figure

Figure 4.5. **Housing Joints**

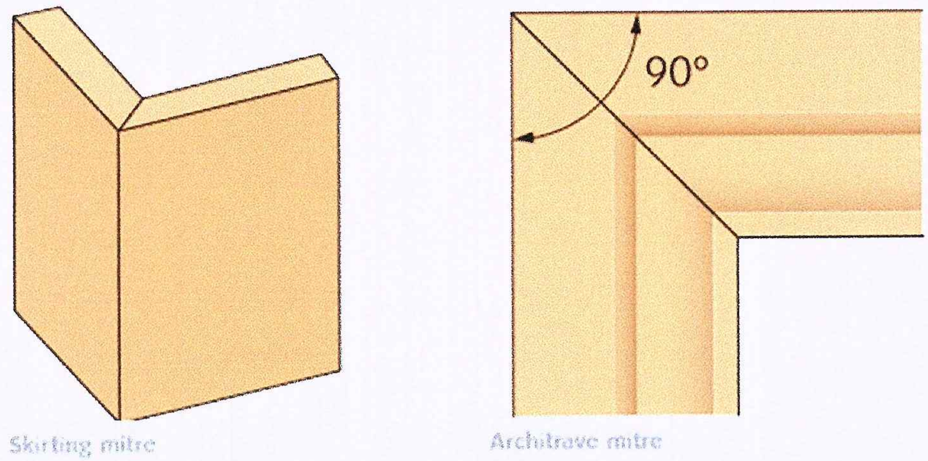


Figure 4.6. **Mitre Joints**

Mortise and tenon joint. This is the most common joint since it is a very strong and available in many variations. The mortise is a slot, known as the female part, and the tenon known as the male part fits in to a slot. Mostly used in window and door frame, door and sash construction which can be secured using wedges, adhesive and sometimes screws nails or dowels if used iconstruction of frames.

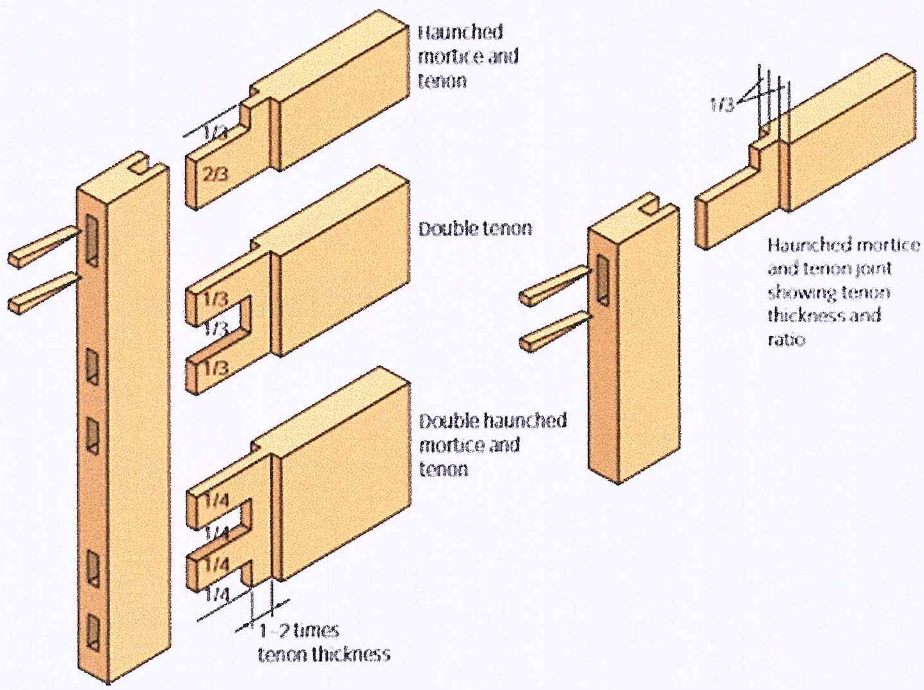


Figure 4.7. **Mortise and Tenon joints**

Dovetail joint. Traditionally, this is used in the construction of drawers. this joints are connected using adhesives alone. The pitch resists the joint being pulled apart under load. Softwood uses 1:6 angle while 1:8 for hardwoods while some uses an average of 1:7.

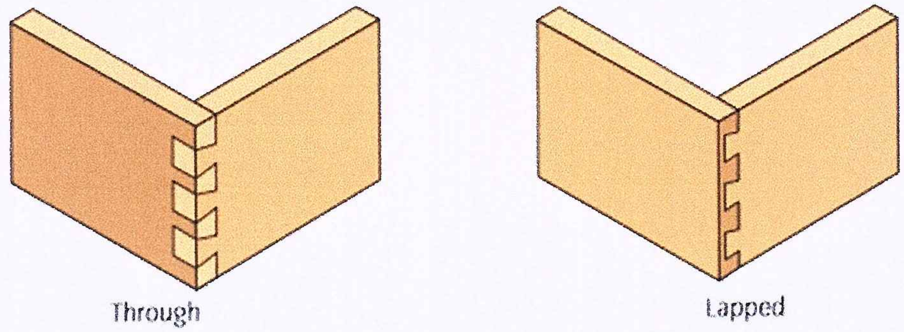


Figure 4.8. **Dovetail Joints**

Lengthening joint. Lengthening joints can be either structural or non-structural. A heading joint is the most common non-structural lengthening joint like a floor or skirting board as jointed in its length which can be simply square or 'splayed'. Further, scarf joint is also a type of non-structural joint for timber and veneers and used in ridge board while structural lengthening joint is often required where load bearing components require jointing such as a ridge board or purlin used in roof construction.

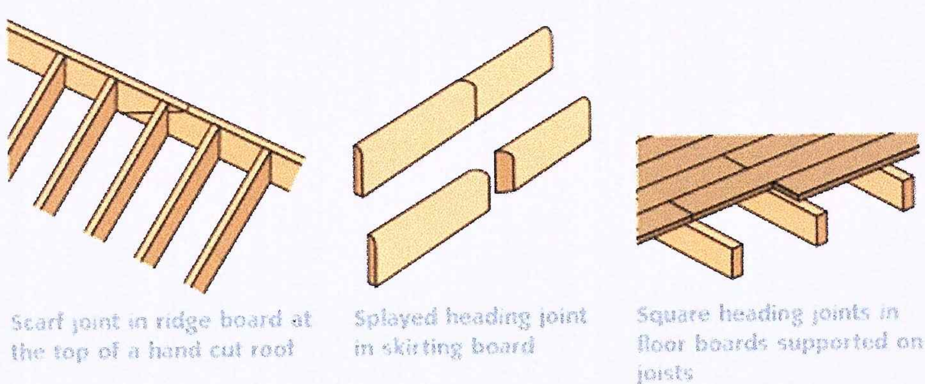


Figure 4.9. **Lengthening Joints**

Edge joint. This joint is used to make timber boards wider which can be 'rubbed', tongued, biscuited or doweled to increase strength to increase the interconnection of the joint.

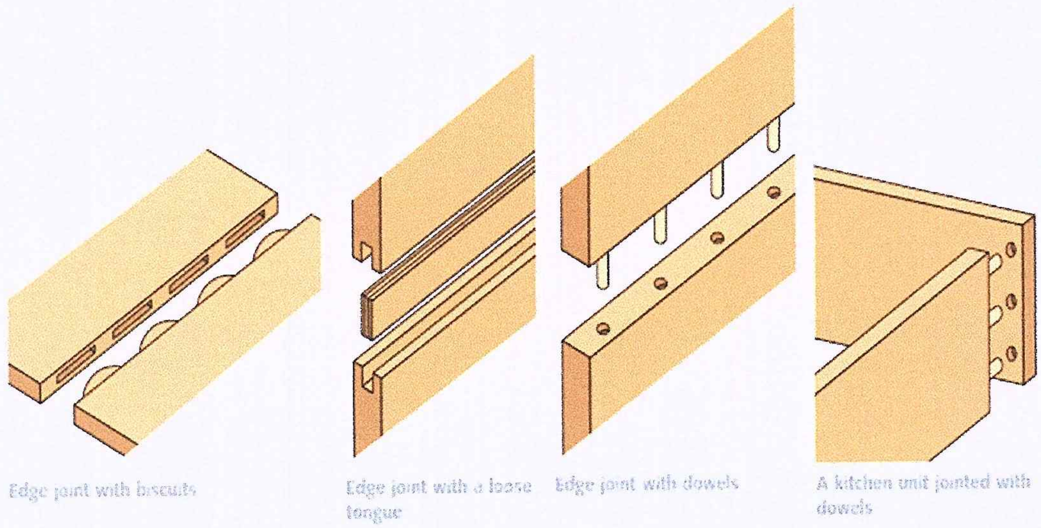


Figure 4.10. **Edge Joints**

Performance of Dovetail Joints and Mortise and Tenon Wood Joints

The strength of the joints in furniture/woodworking depends on the design of the parts and appropriateness of the timber for the construction (Boadu &Boasiako,2017). Joints that greatly resist bending, compression and tensile forces are the most preferred (Smardzewski, 2015).

Several studies have compared the strength of dovetail joints and mortise and tenon joints in furniture and found out that dovetail joints have great resistance to tension from bending forces and could offer an alternative to mortise-tenon.Boadu &Boasiako ,2017; Zhang & Eckelman (1993) and Hoadley (2000). This was because dovetail represents quality and artisanship in furniture and timber building construction due to its admirable grain-to-grain surface connection that overcomes warping. The pins and tails interlock to create a stronger natural mechanical bond with better ability to resist bending forces than mortise-tenon (Edwards, 2012).

It was observed in an experiment on withdrawal strengths of dovetail, mortise-tenon and dowel joints that dovetail had greater strength than mortise-tenon joints (Su and Wang,2007). Further, the performance of dovetail halving joint in leg-and-rail construction constructed with dovetail joints were 70% stronger than those with mortise-tenon joint (Asomani,2009). However, it was noted that the use of dovetail for joining legs, slats and stretchers to rails of chairs was not prominent among manufacturers compared to mortise-tenon since dovetail joints require greater level of care and practice in their construction (Fairham, 2007; Tankut & Tankut,2005).

Tankut and Tankut (2005) stressed that mortise-tenon is the most used joint for manufacturing working chairs due to their strength against twisting and the ease of assembly. However, joints break down with time when chairs are subjected to bending stresses that stretch wood fibres during the sitting process (Eckelman & Haviarova,2006). Experimental studies have found out that rectangular end mortise and tenons are stronger than both round end mortise and tenons and rectangular end tenons fitting into round end mortise joints. Joint geometry shows a significant effect on the strength of those particular joints which is characterized that as tenon width and length were increased, the strength of the joint was correspondingly improved (Erdil et al., 2005; Haviarova et al., 2013; Fine Woodworking 2004).

Some finding also show that there was a greater strength for joints made from 60 mm wide and 45 mm long tenon (393 N m) than those from 30 mm wide and 20 mm long (125 N m) (Kasal et al., 2013) which finding was similar with Erdil et al. (2005) that there is an increase in joint strength when tenon length and width were increased from 12.7 to 50.8 mm and 12.7 to 76.2 mm, respectively. Added by Hajdarević & Martinović (2014), longer and thicker tenons are not easily pushed out of the mortise when stressed making stronger joints than shorter and thinner tenons.

Ratnasingam et al. (2010) stressed that the decision to use a particular timber species and a corresponding joint design for furniture production must be based on experimental results of the performance of the wood-joint design combination. However, the reviewed literature and studies showed no enough studies conducted regarding GMELINA, COCO and WHITE LAUAN wood properties if joints are constructed through dovetail and mortise and tenon joinery methods that prompted the researcher to explore by conducting an experiment regarding the performance of wood joints.

Chapter 3

METHODOLOGY

This chapter discusses the research design, instrumentation, sampling procedure, data gathering procedure as well as statistical tools and treatment that will be used to analyze and interpret the data gathered.

Research Design

This study employed an experimental research design where the variables were carefully tested and/or manipulated.

Instrumentation

The researcher used *ASTM D4761* or the Standard Test Methods for Mechanical Properties of Lumber and Wood-Based Structural Materials in testing the performance of Gmelina, Coconut and White Lauan softwoods. The testing machine used in the experiment was the Computer Display Hydraulic Control Universal Testing Machine (100 kN Cap.), JINAN, Model: WEW-100D for Compression, Tension and Flexural Tests and Shear Test Set-up which were conducted at Northwest Samar State University (NWSSU) Laboratory in Calbayog City, Western Samar with the help of a competent personnel in-charge.

Other tools used in the conduct of the impact testing were the pull-push rule measurements, wooden flat surface, wooden sticks for balancing to a high level, claw hammer for installation and forming positions.

Sampling Procedure

Lumber are sampled by its quality and characteristics and known to be a softwood type. Lumber was prepared though following steps:

1. Planed the lumber into desired size
2. Measure the lumber to its required length
3. Cut it into pieces
4. Labeling samples

For the material used in Impact Test and Shear test

1. Measure both end to prepare the tenon tonque or dovetail tonque
2. Cut and shape to fit it into the mortise hole or dovetail hole
3. Assemble and fix it correctly
4. Labeling samples

Below are the samples tested according to wood specie and test performed.

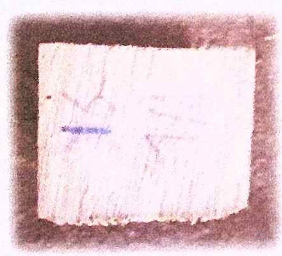


Figure 5.1. **Sample of Wood Specimen for White Lauan Specimen 1**

Figure 5.2. **Sample of Wood Specimen for Compression Parallel to Grain**

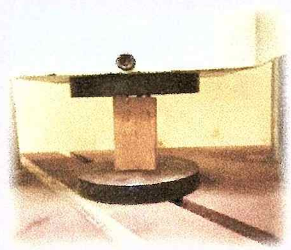


Figure 5.3. **Sample of Wood Specimen for Compression Perpendicular to Grain**

Figure 5.4. **Sample of Wood Specimen for Flexural/Tension Test**

Figure 5.5. **Sample of Wood Specimen for Shearing Test**

Figure 5.6. **Sample of Wood Specimen for Impact Test**

Data Gathering Procedure

Data gathered in this study include 4 sets of tests: compression, flexural/tensile, shear and impact. Compression, flexural/tensile, shear testings were done following the ASTM D4761 or the Standard Test Methods for Mechanical Properties of Lumber and Wood-Based Structural Materials using Computer Display Hydraulic Control Universal Testing Machine.

Compression Test. The three groups of lumbers were tested in 3 trials following ASTM D4761.

Flexure Test/Bend Test. The three groups of lumbers were tested following ASTM D4761.

Shear Test. The three groups of lumbers made of triangular dovetail joints and rectangular mortise and tenon joints were tested following ASTM D4761.

Impact Test. The test performed was a modified test derived from ASTM D4761. the following figures below shows the detailed steps of testing.

Figure 6. **Schematic Diagram Showing the Impact Test Process**

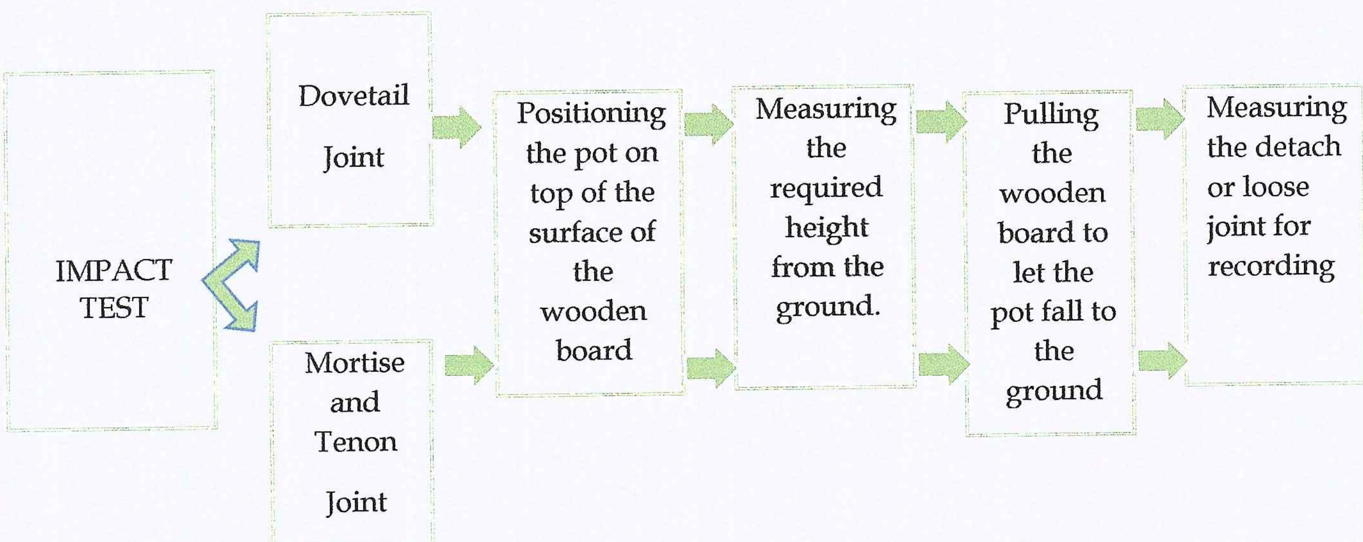


Figure 7 Construction of Joints

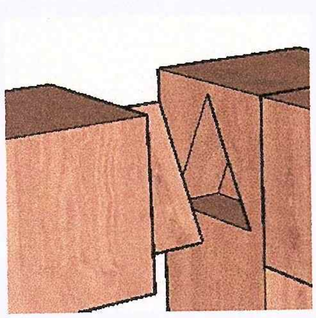


Figure 7.1. **Dovetail Joint**

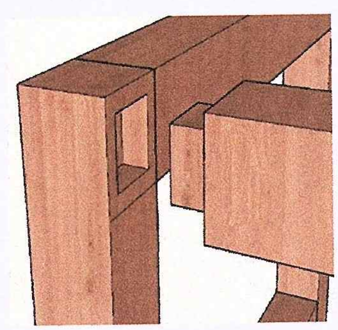


Figure 7.2. **Mortise and Tenon Joint**

3. Positioning the pot on top surface

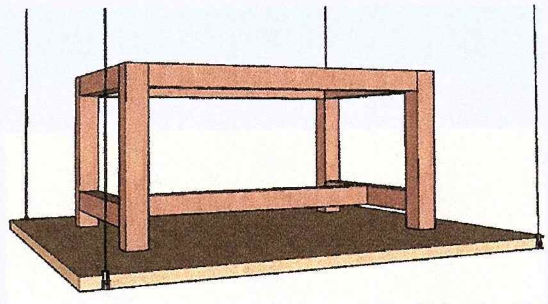


***Figure* 7.3. Positioning the pot on top surface**

3. Measure the required heigth from the ground

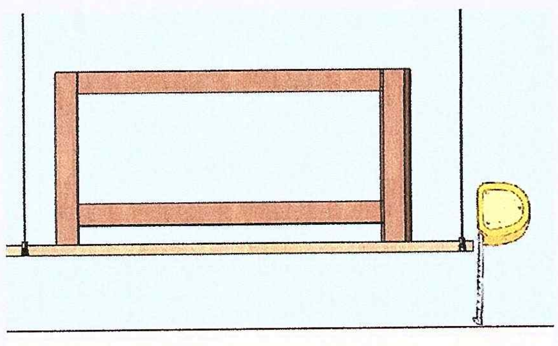


***Figure* 7.4. Measure the required height from the ground**

4. Pull the wooden surface to let the pot fall to the ground.

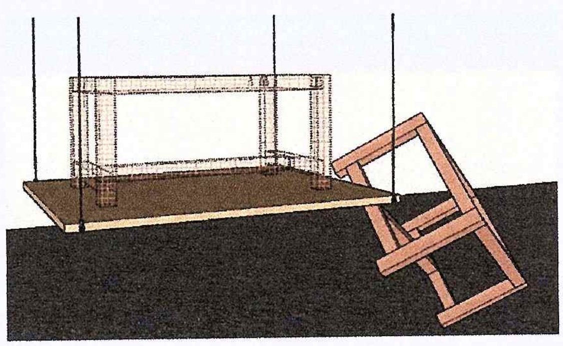


***Figure* 7.5. Pull the wooden surface to let the pot fall to the ground**

5. Measure the detach or loose joint for recording.

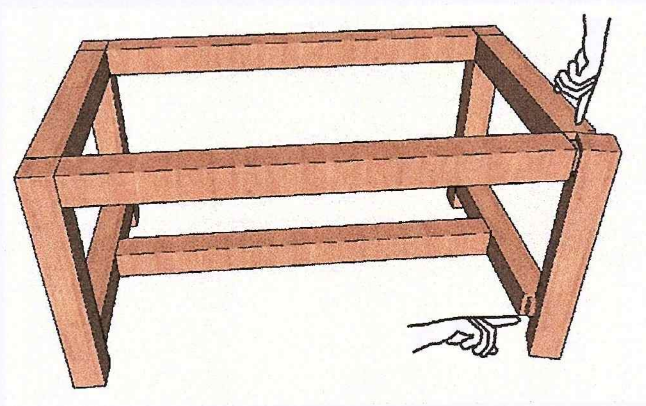


Figure 7.6. **Measure the detach or loose joint for recording**

Data Analysis

The data were proposed by the UTM operator based on the computerized result of the UTM Machine for all the wood specimens tested. In determining the performance of wood specimen in terms of compression, flexure/tension and shear test, data were utilized through the measures of central tendency and the spread of data per wood specie. Using ANOVA, the differences of the performance of the wood specimens were tested considering the wood specie, dimension and type of joints. All statistical tests were done using SPSS.

Chapter 4

PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

This chapter presents the data collected, analyzed and interpreted. Specifically, this presents the performance of softwood samples in terms of compression tests and tensile/bending tests and wood joints in terms of shearing and impact tests.

Table 1

Compression Test Results of Softwood in terms of Dimension and Wood Specie

Table 1.1

Compression Test Results of Wood Samples Parallel to Grain

GMELINA	Width 1 (mm)	Width 2 (mm)	Area	Indicated Maximum Load(kN)	Compressive Strength (MPa)
GL PARS1	43	50	2150	59.1	27.5
GL PARS2	44	50	2200	58.2	26.5
GL PARS 3	40	51	2040	59.4	29.1
Average	**42**	**50**	**2130**	**58.9**	**27.7**
COCO					
CO PARS1	41	51	2091	52.1	24.9
CO PARS2	47	43	2021	45.7	22.6
CO PARS3	43	52	2236	34.6	15.5
Average	**44**	**49**	**2116**	**44.1**	**21.0**
WHITE LAUAN					
WL PARS1	43	52	2236	37.5	16.8
WL PARS2	43	52	2236	37.5	16.8
WL PARS3	41	51	2091	52.5	25.1
Average	**42.3**	**51.7**	**2188**	**42.5**	**19.6**

The table 1.1 shows that GMELINA with an average compressive strength (MPa) =27.7 was found stronger than COCO and WHITE LAUAN woods with an average compressive strength (MPa) = 21.0 and 19.6 respectively.

Further, the compressive strength (MPa) of the wood samples from GMELINA, COCO and WHITE LAUAN were directly relative to their Indicated Maximum Load (kN) from sample 1-3 and among these, GMELINA was still found to have the highest average Indicated Maximum Load (kN) of 58.9 followed by COCO and WHITE LAUAN with 44.1 and 42.5 respectively. This implies that GMELINA is found to be a strong and durable wood material that carpenters must consider in furniture-making and woodworking among the identified woods as clearly depicted in Figure 7. The experiment result was higher compared to the findings of Ataguba (2015) with compression parallel to grain=7.4 MPa. These findings were evident during the experiment where it has been noted that a compressive stress appeared in GMELINA wood sample caused by the large cracks along the grain while COCO wood sample has a fractured fiber hair with radial cracks and a horizontal hair-like type cracks on its fibred end-grain. WHITE LAUAN wood sample has been deformed from its original shape with a minor crack from the compressive stress in the grain. (Please see Appendix B-1 &2 Preliminary and Final Observation in Compression Test Parallel to Grain).

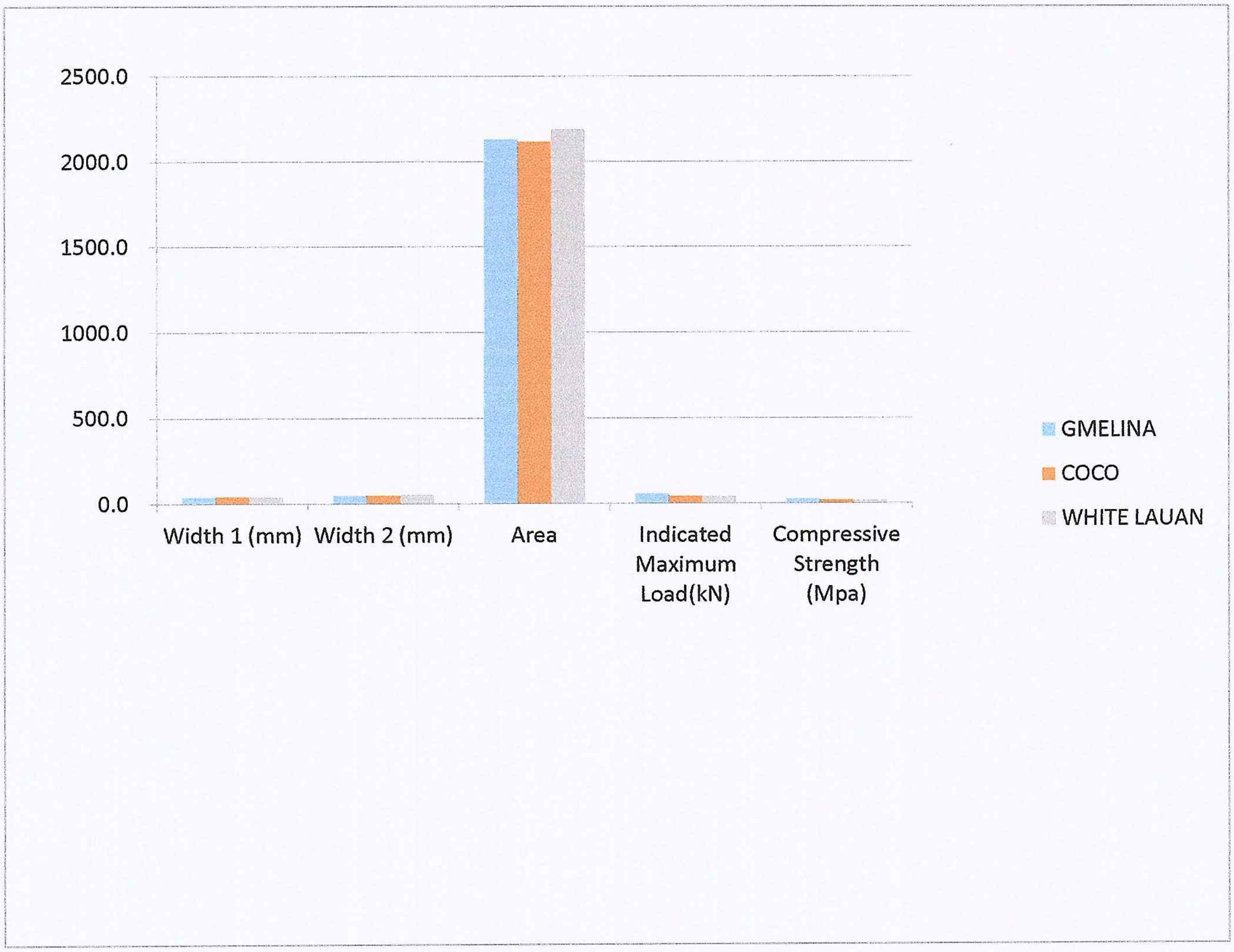


Figure 8. **Compression Strength Parallel to Grain**

Table 1.2

Compression Test Results of Wood Samples Perpendicular to Grain

GMELINA	Width 1 (mm)	Width 2 (mm)	Area	Indicated Maximum Load(kN)	Compressive Strength (MPa)
GL PERS1	46	52	2392	18	7.5
GL PERS2	46	51	2346	9.6	4.1
GL PERS3	46	51.5	2369	13.8	21.3
Average	**46**	**51.5**	**2369**	**13.8**	**10.97**
COCO					
CO PERS1	50	4.9	2450	8.9	36.3
CO PERS2	42	4.9	2058	12.3	6
CO PERS3	46	4.9	2254	10.6	21.2
Average	**46**	**4.9**	**2254**	**10.6**	**21.2**
WHITE LAUAN					
WL PERS1	45	50	2250	46.1	20.5
WL PERS2	45	50	2250	40.9	18.2
WL PERS3	45	50	2250	43.5	4.5
Average	**45**	**50**	**2250**	**43.5**	**14.4**

The table 1.2 shows that COCO with an average compressive strength (MPa) of 21.2 was found higher than WHITE LAUAN and GMELINA woods with an average compressive strength (MPa) = 14.4 and 10.97 respectively as shown in Figure 8. Further, it was observed that there was a variability of the compressive strength perpendicular to grain on the loading direction of the 3 trials per wood specie and was found to be lower than the compressive strength parallel to grain. This was due to the fact that the resistance of wood perpendicular to the grain is simply a matter of the resistance offered by the wood elements to being crushed or flattened given in the literature. This result had shown similarities with Oduor

& Githiomi, (n.d.) which compressive strength falls from the range of 9.84 – 77.56 MPa of COCO lumbers.

These findings were evident since it has been observed that GMELINA and WHITE LAUAN wood samples produced a linear fracture across the grain caused by the high compressive stress while COCO wood sample has an earth wood failure and small cracks along the grains caused by the high compressive stress. (Please see Appendix C-1&2 Preliminary and Final Observation in Compression Test Perpendicular to Grain).

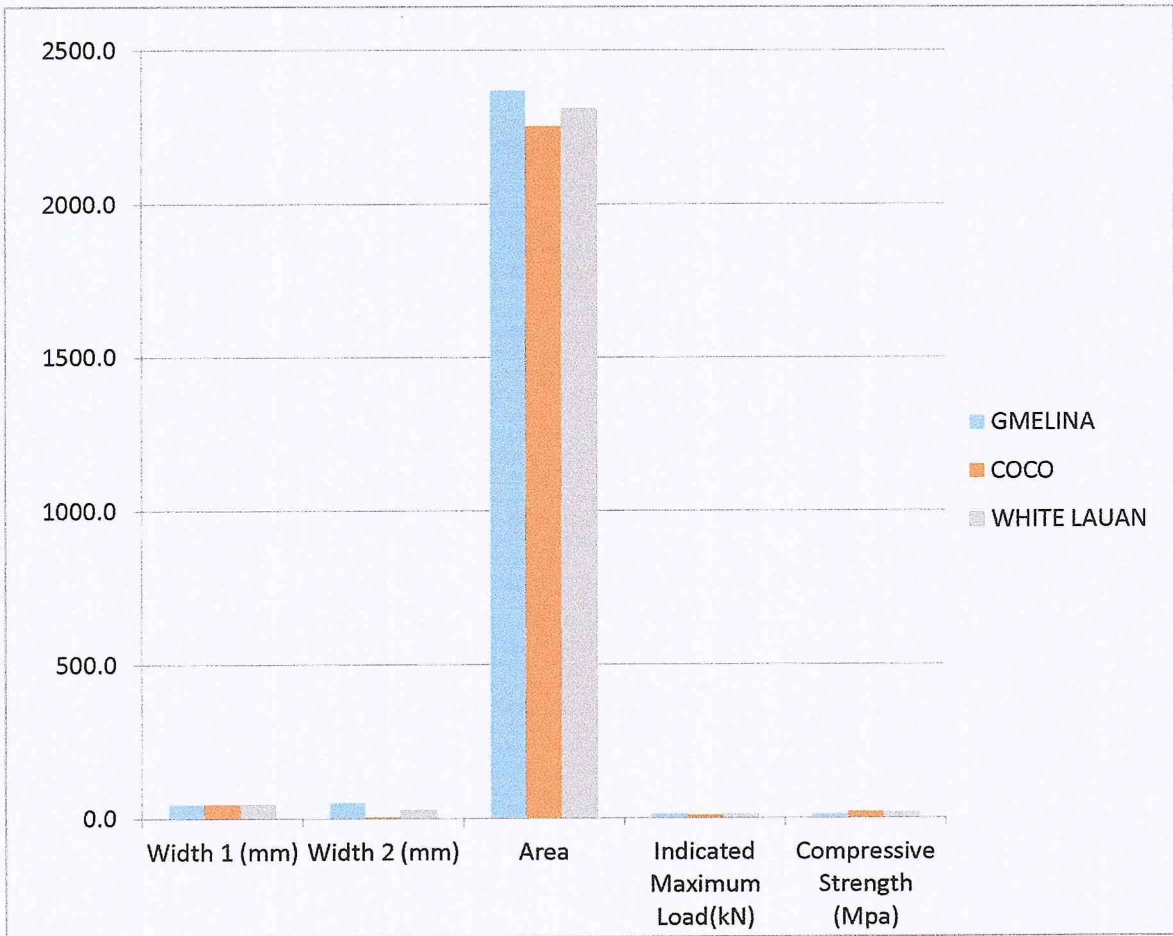


Figure 9. **Compression Strength Perpendicular to Grain**

Table 2

Bending and Tension Test Results on Wood Samples Parallel to Grain

GMELINA	Width 1 (mm)	Width 2 (mm)	Area	Indicated Maximum Load(kN)	Compressive Strength (MPa)
GL BTS1	46	51	0.23	11.3	32.7
GL BTS2	47	51	0.23	14.895	42
GL BTS3	47	51	0.24	9	26.5
Average	**46.7**	**51.0**	**0.2**	**11.7**	**33.7**
COCO					
CO BTS1	40	45	0.23	1.7	7.4
CO BTS2	40	45	0.23	1.7	7.4
CO BTS3	46	52	0.24	5.2	15.1
Average	**42**	**47.3**	**0.2**	**2.9**	**10.0**
WHITE LAUAN					
WL BTS1	46	51	0.24	10.3	31
WL BTS2	46	51	0.24	10.3	31
WL BTS3	46	51	0.24	10.3	31
Average	**46**	**51**	**0.24**	**10.3**	**31**

The table 2 shows that GMELINA with an average bending/tension strength (MPa) of 33.7 was found higher than WHITE LAUAN and COCO woods with an average bending/tension strength (MPa) = 31 and 10 respectively.

Further, as shown in the data, the bending/tension strength (MPa) of the wood samples from GMELINA, COCO and WHITE LAUAN were directly relative to the Indicated Maximum Load (kN) from Trials samples 1-3 and among these, GMELINA was still found to have the highest average Indicated Maximum Load (kN) of 11.7 followed by WHITE LAUAN and COCO with 10.3 and 2.9 respectively. This implies that GMELINA is found to be a strong and durable wood material that carpenters must consider in furniture-making and woodworking using softwoods. This finding are within the range of strength reported in the previous studies by Agatuba (2015), Oduor & Githiomi, (n.d.) and CIRAD, (2012). This is clearly depicted in Figure 9.

These finding were evident during the bending/tensile testing, where it was observed that there was a tension failure under bending in GMELINA wood samples similar with COCO wood samples but with a quite long-fibred tension than GMELINA wood sample. It was also noticed that WHITE LAUAN has a short-fibred tension failure parallel to grain. (Please see Appendix D-1&2- Preliminary and Final Observation in Bending/Tension Test Parallel to Grain).

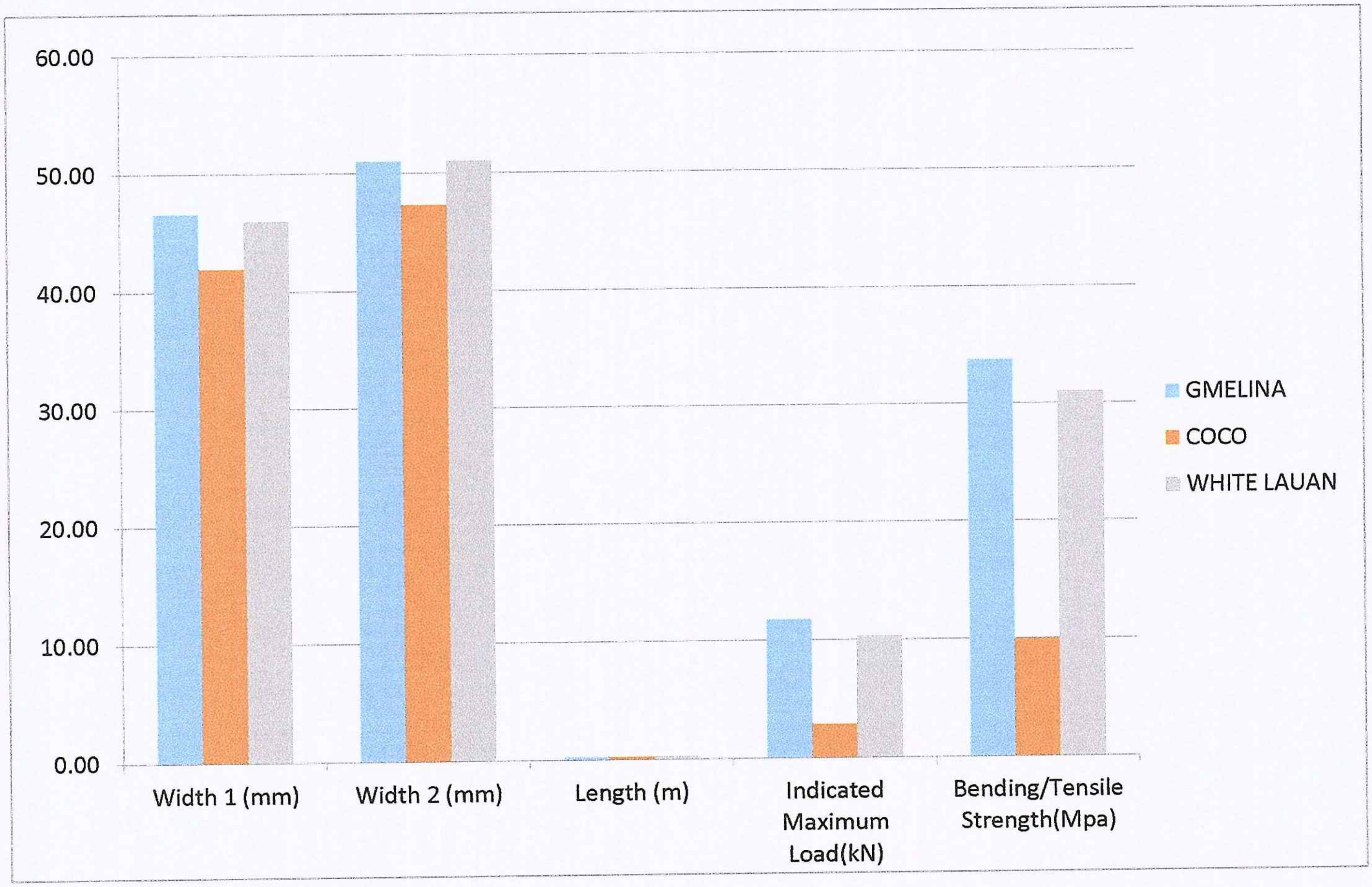


Figure 10. **Bending and Tensile Strength Parallel to Grain**

Table 3

Shear Test Results of Dovetail Joints Perpendicular to Grain

GMELINA Dovetail Joint	Area (mm^2)	Indicated Maximum Load(kN)	Shear Strength (MPa)
GL DTS1	357	10.9	30.4
GL DTS2	748.38	9.8	13.1
Average	**552.69**	**10.35**	**21.75**
COCO Dovetail Joint			
CO DTS1	402	1	2.6
CO DT S2	410	8.1	19.8
Average	**406**	**4.55**	**11.2**
WHITE LAUAN Dovetail Joint			
WL DTS1	548.38	2.7	4.9
WL DTS2	320	9.7	30.3
Average	**434.19**	**6.2**	**17.6**

The Table 3 presents the Shear Test Results of Dovetail Joints Perpendicular to Grain.

The data reveals that GMELINA dovetail joints with an average area (A=552.69 mm^2) and an average yield to an indicated maximum load of (kN)=10.35 has an average shear strength of (MPa)=21.75 has a greater strength than WHITE LAUAN and COCO dovetail joints with an average MPa of 17.6 and 11.2 respectively.

Further, as shown in the data, the shear strength (MPa) of dovetail joints of the wood samples from GMELINA, COCO and WHITE LAUAN were directly relative to the Indicated Maximum Load (kN) from Trials 1 to 3 and among these, GMELINA was still found to have the highest average Indicated Maximum Load (kN) of 10.35 followed by WHITE LAUAN and COCO with 6.2 and 4.55 respectively.

This implies that GMELINA is found to be a strong and durable wood material among the wood species used in the study which carpenters must consider in furniture-making and woodworking using softwoods. This is clearly depicted in Figure 10.

Further, this implies that GMELINA and WHITE LAUAN Dovetail Joints with smaller area have greater shear strength than those with bigger area of wood samples. This finding was in opposite with COCO wood sample which has resulted to an 85% increase in shear strength in COCO sample 2 having a very minimal increased area which led to an increase in the maximum load of almost 90%. This finding are within the range of strength reported in the previous studies by Agatuba (2015), Oduor & Githiomi, (n.d.) and CIRAD, (2012).

These findings were noted during the observation that GMELINA dovetail joint has a shear tension failure causing the tenon to slide longitudinally on beam and broke the dovetail joints. COCO dovetail joints were detached on hole and cracked continually on longitudinal surface. Similar with COCO dovetail joints, WHITE LAUAN dovetails pin joints were also pulled-out on hole and produced a small horizontal hair-type cracks. (Please see Appendix E-1&2 Preliminary and Final Observation in Shear Test Perpendicular to Grain

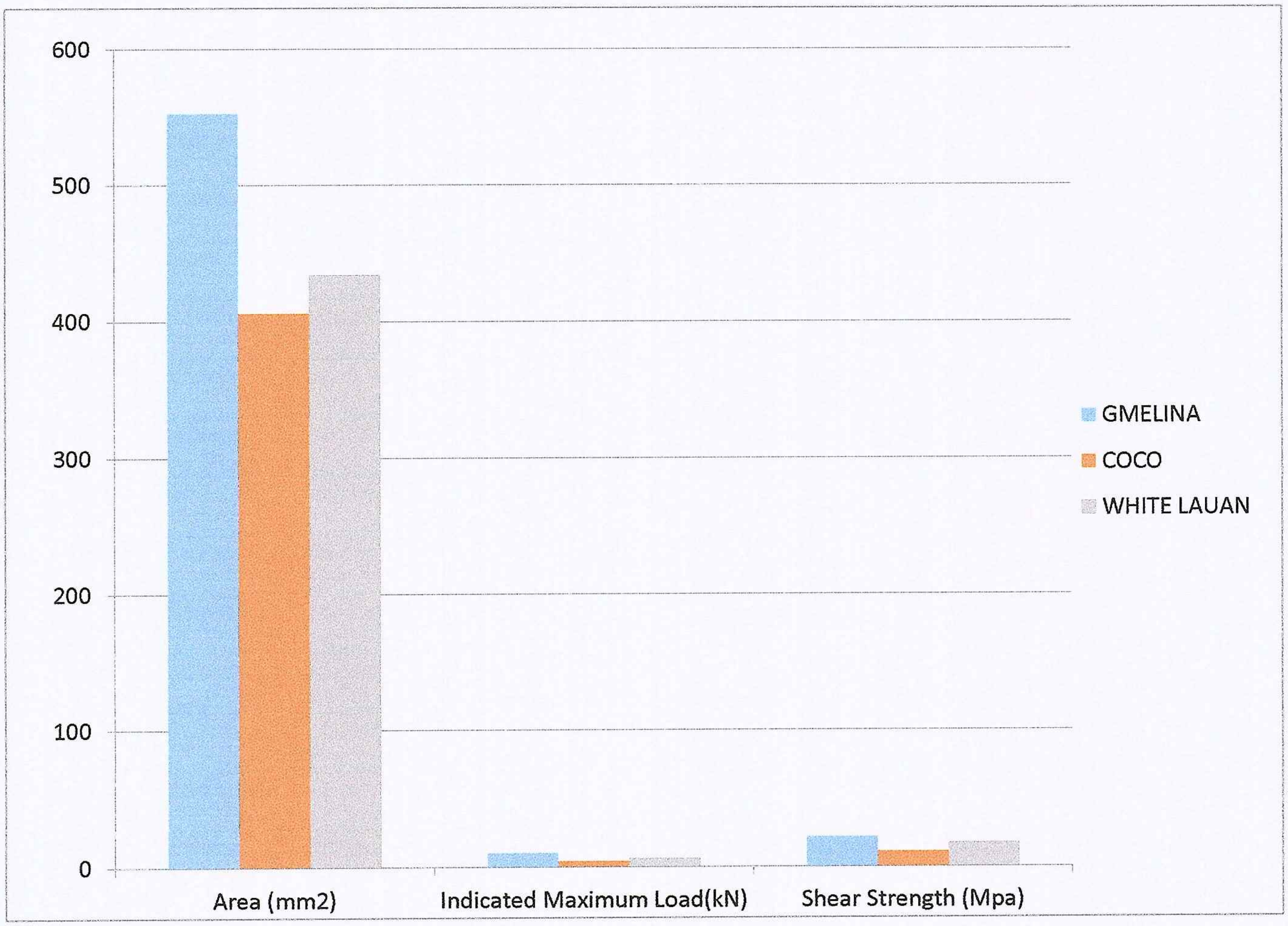


Figure 11. **Shear Strength of Dovetail Joints**

Table 4

Shear Test Results of Mortise and Tenon Joints Perpendicular to Grain

GMELINA Mortise &Tenon Joint	Area (mm^2)	Indicated Maximum Load(kN)	Shear Strength (MPa)
GL MTS1	1147	8.6	7.5
GL MTS2	899.04	7.3	8.1
Average	**1023.02**	**7.95**	**7.8**
COCO Mortise and Tenon Joint			
CO MTS1	1150	2.5	2.1
CO MT S2	1148	8.7	7.6
Average	**1149**	**5.6**	**4.85**
WHITE LAUAN Mortise and Joint			
WL MTS1	899.04	3.1	3.5
WL MTS2	1147	5.3	4.6
Average	**1023.02**	**4.2**	**4.05**

The table 4 shows that GMELINA mortise and tenon joints with an average area (A=1023 mm^2) yield to an indicated maximum load of (kN)=7.95 has an average shear strength (MPa) of 7.8 compared to COCO with an area (A=1149 mm^2) yield to an indicated maximum load of (kN)=5.6 has an average shear strength of (MPa)=4..85 while WHITE LAUAN with an average area (A=1023 mm^2) yield to an indicated maximum load of (kN)=4.2 has an average shear strength of (MPa)=4.05 as shown in Figure 11. This finding contribute to the body of knowledge that Gmelina has relatively higher strength than COCO and WHITE LAUAN constructed using the mortise and tenon joints.

These findings are seen during the shearing test where GMELINA mortise and tenon joints failed and produced cracks at the end of the beam causing to a fractured tenon joint. COCO mortise and tenon joints also failed in the shear test, however, unlike GMELINA joint, the COCO tenon joints were pulled-out from the mortise tenon hole and cracked into a longitudinal surface. WHITE LAUAN mortise and tenon joints also have the shear tension failure causing the tenon joint continually to a longitudinal surface. (Please see Appendix E-1&2 Preliminary and Final Observation in Shear Test Perpendicular to Grain)

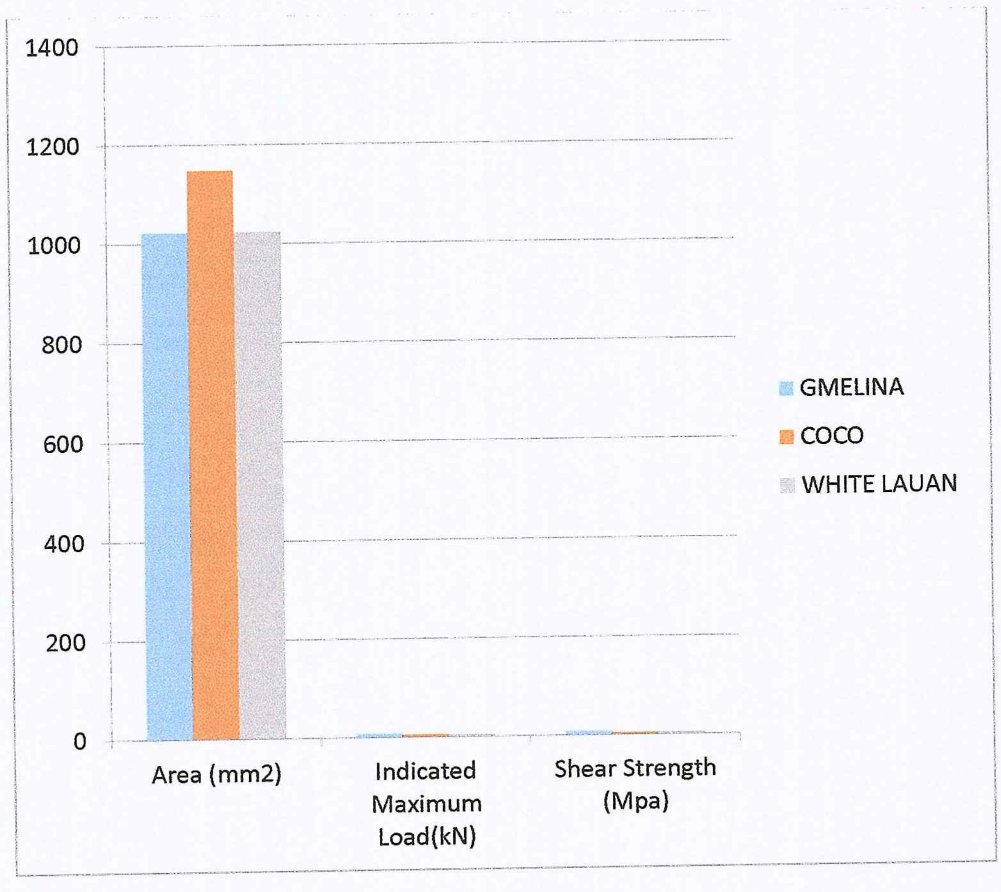


Figure 12. **Shear Strength of Mortise and Tenon Joints**

Table 5

Comparative Analysis on Impact Testing Results of Dovetail Joints and Mortise and Tenon Joints on Wood Projects

JOINTS	GMELINA		COCO		WHITE LAUAN	
	DOVETAIL JOINTS					
TEST	Dragged (mm)	detached	dragged (mm)	detached	dragged (mm)	detached
PRELIM	43mm	6 joints	60mm	6 joints	46mm	0
FINAL	67mm	5 joints	43mm	0	58mm	1 joint
Total	**110 mm**	**11 joints**	**103 mm**	**6 joints**	**104 mm**	**1 joint**
	MORTISE AND TENON JOINTS					
PRELIM	49mm	3 joints	44mm	6 joints	24mm	0
FINAL	52mm	4 joint	51mm	9 joint	40mm	0
Total	**101 mm**	**7 joints**	**95 mm**	**15 joints**	**64 mm**	**0**

The table shows that among the two joint, dovetail joints made of Gmelina got the highest recorded dragged position upon impact test from several heights than mortise and tenon joints of the different wood samples while Coco mortise and tenon joints got the highest recorded detached joints among other wood species.

On an average, the data shows that mortise and tenon joints perform better than dovetail joints among GMELINA, COCO and WHITE LAUAN.

Table 6

Analysis of Variance (ANOVA) on the Compression Strength of Softwood in terms of Dimension and Wood Specie

Table 6.1

Analysis of Variance (ANOVA) on the Compression Strength Parallel to Grain in terms of Dimension and Wood Specie

Dependent Variable: Compression Strength (MPa)

Test	*df*	*F*	*p-value*	Interpretation
Overall Model	6	26.192	.037	Significant
Wood	2	31.921	.030	Significant
Area	2	27.752	.035	Significant

p= <.05 = Significant
p= ≥.05 = Not significant

The data show that the test of compression parallel to grain in the overall ANOVA model df=6(F, 26.192) p=.037 made the strength of wood samples significantly different with underlying parameters. This implies that there was a significant difference between the compression strengths parallel to grain of softwoods as to its dimension and wood specie which rejected the null hypothesis of the study at .05 level of significance.

Particularly, the wood species GMELINA and COCO were found statistically different at p=.042 which implies that the average strength of GMELINA was significantly greater than COCO and shall be considered an option for furniture materials.

Table 6.2

Analysis of Variance (ANOVA) on the Compression Strength Perpendicular to Grain in terms of Dimension and Wood Specie

Dependent Variable: Compression Strength (MPa)

Test	*df*	*F*	*p-value*	Interpretation
Overall Model	4	1.967	.264	Not significant
Wood	2	3.270	.144	Not significant
Area	2	2.909	.166	Not significant

p= <.05 = Significant
p= ≥.05 = Not significant

The data show that the test of compression perpendicular to grain in the overall ANOVA model df=4(F, 1.967) p=.264 made the compression strength of softwoods show no difference with underlying parameters. Further, there was no significant difference between the compression strengths perpendicular to grain of softwoods as to its dimension and the identified wood specie. This accepted the null hypothesis of the study. This finding contributes to the body of literature that GMELINA, COCO and WHITE LAUAN have no significant difference as to its compression strength perpendicular to grain.

Table 7

Analysis of Variance (ANOVA) on the Bending/Tensile Strength Parallel to Grain in terms of Dimension and Wood Specie

Dependent Variable: Bending/Tensile Strength Parallel to Grain (MPa)

Test	*df*	*F*	*p-value*	Interpretation
Overall Model	4	.999	.628	Not significant
Wood	2	.089	.921	Not significant
Area	2	1.596	.488	Not significant

p= <.05 = Significant
p= ≥.05 = Not significant

The data show that bending/tensile strength perpendicular to grain in the overall ANOVA model df=4(F=.999) p=.628 showed no significant difference with underlying parameters. This implies that bending/tensile strength parallel to grain of softwoods were not different as to its dimension and wood specie. This finding accepted the null hypothesis of the study at .05 level of significance. This implies that among the tested wood samples, wood specie and area/dimension did not make any differences as to the bending/tensile strength of the wood of GMELINA, COCO and WHITE LAUAN. This finding contributes to the body of literature that GMELINA, COCO and WHITE LAUAN have no significant difference in terms of its bending or tensile strength parallel to grain.

Table 8

Analysis of Variance (ANOVA) on the Shear Strength of Dovetail Joints and Mortise and Tenon Joints in terms of Dimension and Wood Specie

Table 8.1

Analysis of Variance (ANOVA) on the Shear Test Performance of Dovetail Joints and Mortise and Tenon Joints in terms of Dimension

Dependent Variable: Shear Strength

Test	*df*	*F*	*p-value*	Interpretation
Overall Model	2	2.400	.146	Not significant
Joints	1	2.469	.151	Not significant
Area	1	.203	.663	Not significant
Joints vs. Area	0	0	0	No interaction

p= <.05 = Significant
p= ≥.05 = Not significant

The data show that the shear strength perpendicular to grain of the dovetail joints and mortise and tenon joints in the overall ANOVA model df = 2(F, 2.400) p=.146 showed no significant difference with underlying parameters. This implies that the shear strength perpendicular to grain were not different as to its dimension and wood specie. This finding accepted the null hypothesis of the study at .05 level of significance. Further, no relative reactions or significant evidence shown in the experiment that the 3 types of wood with its specific dimensions will result to a greater strength of mortise and tenon joints than dovetail joints or the reverse. Therefore, both joints are still effective in any construction of wooden projects like those in the furniture making industry. Thus, this finding adheres in the literature that joinery methods are useful provided that the standards prescribed in making any wooden projects like furniture are specifically designed and joints are carefully chosen which will make the construction more effective (Likos et al., 2012). However, this finding caught exemption of the existing literature on the interaction of joints and its dimension.

Table 8.2

Analysis of Variance (ANOVA) on the Mean Shear Test Performance of Dovetail Joints and Mortise and Tenon Joints in terms of Wood Specie

Dependent Variable: Shear Strength

Test	*Df*	*F*	*p-value*	Interpretation
Overall Model	5	.963	.506	Not significant
Joints	1	3.360	.106	Not significant
Wood	2	.434	.677	Not significant
Joints vs. Wood	2	.173	.846	Not significant

p= <.05 = Significant
p= ≥.05 = Not significant

The data show that the shear strength perpendicular to grain in the overall ANOVA model d5=4(F=.963) p=.506 showed no significant difference with underlying parameters. The shear strength perpendicular to grain of softwoods were not different as to its dimension and wood specie. This finding accepted the null hypothesis of the study at .05 level of significance. This finding was in exemption of the existing literature that dovetail joints are stronger than mortise and tenon joints (Boadu &Boasiako ,2017; Zhang & Eckelman ,1993 and Hoadley ,2000; Su and Wang,2007).

Table 9

Analysis of Variance between the Impact Test Performance of the Dovetail Joints and Mortise and Tenon Joints

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	82.738	3	27.579	1.949	.142[a]
Residual	452.900	32	14.153		
Total	**535.639**	**35**	**41.732**		

a. Predictors: (Constant), height, wood, joint

b. Dependent Variable: maximum change (mm)

p= <.05 = Significant
p= ≥.05 = Not significant

The Table 7.2 presents the Test of Difference between the Impact Test Performance of the Dovetail Joints and Mortise and Tenon Joints

The data shows that the strength of dovetail joints and mortise and tenon joints were not significantly different with p=.142>@=.05 with the predictors: height, type of wood and type of joint.

This implies that both joinery methods were capable to absorb shocks that cause stresses beyond the proportional limit of the joints considering the increased heights and the type of wood used which accepted the null hypothesis of the study.

Chapter 5

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Summary of Findings

The findings show that GMELINA with an average compressive strength (MPa) =27.7 was found stronger than COCO and WHITE LAUAN woods with an average compressive strength (MPa) = 21.0 and 19.6 respectively. Further, the compressive strength (MPa) of the wood samples were directly relative to their Indicated Maximum Load (kN). During the experiment where it has been noted that a compressive stress appeared in GMELINA wood sample caused by the large cracks along the grain while COCO wood sample has a fractured fiber hair with radial cracks and a horizontal hair-like type cracks on its fibred end-grain. WHITE LAUAN wood sample has been deformed from its original shape with a minor crack from the compressive stress in the grain.

On compression perpendicular to grain, COCO with an average compressive strength (Mpa) of 21.2 was found higher than WHITE LAUAN and GMELINA woods with an average compressive strength (MPa) = 14.4 and 10.97 .GMELINA and WHITE LAUAN wood samples produced a linear fracture across the grain caused by the high compressive stress while COCO wood sample has an earth wood failure and small cracks along the grains caused by the high compressive stress.

On bending/tension strength, GMELINA with an average bending/tension strength (MPa) of 33.7 was found higher than WHITE LAUAN and COCO woods with an average bending/tension strength (MPa) = 31 and 10 respectively which 0were directly relative to the Indicated Maximum Load (kN). A tension failure under bending in GMELINA wood samples similar with COCO wood samples but with a quite long-fibred tension than GMELINA wood sample and WHITE LAUAN has a short-fibred tension failure parallel to grain.

On shear strength, GMELINA dovetail joints has an average shear strength of (MPa)=21.75 with greater strength than WHITE LAUAN and COCO dovetail joints with an average MPa of 17.6 and 11.2 respectively which were directly relative to their indicated maximum loads. GMELINA dovetail joint has a shear tension failure causing the tenon to slide longitudinally on beam and broke the dovetail joints, COCO dovetail joints were detached on hole and cracked continually on longitudinal surface and WHITE LAUAN dovetails pin joints were also pulled-out on hole and produced a small horizontal hair-type cracks.

On mortise and tenon joints, GMELINA with an average shear strength (MPa) of 7.8 compared to COCO has an average shear strength of (MPa)=4..85 while WHITE LAUAN of (MPa)=4.05. GMELINA mortise and tenon joints failed and produced cracks at the end of the beam causing to a fractured tenon joint. COCO mortise and tenon joints also failed in the shear test, however, unlike GMELINA joint, the COCO tenon joints were pulled-out from the mortise tenon hole and cracked into a longitudinal surface. WHITE LAUAN mortise and tenon joints also have the shear tension failure causing the tenon joint continually to a longitudinal surface.

On impact strength, findings show that dovetail joints made of Gmelina got the highest recorded dragged position upon impact test from several heights than mortise and tenon joints of the different wood samples while Coco mortise and tenon joints got the highest recorded detached joints among other wood species.

On the test of difference on compression parallel to grain, in the overall ANOVA model df=6(F, 26.192) p=.037 made the strength of wood samples significantly different with underlying parameters. Particularly, the wood species GMELINA and COCO were found statistically different at p=.042 which implies that the average strength of GMELINA was significantly greater than COCO and shall be considered an option for furniture materials.

On the test of compression perpendicular to grain, the overall ANOVA model df=4(F, 1.967) p=.264 made the compression strength of softwoods show no difference with underlying parameters. Further, there was no significant difference between the compression strengths perpendicular to grain of softwoods as to its dimension and the identified wood specie

On the test of difference on bending/tensile strength perpendicular to grain, the overall ANOVA model df=4(F=.999) p=.628 showed no significant difference with underlying parameters.

On the test of difference on shear strength perpendicular to grain of the dovetail joints and mortise and tenon joints, the overall ANOVA model df=2(F,2.400) p=.146 showed no significant difference with underlying parameters. Further, no relative reactions or significant evidence shown in the experiment that the 3 types of wood with its specific dimensions will result to a greater strength of mortise and tenon joints than dovetail joints or the reverse.

On the test of difference of shear strength perpendicular to grain, the overall ANOVA model d5=4(F=.963) p=.506 showed no significant difference with underlying parameters.

On the test of difference on impact strength, dovetail joints and mortise and tenon joints were not significantly different with p=.142>@=.05 with the predictors: height, type of wood and type of joint.

Conclusions

Based on the findings of the study, the following conclusions were drawn:
On the basis of the findings of the study, it is therefore concluded that:

1. Gmelina offers greater wood properties in terms of dimensions. However, this does not necessarily considered as a factors of the strength of other wood samples.
2. Gmelina offers a greater strength in terms of compression parallel to grain and tensile strength while coco offers a greater compressive strength perpendicular to grain.
3. Dovetail joint offer a greater shear strength and low impact strength compared to mortise and tenon joints.

4. Mortise and tenon joints offers relatively low shear strength and a greater impact strength compared to dovetail joint.
5. Dovetail joints and mortise and tenon joints have insignificant difference in strength under dimensions and species.
6. Dovetail joints and mortise and tenon joints have insignificant difference in shear strength and impact strength.

Recommendations

Based on the conclusions of the study, the following is hereby recommended.

1. Gmelina shall be given a place in woodworking, but this should not discout other Philippine woods.
2. End-users shall explore more on the properties of Coco lumber as a good material in furniture and woodworking activities.
3. End-users shall explore techniques in improving the impact strength of dovetail joints.
4. End-users shall explore techniques in improving the shear strength of mortise and tenon joints.
5. End-users shall explore more on other wood properties as variables in effect to the better performance of wood joints other than dimension and species.

6. End-users shall explore more on the other properties as variables in the performance of both dovetail and mortise and tenon joints in terms of shear and impact strength.

BIBLIOGRAPHY

Ataguba, C. et al. (2015). A Comparative study of Some Mechanical Properties of Gmelina arborea, parkia biglobosa and prosopis africana timbers for Structural use, *International Journal of technical Research and Applications* e-ISSN: 2320-8163, www.ijtra.com Volume 3, Issue 3, PP. 320-324

Branco, J.M & Descamps, T. (2015) A*nalysis and Strengthening of Carpentry Joints.* Retrieved from www.researchgate.com

Csanady, E. et al, 2019. Optimum Design and Manufacture of Wood Products, 224. Retrieved from www.books.google.com

Hassan, R. A. I. (2012). *Performance of Mortise and Tenon Connection fastened with wood and steel dowel.* World Committee on Timber Engineering.

Hassan, R. & A. I. (2012) Experimental Performance of Mortice and Tenon Joint Strengthened with Glass Fibre Reinforced Polymer under Tensile Load. *IEEE Symposium on Business, Engineering & Industrial Applications (ISBEIA).*

Hiziroglu, S. (n.d.). S*trength Properties of Wood for Practical Applications.* From www.fapc.biz.

Huber, H. & Eckelman, C. (1999). *The Role of Wood Science in Investigating Wood Failures.*

Ioras, J. R. (2010). Bending and fatigue strength of mortise and tenon furniture joints made from oil palm lumber. *Eur. J. Wood Prod.* (2011) 69:677-679 DOI 10.1007/s00107-010-0501-3.

Isopescu, D. & O. S. (2012). *Analysis Of Wood Bending properties On Standardized Samples And Structural Size Beams Tests.*

Leng, W. L. (2019). The application Research of Mortise and Tenon Structure In Cultural and Creative Products. I*OP Conference Series: materials Science and Engineering.*

Liu, W. (2019). The Application Research of Mortise and Tenon structure in Cultural and Creative Producrs, I*OP Conf. Series: Materials Science and Engineering* 573, 012006. IOP Publishing doi: 10.1088/1757-899X/573/1/012006

Marinova, V. J. (2006). Ult*imate bending strength and stiffness under compression test of end corner miter joints constructed of solid wood.* https://www.researchgate.net/publication/274080810.

Naylor, A. & N. P. (2012). *Determination of wood strength properties through standard test procedures.* Retrieved February 2020, from: https://www.researchgate.net/publication/301680152

Oduor, N. and Githiomi, J. Wood Characteristics and properties of Cocos Nucifera (the coconut tree) grown in Kwale District, *Kenya Forestry Research Institute (KEFRI), Forest Products research centre*, P. O. Box 64636, 00620 Nairobi, Kenya

Oktee, J. G. (2013). Bending moment capacity of simple and haunched mortise and tenon furniture joints under tension and compression loads from http://journals.tubitak.gov.tr/agriculture/Turkish *Journal of Agriculture and Forestry* Turk J Agric For

Osamah, M. G. et al (2016). Comparison Study between Hardwood and Softwood. *Journal of Babylon University/ Engineering Sciences.*

Rowell, R. M. (2005). *Handbook of wood chemistry and wood composites.* CRC Press, 200 N.W. Corporate Blvd., Boca Raton, Florida USA.

Spaeth, T. D. (2014). Universal Dovetail Joint. Speculative Counterculture, *Proceedings of the 19th International Conference on Computer aided Architectural Design Research in Asia.*

Tankut, A. & N. T. (2004) The Effects of Joint Forms (Shape) and Dimensions on the Strengths of Mortise and Tenon Joints. *Turk J Agric*, 493-498.

Winandy, J. and Rowell M., Chemistry of wood strength forest prodecuts laboratory 1999. Wood handbook - wood as an engineering material. Gen. Tech Rep. Fpl-gtr-113. Madison, wi: *U.S. Department of Agriculture, Forest Service, Forest Products Laborato*ry. 463 p.

Wu, G. et al (2019). Mechanical performance of mortise and tenon joints pre-reinforced with slot-in bamboo scrimber plates. *Journal of Wood Science,* 38.

Zaragoza, E. C. (2018). The Philippines' Wood Industry from www.agriculture.com

OTHER ONLINE SOURCES

www.books.google.com

www.woodworking.com

www.researchgate.com

www.agriculture.com

www.psa.gov.ph

Twi-global.com

Oxford Advanced Learners Dictionary, 2019

The Dictionary. Com 2019

Cambridge English Dictionary, 2019

21st Century Universal Dictionary, 2012

SUMMARY OF THE LABORATORY STANDARDIZED TESTING RESULTS OF WOODS

NAME OF TEST	*PRELIMINARY TEST*			*FINAL TEST*		
	GMELINA	*COCO*	*WHITE LAUAN*	*GMELINA*	*COCO*	*WHITE LAUAN*
	Compressive Strength (Mpa)			*Compressive Strength (Mpa)*		
1. COMPRESSION TEST PARALLEL TO GRAIN	27.5	24.9	16.8	29.1	15.5	25.5
2. COMPRESSION TEST PERPENDICULAR TO GRAIN	7.5	36.3	20.5	22.5	18.2	4.6
3. BENDING AND TENSION PARALLEL TO GRAIN	42	7.4	31.0	26.5	15.1	31
4. SHEAR PERPENDICULAR TO GRAIN(DOUBLE)						
Dovetail Joint without Nail or Wood Glue	30.4	2.6	4.9	13.1	19.8	30.3
Mortise and Tenon Joint without Nail or Wood Glue	7.5	2.1	3.5	8.1	7.6	4.6

5..IMPACT TEST (PRELININARY)						
Height from the Ground	*Dovetail Joint without nail or glue*					
	GMELINA		***COCO***		***WHITE LAUAN***	
	dragged (mm)	*detached*	*dragged (mm)*	*detached*	*dragged (mm)*	*detached*
½ meter	2	none	2	none	5	none
1 meter	4	none	10	none	6	none
1 ½ meter	10	none	13	none	4	none
2 meter	2	2	14	1	15	none
2 ½ meter	15	1	10	3	8	none
3 meter	10	3	11	2	8	none
	43mm	**6 joints**	**60mm**	**6 joints**	**46mm**	**0**

Height from the Ground	Mortise and Tenon Joint without Nail or Wood Glue					
	GMELINA		COCO		WHITE LAUAN	
	dragged (mm)	detached	dragged (mm)	detached	dragged (mm)	detached
½ meter	0	none	2	none	2	none
1 meter	6	none	6	none	0	none
1 ½ meter	16	2	5	none	5	none
2 meter	10	none	14	1	4	none
2 ½ meter	4	none	9	2	5	none
3 meter	13	1	8	3	8	none
	49mm	3 joints	44mm	6 joints	24mm	0

5..IMPACT TEST (FINAL)

Height from the Ground	Dovetail Joint without nail or glue					
	GMELINA		COCO		WHITE LAUAN	
	dragged (mm)	detached	dragged (mm)	detached	dragged (mm)	detached
½ meter	10	none	5	none	10	none
1 meter	15	none	6	none	15	none
1 ½ meter	10	none	4	none	4	none
2 meter	9	1	15	none	3	1
2 ½ meter	9	2	5	none	10	none
3 meter	14	2	8	none	16	none
	67mm	**5 joints**	**43mm**	**0**	**58mm**	**1 joint**

Height from the Ground	Mortise and Tenon Joint without Nail or Wood Glue					
	GMELINA		COCO		WHITE LAUAN	
	dragged (mm)	detached	dragged (mm)	detached	dragged (mm)	detached
½ meter	4	none	4	none	4	none
1 meter	9	none	14	none	3	none
1 ½ meter	9	1	3	none	5	none
2 meter	14	none	11	2	9	none
2 ½ meter	8	1	11	3	10	none
3 meter	8	2	8	4	9	none
	52mm	**4 joint**	**51mm**	**9 joint**	**40mm**	**0**

Joints	dragged (mm)						Records of Preliminary Result

Dovetail Joint	43mm		60mm		46mm		GMELINA
		6 joints		6 joints		0	detached
Mortise and Tenon Joint	49mm		44mm		24mm		117 mm
		3 joints		6 joints		0	9 joints
TOTAL	92mm	9	104mm	12	70mm	0	

RECORDS OF FINAL RESULT

	GMELINA		COCO		WHITE LAUAN		TOTAL
Joints	dragged (mm)	detached	dragged (mm)	detached	dragged (mm)	detache d	
Dovetail Joint	67mm		43mm		58mm		168 mm
		5 joints		0		1 joint	6 joints
Mortise and Tenon Joint	52mm		51mm		40mm		143 mm
		4 joint		9 joint		0	13 joints
TOTAL	119mm	9	94mm	9	98mm	1	
GRAND TOTAL	211 mm	18 joints	202 mm	21 joints	163 mm	1 Joint	

SUMMARY RESULT ON THE PERFORMANCE OF WOOD						
	GMELINA		*COCO*		*WHITE LAUAN*	
	dragged	*detached*	*dragged*	*detached*	*dragged*	*detached*
TOTAL	211 mm	18 joints	202 mm	21 joints	163 mm	1 joint

SUMMARY RESULT ON THE PERFORMANCE OF JOINTS			
	Preliminary Test	*Final Test*	*TOTAL*
Dovetail Joint			
Dragged (mm)	149 mm	168 mm	**317 mm**
Detached	12 joints	6 joints	**18 joints**
Mortise and Tenon Joint			
Dragged (mm)	117 mm	143 mm	**260 mm**
Detached	9 joints	13 joints	**22 joints**

APPENDIX- A

SUMMARY OF STANDARDIZED RESULTS OF WOOD SAMPLES AND JOINTS

Republic of the Philippines
NORTHWEST SAMAR STATE UNIVERSITY
Main Campus, Calbayog City

AS-BAO FORM-B No. 2020-02
O.R. No. 3119995A
Date Tested: FEBRUARY 5, 2020

PRELIMINARY AND FINAL OBSERVATION IN COMPRESSION PARALLEL TO GRAIN

PRELIMINARY TEST RESULT ON WOOD SAMPLES

Sample ID	Width 1 (mm)	Width 2 (mm)	Area	Indicated Maximum Load(kN)	Compressive Strength (Mpa)	Remarks
GMELINA Sample 1	43	50	2150	59.1	27.5	
COCO Sample 2	41	51	2091	52.1	24.9	
WHITE LAUAN Sample 3	43	52	2236	37.5	16.8	
x-x-x-Nothing Follows-x-x-x						

AS-BAO FORM-B No. 2020-02
O.R. No. 3119995A
Date Tested: MARCH 24,2020

FINAL TEST RESULT ON WOOD SAMPLES

Sample ID	Width 1 (mm)	Width 2 (mm)	Area	Indicated Maximum Load(kN)	Compressive Strength (Mpa)	Remarks
GMELINA Sample 1	40	51	2040	59.4	29.1	
COCO Sample 2	43	52	2236	34.6	15.5	
WHITE LAUAN Sample 3	41	51	2091	52.5	25.1	
x-x-x-Nothing Follows-x-x-x						

APPENDIX- A
SUMMARY OF STANDARDIZED RESULTS OF WOOD SAMPLES AND JOINTS

Republic of the Philippines
NORTHWEST SAMAR STATE UNIVERSITY
Main Campus, Calbayog City

AS-BAO FORM-B No. 2020-02
O.R. No. 3119995A
Date Tested: FEBRUARY 5, 2020

PRELIMINARY AND FINAL OBSERVATION IN COMPRESSION PERPENDICULAR TO GRAIN

PRELIMINARY TEST RESULT ON WOOD SAMPLES

Sample ID	Width 1 (mm)	Width 2 (mm)	Area	Indicated Maximum Load(kN)	Compressive Strength (Mpa)	Remarks
GMELINA Sample 1	46	52	2392	18.0	7.5	
COCO Sample 2	50	4.9	2450	8.9	36.3	
WHITE LAUAN Sample 3	45	50	2250	46.1	20.5	
x-x-x-Nothing Follows-x-x-x						

AS-BAO FORM-B No. 2020-02
O.R. No. 3119995A
Date Tested: MARCH 24, 2020

FINAL TEST RESULT ON WOOD SAMPLES

Sample ID	Width 1 (mm)	Width 2 (mm)	Area	Indicated Maximum Load(kN)	Compressive Strength (Mpa)	Remarks
GMELINA Sample 1	45	51	2295	52.1	22.7	
COCO Sample 2	45	50	2250	40.9	18.2	
WHITE LAUAN Sample 3	46	50	2300	10.5	4.6	
x-x-x-Nothing Follows-x-x-x						

APPENDIX- A
SUMMARY OF STANDARDIZED RESULTS OF WOOD SAMPLES AND JOINTS

Republic of the Philippines
NORTHWEST SAMAR STATE UNIVERSITY
Main Campus, Calbayog City

AS-BAO FORM-B No. 2020-02
O.R. No. 3119995A
Date Tested: FEBRUARY 5, 2020

PRELIMINARY AND FINAL OBSERVATION IN BENDING AND TENSION PARALLEL TO GRAIN

PRELIMINARY TEST RESULT ON WOOD SAMPLES

Sample ID	Width 1 (mm)	Width 2 (mm)	Length (m)	Indicated Maximum Load(kN)	Bending/Tensile Strength(Mpa)	Remarks
GMELINA Sample 1	47	51	0.23	14.895	42.0	
COCO Sample 2	40	45	0.23	1.7	7.4	
WHITE LAUAN Sample 3	46	51	0.24	10.3	31.0	
X-X-X- NOTHING FOLLOWS –X-X-X						

AS-BAO FORM-B No. 2020-02
O.R. No. 3119995A
Date Tested: MARCH 24, 2020

FINAL TEST RESULT ON WOOD SAMPLES

Sample ID	Width 1 (mm)	Width 2 (mm)	Length (m)	Indicated Maximum Load(kN)	Bending/Tensile Strength(Mpa)	Remarks
GMELINA Sample 1	47	51	0.24	9.0	26.5	
COCO Sample 2	46	52	0.24	5.2	15.1	
WHITE LAUAN Sample 3	46	51	0.24	10.3	31.0	
X-X-X- NOTHING FOLLOWS –X-X-X						

APPENDIX- A

SUMMARY OF STANDARDIZED RESULTS OF WOOD SAMPLES AND JOINTS

Republic of the Philippines
NORTHWEST SAMAR STATE UNIVERSITY
Main Campus, Calbayog City

AS-BAO FORM-B No. 2020-02
O.R. No. 3119995A
Date Tested: FEBRUARY 5, 2020

PRELIMINARY AND FINAL OBSERVATION IN SHEAR TEST PERPENDICULAR TO GRAIN

PRELIMINARY TEST RESULT ON WOOD SAMPLES

Sample ID	Area (mm^2)	Indicated Maximum Load(kN)	Shear Strength (Mpa)	Remarks
GMELINA Mortise &Tenon Joint	1147	8.6	7.5	
GMELINA Dovetail Joint	357	10.9	30.4	
COCO Mortise &Tenon Joint	1150	2.5	2.1	
COCO Dovetail Joint	402	1.0	2.6	
WHITE LAUAN Mortise &Tenon Joint	899.04	3.1	3.5	
WHITE LAUAN Dovetail Joint	548.38	2.7	4.9	
x-x-x-x-Nothing Follows-x-x-x-x				

AS-BAO FORM-B No. 2020-02
O.R. No. 3119995A
Date Tested: MARCH 24, 2020

FINAL TEST RESULT ON WOOD SAMPLES

Sample ID	Area (mm^2)	Indicated Maximum Load(kN)	Shear Strength (Mpa)	Remarks
GMELINA Mortise &Tenon Joint	899.04	7.3	8.1	

GMELINA Dovetail Joint	748.38	9.8	13.1	
COCO Mortise & Tenon Joint	1148	8.7	7.6	
COCO Dovetail Joint	410	8.1	19.8	
WHITE LAUAN Mortise &Tenon Joint	1147	5.3	4.6	
WHITE LAUAN Dovetail Joint	320	9.7	30.3	
x-x-x-x-Nothing Follows-x-x-x-x				

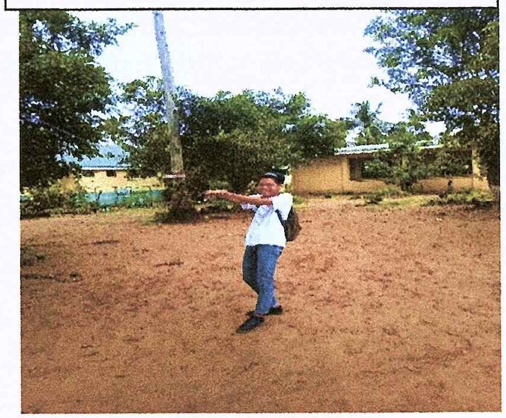
APPENDIX F
PRELIMINARY AND FINAL PHOTO DOCUMENTATION ON IMPACT TESTING OF DOVETAIL JOINTS AND MORTISE AND TENON JOINTS

APPENDIX F-1

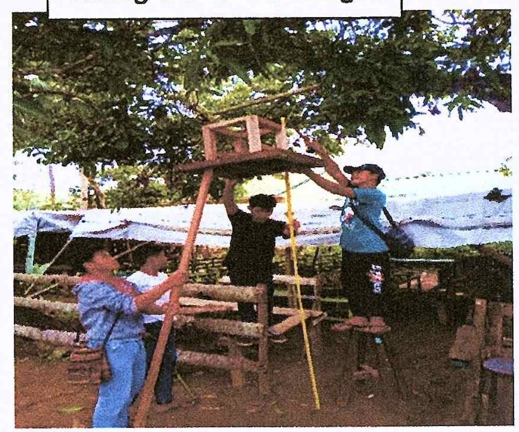
Preliminary Photo documentation on Impact Testing of Dovetail joints without the Aid of Nail or Wood Glue

Proper positioning

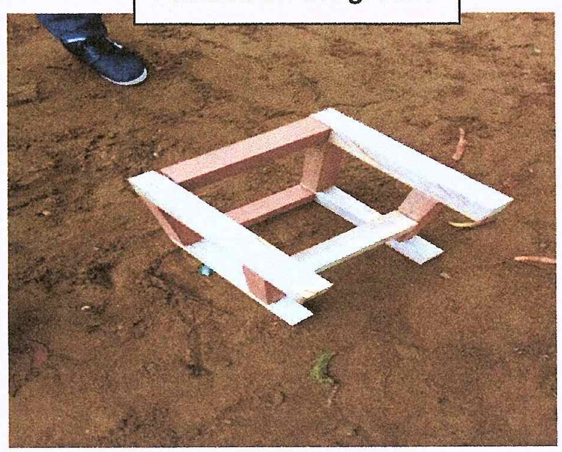
Pulling the wooden pot to fall down



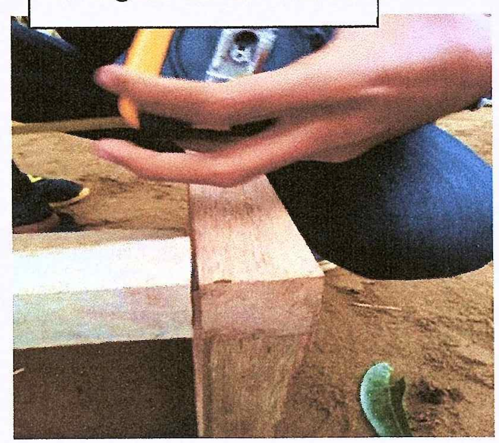
Taking the desired height



Position on the ground



Taking the measurement

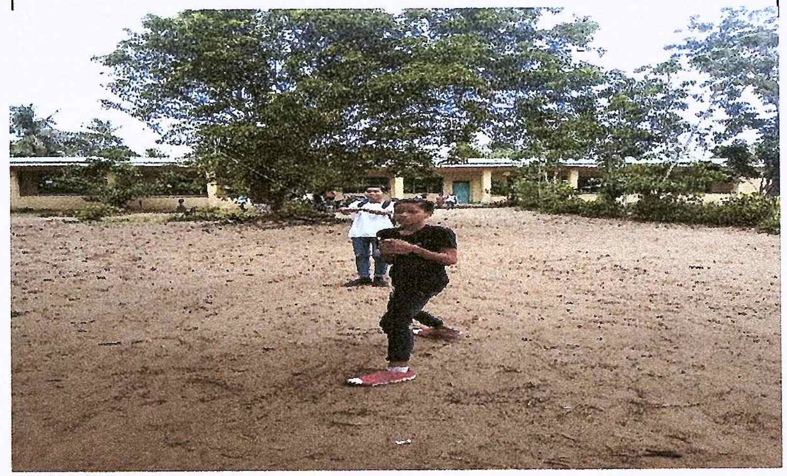


APPENDIX F-2

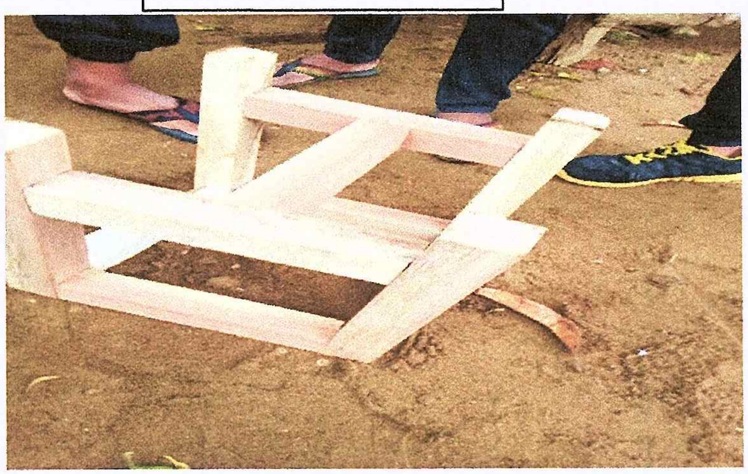
Final Photo documentation on Impact Testing of Mortise and Tenon Joints without the Aid of Nail or Wood Glue

Taking measurement for height

Pulling the nylon string to fall



Position on the ground



Taking and recording the joint position

PRELIMINARY AND FINAL PHOTO OBSERVATION NOTES ON IMPACT TESTING OF DOVETAIL JOINTS AND MORTISE AND TENON JOINTS

PRELIMINARY OBSERVATIONAL NOTES
IMPACT TEST ON WHITE LAUAN (MORTISE AND TENON JOINT)

Height	**No. of joint Dragged/ Pulled-out/ruined**	**EXTEND OF DAMAGES** • Dragged a little from its original position • Detached / Pulled out from its original position • Broken/Ruined joint			
		Joint 1	**Joint 2**	**Joint 3**	**Joint 4**
½ meter	1	2mm Dragged a little from its original position			
1 meter	-				
1 ½ meter	2	4mm Dragged a little from its original position	5mm Dragged a little from its original position		
2 meter	4	3mm Dragged a little from its original position	3mm Dragged a little from its original position	4mm Dragged a little from its original position	2mm Dragged a little from its original position
2 ½ meter	4	5mm Dragged a little from its original position	3mm Dragged a little from its original position	5mm Dragged a little from its original position	5mm Dragged a little from its original position
3 meter	4	8mm Dragged a little from its original position	5mm Dragged a little from its original position	4mm Dragged a little from its original position	6mm Dragged a little from its original position

FINAL OBSERVATIONAL NOTES
IMPACT TEST ON WHITE LAUAN (MORTISE AND TENON JOINT)

Height	No. of joint Dragged/Pulled-out/ruined	EXTEND OF DAMAGES • Dragged a little from its original position • Detached /Pulled out from its original position • Broken/Ruined joint			
		Joint 1	**Joint 2**	**Joint 3**	**Joint 4**
½ meter	2	4mm Dragged a little from its original position	3mm Dragged a little from its original position		
1 meter	2	3mm Dragged a little from its original position	3mm Dragged a little from its original position		
1 ½ meter	4	5mm Dragged a little from its original position	3mm Dragged a little from its original position	3mm Dragged a little from its original position	3mm Dragged a little from its original position
2 meter	4	9mm Dragged a little from its original position	6mm Dragged a little from its original position	5mm Dragged a little from its original position	**6mm** Dragged a little from its original position
2 ½ meter	4	2mm Dragged a little from its original position	5mm Dragged a little from its original position	10mm Dragged a little from its original position	**1mm** Dragged a little from its original position
3 meter	4	9mm Dragged a little from its original position	7mm Dragged a little from its original position	9mm Dragged a little from its original position	**6mm** Dragged a little from its original position

PRELIMINARY OBSERVATIONAL NOTES

IMPACT TEST ON WHITE LAUAN (DOVETAIL JOINT)

Height	No. of joint Dragged/ Pulled-out/ruined	EXTEND OF DAMAGES • Dragged a little from its original position • Detached /Pulled out from its original position • Broken/Ruined joint				
		Joint 1	**Joint 2**	**Joint 3**	**Joint 4**	**Joint 5**
½ meter	4	10mm Dragged a little from its original position	4mm Dragged a little from its original position	2mm Dragged a little from its original position	2mm Dragged a little from its original position	
1 meter	5	15mm Dragged a little from its original position	4mm Dragged a little from its original position	4mm Dragged a little from its original position	2mm Dragged a little from its original position	2mm Dragged a little from its original position
1 ½ meter	4	4mm Dragged a little from its original position	4mm Dragged a little from its original position	1mm Dragged a little from its original position	1mm Dragged a little from its original position	
2 meter	4	detached	3mm Dragged a little from its original position	3mm Dragged a little from its original position	3mm Dragged a little from its original position	
2 ½ meter	5	10mm Dragged a little from its original position	4mm Dragged a little from its original position	4mm Dragged a little from its original position	2mm Dragged a little from its original position	2mm Dragged a little from its original position
3 meter	5	16mm Dragged a little from its original position	6mm Dragged a little from its original position	12mm Dragged a little from its original position	9mm Dragged a little from its original position	14mm Dragged a little from its original position

FINAL OBSERVATIONAL NOTES

IMPACT TEST ON WHITE LAUAN (DOVETAIL JOINT)

Height	**No. of joint Dragged/Pulled-out/ruined**	**EXTEND OF DAMAGES** • Dragged a little from its original position • Detached /Pulled out from its original position • Broken/Ruined joint							
		Joint 1	**Joint 2**	**Joint 3**	**Joint 4**	**Joint 5**	**Joint 6**		
½ **meter**	**1**	5mm Dragged a little from its original position							
1 meter	**3**	6mm Dragged a little from its original position	3mm Dragged a little from its original position	2mm Dragged a little from its original position					
1 ½ meter	**4**	4mm Dragged a little from its original position	4mm Dragged a little from its original position	2mm Dragged a little from its original position	2mm Dragged a little from its original position				
2 meter	**8**	15mm Dragged a little from its original position	7mm Dragged a little from its original position	6mm Dragged a little from its original position	**7mm** Dragged a little from its original position	8mm Dragged a little from its original position	7mm Dragged a little from its original position	3mm Dragged a little from its original position	**4mm** Dragged a little from its original position

2 ½ meter	**5**	3mm Dragged a little from its original position	4mm Dragged a little from its original position	5mm Dragged a little from its original position	**5mm** Dragged a little from its original position	**4mm** Dragged a little from its original position			
3 meter	**4**	8mm Dragged a little from its original position	4mm Dragged a little from its original position	4mm Dragged a little from its original position	**2mm** Dragged a little from its original position				

PRELIMINARY OBSERVATIONAL NOTES

IMPACT TEST ON COCO (MORTISE AND TENON JOINT)

Height	No. of joint Dragged/ Pulled-out/ruined	**EXTEND OF DAMAGES** • Dragged a little from its original position • Detached / Pulled out from its original position • Broken/Ruined joint							
		Joint 1	**Joint 2**	**Joint 3**	**Joint 4**	**Joint 5**	**Joint 6**	**Joint 7**	
½ meter	3	1mm Dragged a little from its original position	2mm Dragged a little from its original position	2mm Dragged a little from its original position					
1 meter	6	6mm Dragged a little from its original position	6mm Dragged a little from its original position	2mm Dragged a little from its original position	4mm Dragged a little from its original position	5mm Dragged a little from its original position	2mm Dragged a little from its original position	2mm Dragged a little from its original position	
1 ½ meter	7	3mm Dragged a little from its original position	2mm Dragged a little from its original position	1mm Dragged a little from its original position	2mm Dragged a little from its original position	5mm Dragged a little from its original position	5mm Dragged a little from its original position		
2 meter	6	detached	6mm Dragged a little from its original position	14mm Dragged a little from its original position	6mm Dragged a little from its original position	9mm Dragged a little from its original position	9mm Dragged a little from its original position		
2 ½ meter	8	detached	detached	9mm Dragged a little from its	1mm Dragged a little from its	8mm Dragged a little from	4mm Dragged a little from		

				original position	original position	its original position	its original position		
3 meter	8	detached	detached	detached	4mm Dragged a little from its original position	1mm Dragged a little from its original position	8mm Dragged a little from its original position	6mm Dragged a little from its original position	2mm Dragged a little from its original position

FINAL OBSERVATIONAL NOTES

IMPACT TEST ON COCO (MORTISE AND TENON JOINT)

Height	**No. of joint Dragged/Pulled-out/ruined**	**EXTEND OF DAMAGES** • Dragged a little from its original position • Detached /Pulled out from its original position • Broken/Ruined joint							
		Joint 1	**Joint 2**	**Joint 3**	**Joint 4**	**Joint 5**	**Joint 6**	**Joint 7**	**Joint 8**
½ meter	2	4mm Dragged a little from its original position	2mm Dragged a little from its original position						
1 meter	5	14mm Dragged a little from its original position	9mm Dragged a little from its original position	5mm Dragged a little from its original position	4mm Dragged a little from its original position	2mm Dragged a little from its original position			
1 ½ meter	5	detached	2mm Dragged a little from its original position	2mm Dragged a little from its original position	3mm Dragged a little from its original position	3mm Dragged a little from its original position			
2 meter	4	detached	detached	3mm Dragged a little from its original position	**11mm** Dragged a little from its original position				

2 ½ meter	**6**	detached	detached	detached	**7mm** Dragged a little from its original position	11mm Dragged a little from its original position	**4mm** Dragged a little from its original position		
3 meter	7	detached	detached	detached	**detached**	8mm Dragged a little from its original position	**3mm** Dragged a little from its original position	5mm Dragged a little from its original position	

PRELIMINARY OBSERVATIONAL NOTES

IMPACT TEST ON COCO (DOVETAIL JOINT)

Height	**No. of joint Dragged/ Pulled-out/ruined**	**EXTEND OF DAMAGES** • Dragged a little from its original position • Detached /Pulled out from its original position • Broken/Ruined joint								
		Joint 1	**Joint 2**	**Joint 3**	**Joint 4**	**Joint 5**	**Joint 6**	**Joint 7**	**Joint 8**	**Joint 9**
½ meter	2	2mm Dragged a little from its original position	2mm Dragged a little from its original position							
1 meter	7	deatched	10mm Dragged a little from its original position	4mm Dragged a little from its original position	8mm Dragged a little from its original position	4mm Dragged a little from its original position	3mm Dragged a little from its original position	7mm Dragged a little from its original position		
1 ½ meter	4	6mm Dragged a little from its original position	11mm Dragged a little from its original position	13mm Dragged a little from its original position	3mm Dragged a little from its original position					
2 meter	7	detached	2mm Dragged a little from its original position	2mm Dragged a little from its original position	1mm Dragged a little from its original position	8mm Dragged a little from its original position	14mm Dragged a little from its original position	9mm Dragged a little from its original position		

2 ½ meter	7	detached	detached	detached	10mm Dragged a little from its original position	9mm Dragged a little from its original position	6mm Dragged a little from its original position	6mm Dragged a little from its original position		
3 meter	6	detached	detached	9mm Dragged a little from its original position	9mm Dragged a little from its original position	11mm Dragged a little from its original position	1mm Dragged a little from its original position			

FINAL OBSERVATIONAL NOTES

IMPACT TEST ON COCO (DOVETAIL JOINT)

Height	No. of joint Dragged/Pulled-out/ruined	EXTEND OF DAMAGES • Dragged a little from its original position • Detached /Pulled out from its original position • Broken/Ruined joint							
		Joint 1	**Joint 2**	**Joint 3**	**Joint 4**	**Joint 5**	**Joint 6**	**Joint 7**	**Joint 8**
½ meter	**1**	5mm Dragged a little from its original position							
1 meter	**3**	6mm Dragged a little from its original position	3mm Dragged a little from its original position	2mm Dragged a little from its original position					
1 ½ meter	**4**	4mm Dragged a little from its original position	4mm Dragged a little from its original position	2mm Dragged a little from its original position	2mm Dragged a little from its original position				
2 meter	**8**	15mm Dragged a little from its original position	7mm Dragged a little from its original position	6mm Dragged a little from its original position	**7mm** Dragged a little from its original position	8mm Dragged a little from its original position	7mm Dragged a little from its original position	3mm Dragged a little from its original position	**4mm** Dragged a little from its original position

2 ½ meter	**5**	3mm Dragged a little from its original position	4mm Dragged a little from its original position	5mm Dragged a little from its original position	**5mm** Dragged a little from its original position	**4mm** Dragged a little from its original position			
3 meter	**4**	8mm Dragged a little from its original position	4mm Dragged a little from its original position	4mm Dragged a little from its original position	**2mm** Dragged a little from its original position				

PRELIMINARY OBSERVATIONAL NOTES

IMPACT TEST ON GMELINA (MORTISE AND TENON JOINT)

Height	**No. of joint Dragged/ Pulled-out/ruined**	**EXTEND OF DAMAGES** • Dragged a little from its original position • Detached /Pulled out from its original position • Broken/Ruined joint							
		Joint 1	**Joint 2**	**Joint 3**	**Joint 4**	**Joint 5**	**Joint 6**	**Joint 7**	**Joint 8**
½ meter	**0**								
1 meter	**1**	6mm Dragged a little from its original position							
1 ½ meter	**6**	detached	detached	16mm Dragged a little from its original position	13mm Dragged a little from its original position	6mm Dragged a little from its original position	6mm Dragged a little from its original position		
2 meter	**4**	3mm Dragged a little from its original position	10mm Dragged a little from its original position	8mm Dragged a little from its original position	4mm Dragged a little from its original position				
2 ½ meter	**8**	4mm Dragged a little from its original position	4mm Dragged a little from its original position	4mm Dragged a little from its original position	4mm Dragged a little from its original position	2mm Dragged a little from its original position	2mm Dragged a little from its original position	2mm Dragged a little from its original position	2mm Dragged a little from its original position
3 meter	**7**	detached	10mm	10mm	13mm	13mm	6mm	7mm	

			Dragged a little from its original position	Dragged a little from its original position	Dragged a little from its original position	Dragged a little from its original position	Dragged a little from its original position	Dragged a little from its original position	

FINAL OBSERVATIONAL NOTES

IMPACT TEST ON GMELINA (MORTISE AND TENON JOINT)

Height	No. of joint Dragged/Pulled-out/ruined	EXTEND OF DAMAGES • Dragged a little from its original position • Detached /Pulled out from its original position • Broken/Ruined joint							
		Joint 1	**Joint 2**	**Joint 3**	**Joint 4**	**Joint 5**	**Joint 6**	**Joint 7**	**Joint 8**
½ meter	1	4mm Dragged a little from its original position							
1 meter	2	7mm Dragged a little from its original position	9mm Dragged a little from its original position						
1 ½ meter	6	detached	5mm Dragged a little from its original position	7mm Dragged a little from its original position	9mm Dragged a little from its original position	5mm Dragged a little from its original position	3mm Dragged a little from its original position		
2 meter	4	9mm Dragged a little from its original position	14mm Dragged a little from its original position	11mm Dragged a little from its original position	10mm Dragged a little from its original position				

2 ½ meter	**6**	detached	8mm Dragged a little from its original position	6mm Dragged a little from its original position	5mm Dragged a little from its original position	3mm Dragged a little from its original position	4mm Dragged a little from its original position		
3 meter	**6**	detached	detached	10mm Dragged a little from its original position	9mm Dragged a little from its original position	8mm Dragged a little from its original position	9mm Dragged a little from its original position		

PRELIMINARY OBSERVATIONAL NOTES

IMPACT TEST ON GMELINA (DOVETAIL JOINT)

Height	No. of joint Dragged/ Pulled-out/ruined	EXTEND OF DAMAGES • Dragged a little from its original position • Detached /Pulled out from its original position • Broken/Ruined joint							
		Joint 1	**Joint 2**	**Joint 3**	**Joint 4**	**Joint 5**	**Joint 6**	**Joint 7**	**Joint 8**
½ meter	2	10mm Dragged a little from its original position	4mm Dragged a little from its original position						
1 meter	3	15mm Dragged a little from its original position	4mm Dragged a little from its original position	4mm Dragged a little from its original position					
1 ½ meter	4	7mm Dragged a little from its original position	10mm Dragged a little from its original position	8mm Dragged a little from its original position	7mm Dragged a little from its original position				
2 meter	4	detached	9mm Dragged a little from its original position	7mm Dragged a little from its original position	6mm Dragged a little from its original position				
2 ½ meter	5	detached	detached	6mm Dragged a little from its original position	4mm Dragged a little from its	9mm Dragged a little from			

					original position	its original position			
3 meter	7	detached	detached	10mm Dragged a little from its original position	12mm Dragged a little from its original position	14mm Dragged a little from its original position	3mm Dragged a little from its original position	3mm Dragged a little from its original position	

FINAL OBSERVATIONAL NOTES

IMPACT TEST ON GMELINA (DOVETAIL JOINT)

Height	No. of joint Dragged/Pulled-out/ruined	EXTEND OF DAMAGES • Dragged a little from its original position • Detached /Pulled out from its original position • Broken/Ruined joint							
		Joint 1	**Joint 2**	**Joint 3**	**Joint 4**	**Joint 5**	**Joint 6**	**Joint 7**	**Joint 8**
½ meter	2	2mm Dragged a little from its original position	2mm Dragged a little from its original position						
1 meter	3	4mm Dragged a little from its original position	2mm Dragged a little from its original position	2mm Dragged a little from its original position					
1 ½ meter	4	10mm Dragged a little from its original position	10mm Dragged a little from its original position	9mm Dragged a little from its original position	2mm Dragged a little from its original position				
2 meter	5	detached	detached	2mm Dragged a little from its original position	**2mm** Dragged a little from its original position	8mm Dragged a little from its original position			

2 ½ meter	6	detached	10mm Dragged a little from its original position	10mm Dragged a little from its original position	**8mm** Dragged a little from its original position	**8mm** Dragged a little from its original position	**15mm** Dragged a little from its original position		
3 meter	7	detached	detached	detached	**10mm** Dragged a little from its original position	4mm Dragged a little from its original position	4mm Dragged a little from its original position	4mm Dragged a little from its original position	

CURRICULUM VITAE

Name	:	**MARDONIO TUBILLAS RIBO**
Sex	:	**Male**
Date of Birth	:	**July 22, 1978**
Place of Birth	:	**San Vicente, Catubig, Northern Samar**
Present Position	:	**Teacher III**
Civil Status	:	**Married**

EDUCATIONAL BACKGROUND

Elementary	:	**Catubig 1 Central School** Catubig, Northern Samar 1985-1991
Secondary	:	**Pedro Rebadulla Memoral Agricultural College (now UEP-Catubig)** Catubig, Northern Samar 1991-1995
Tertiary	:	**University of Eastern Philippines** Catarman, Northern Samar
Degree Course	:	**Bachelor of Science in Industrial Education** Major in Industrial Arts 1995-1999
Graduate Studies	:	**Samar State University** Catbalogan, City
Professional Studies	:	**Master in Technician Education** Major in Civil Technology 2016-2020

EMPLOYMENT

Teacher III	:	**Department of Education** Bobon School for Philippine Craftsmen, Bobon, Northern Samar

LIST OF TABLES

LIST OF FIGURES