ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25dec821

Analysis of Two-Side Wood Joints Using the European Yield Model (EYM) Method Referring to SNI 7973:2013

Nur Syamsia Djamhuri[1]; Gusti Made Oka[2]; Kusnindar A. Chauf[3]

[1,2,3]Department of Civil Engineering, Faculty of Engineering, Tadulako University, Central Sulawesi, Indonesia

Publication Date: 2025/12/27

Abstract: The connection is the most critical part in a wooden structure because it plays a direct role in transmitting forces between elements. This study analyzed the behavior of two Palapi wood (Heritiera simplicifolia.) joints using a single bolt based on the European Yield Model (EYM) method referring to SNI 7973:2013. The parameters reviewed included the physical properties of wood, mechanical properties, wood bearing strength, bolt flexural strength, and theoretical and experimental connection capacity. The test results showed an average water content of 11.50% and a density of 0.43 g/cm³. The average shear strength parallel to the grain reached 19.21 MPa, the compressive strength parallel to the grain was 25.63 MPa, and the wood bearing strength increased with increasing bolt diameter. Comparison of the theoretical EYM results and the experimental results showed a significant difference, mainly influenced by the failure of the wood bearing and the plastic deflection of the bolt. The results of this study are expected to be a reference in designing wood joints more safely and efficiently, especially for the use of local Palapi wood in construction.

Keywords: *Palapi Wood, Bolted Connection, European Yield Model, SNI 7973:2013, Wood Connection.*

How to Cite: Nur Syamsia Djamhuri; Gusti Made Oka; Kusnindar A. Chauf (2025) Analysis of Two-Side Wood Joints Using the European Yield Model (EYM) Method Referring to SNI 7973:2013. *International Journal of Innovative Science and Research Technology*,10(12), 1718-1731. https://doi.org/10.38124/ijisrt/25dec821

I. INTRODUCTION

Wood is a widely used construction material due to its high strength-to-weight ratio and its renewable resource. However, the main weakness of wood structures lies in the joints. Poorly designed joints can be the starting point for structural failure.

Palapi Wood (*Heritiera simplicifolia*.) is a local wood species widely used in Central Sulawesi, particularly in the furniture and light construction industries. Information on the mechanical characteristics and joint behavior of Palapi wood is still very limited. Therefore, this study aims to analyze the joint strength of two Palapi wood sections using a single bolt based on the method. *European Yield Model* (EYM) refers to SNI 7973:2013.

➢ *The Research Objectives Include:*

- Determining the physical and mechanical properties of Palapi wood.
- Analyze the strength capacity of the connection experimentally and theoretically.
- Identify the failure mode that occurred at the connection.

II. THEORETICAL BASIS

Wood is a natural building material that has been used for centuries in building construction. As a structural material, wood has several advantages, including high specific strength (strength-to-weight ratio), ease of shaping, and good thermal insulation properties. However, wood also has limitations, such as sensitivity to moisture, rot, and insect damage, all of which can affect the performance of a structure, including its joints.

➢ *Joint of Two Wooden Faces*

A two-piece wood joint is a joining technique involving three wooden elements, typically one main element and two side elements, connected using connecting tools such as bolts, nails, or dowels. This technique is commonly used in roof truss construction, beam-column connections, and truss connections.

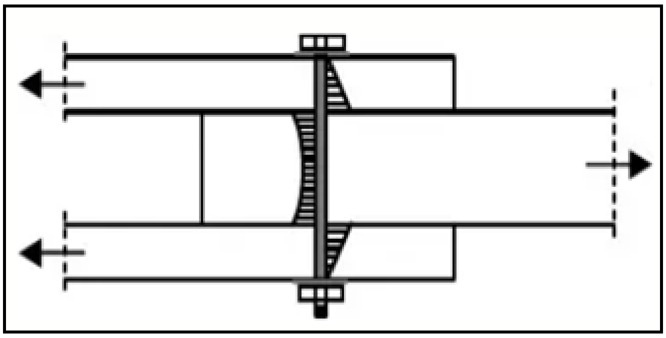

Fig 1 Two-View Method Wood Form

➢ *EYM (European Yield Model)*

European Yield Model (EYM) is a model developed in Europe (based on Johansen's theory) and is used to determine the shear capacity of wood joints with mechanical connectors (nails, bolts, screws). In the design of wood joints, a commonly used calculation approach is based on the European Yield Model (EYM), which identifies various failure modes of joints based on the characteristics of the joint and the wood.

➢ *Connection Failure Mode*

Failure modes of wood in two-section joints refer to the manner or form of failure that occurs when three wood elements are connected (e.g., with nails, screws, bolts, or joint plates), and the connection is subjected to loading until one or more of the components fails to withstand the load.

Table 1 Connection Failure Modes

Failure Mode	Description
I_m	Failure of the support on the main beam or the middle part of the wooden components and the connecting tools has not failed/is still elastic.
I_s	The failure of the support on the side beam of the wooden component and the connecting tool has not failed/is still elastic.
III_s	The failure of the support in the side timber is accompanied by one plastic hinge at the joint in one shear plane.
IV	The formation of two plastic joints in a joint in one shear plane.

(Source: NDS, 2018)

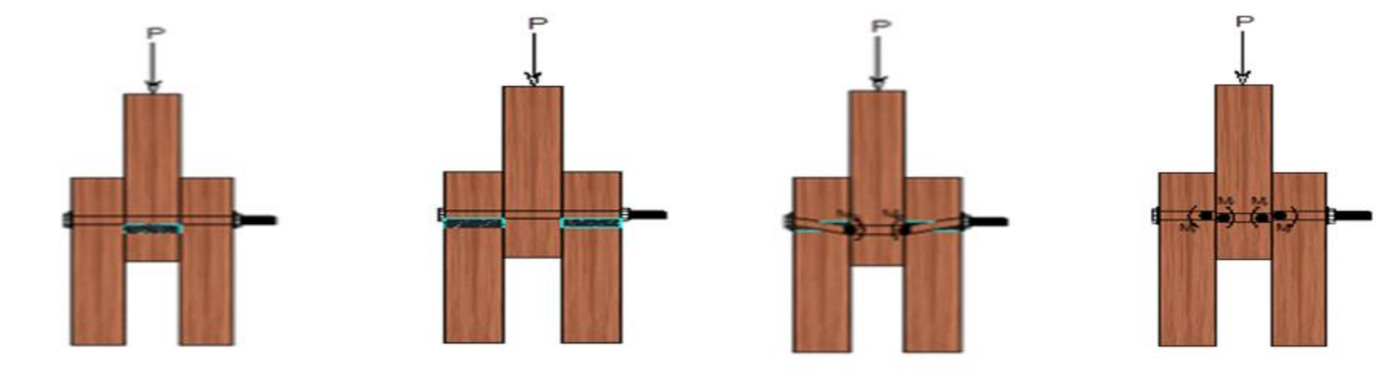

Fig 2 IM Failure Mode Fig 3 Failure Mode Is Fig 4 Failure Mode IIIs Fig 5 Failure Mode IV

Fig 2 Failure Mode

III. MATERIAL AND METHOD

➢ *Research Design*

Two-face timber design is a technique of joining three wooden structural elements to form a strong and stable connection. This connection is often used in the construction of wooden building frames such as trusses, beam-columns, or roof truss connections. Two-face timber design refers to the design of wooden beam elements with a square or rectangular cross-section analyzed in two primary dimensions: width and height. In the context of structural engineering, the term "two-face" emphasizes the importance of both cross-sectional dimensions in determining mechanical properties such as flexural strength, stiffness, and stability of the timber element.

➢ *Research Procedures*

- *Physical Properties of Wood*

Moisture content and density testing aims to determine the physical properties of wood that significantly affect the strength and behavior of joints. The data obtained is analyzed to understand the characteristics of the wood being tested and its relationship to quality standards and its use in the construction or industrial sector in accordance with the SNI 03-6850-2002 Testing Methods for Measuring Moisture Content in Wood and Woody Materials.

Water in wood consists of two forms: bound and free. Bound water is water found in the cell walls. Free water is found in the cell cavities. The amount of free water depending on the porosity and volume of the wood (Siau, 1971). In general, air-dried wood in Indonesia has a water content of between 12% -18%, or an average of 15%.

According to article 4.1.4 of SNI 7973-2013, the reference design values stipulated here apply to dry service conditions such as in closed structures, where the moisture content does not exceed 19%. Regardless of the moisture content at the time of implementation. For wood used in conditions where the moisture content of the wood exceeds 19%. For long periods of time, the design value must be multiplied by the wet service factor, C_m stipulated in. Soenardi (1978) stated that the main difference between density and specific gravity is that specific gravity is not unitary, while density is expressed in gr/cm3 or kg/m3. Soenardi (1978) divided the specific gravity of wood into 4 groups, namely:

- ✓ Very heavy wood (density > 0.90)
- ✓ Heavy wood (density 0.70-0.90)
- ✓ Medium wood (density 0.40-0.70)
- ✓ Light wood (density < 0.40).

The physical properties of palapi wood (Herritiera simplicifolia) show that the average fresh water content is (60.85%), the average dry water content is (18.43%), and the average density of Palapi wood is (0.41 gr/cm3). Natural durability tests show that Palapi wood is classified as durability classification class II (Durable).

$$MC\ (\%) = (W_{wet} - W_{dry}) / W_{dry} \times 100 \quad (1)$$

➢ *Mechanical Properties of Wood*

- *Parallel Grain Compressive Strength Test*

The test specimens for compressive strength parallel to the grain are divided into two parts, namely the test specimens for compressive strength parallel to the grain without nodes and with nodes. The shape and size of the test specimens follow the ISO-22157:2004 standard. The height of the test specimens for compressive strength parallel to the grain (H) is taken equal to the outer diameter of the wood. In making the test specimens, the positions taken are at the base, middle and end of the log. In taking the logs, they are selected randomly with the hope that the characteristics of the wood can represent the characteristics of the bamboo as a whole.

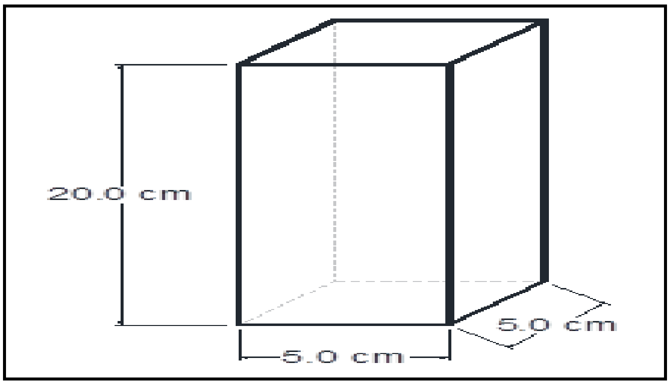

Fig 3 Dimensions of Samples of Compressive Strength Parallel to Grain

- *Perpendicular to Fiber Compressive Strength Test*

Wood is anisotropic, meaning its strength varies depending on the grain direction. Forces perpendicular to the grain (radial or tangential to the growth direction) are typically much weaker than those parallel to the grain. Therefore, this test is important for*predict*fiber splitting damage at joints, especially around dowel holes or bolted joints.

The tensile strength test perpendicular to the grain aims to determine the wood's resistance to tensile forces acting against the grain (transverse). This is particularly important in three-component joints, particularly those involving bolt tension against the wood surface.

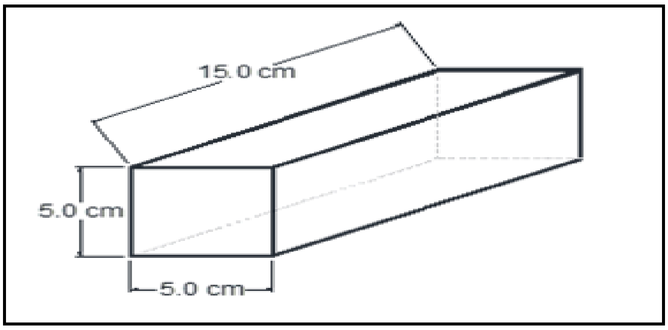

Fig 4 Perpendicular Compressive Strength Sample to Fiber

- *Flexural strength test*

Flexural strength testing is performed by indirectly loading the wood through a bending force, typically using the three-point bending test method. The force is applied at mid-span while both ends of the test piece are supported. The goal is to measure the maximum stress in the outer fibers that acts as the wood bends.

Flexural strength testing aims to determine the wood's ability to withstand bending loads (moments) before damage occurs. In the context of connecting two wooden sections, flexural properties are crucial because the wooden elements in the connection often experience loads that cause bending, particularly when used as beams or framing members.

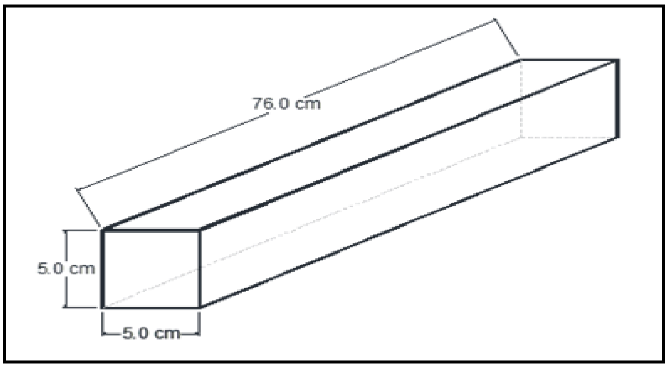

Fig 5 Flexural Strength Sample Dimensions

- *Wood Shear Strength Test*

The wood shear strength test is an important mechanical test for assessing the ability of wood to withstand shear forces parallel to the grain. This test aims to determine the maximum stress that can be sustained before failure occurs in the shear plane, which is very relevant for the design of joints, beams, and structural elements subjected to shear loads. The test method generally follows the SNI 03-3400-1994 standard, with block or cube-shaped specimens that have certain grooves or notches to ensure a controlled shear plane.

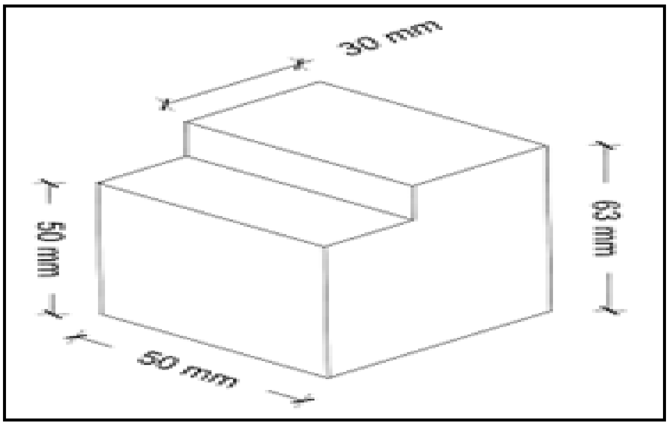

Fig 6 Shear Strength Parallel to Grain

- *Wood Support Strength Test*

Bearing strength of wood is the ability of wood to withstand pressure or loads applied to the contact area between the wood and other objects, such as bolts or dowels.

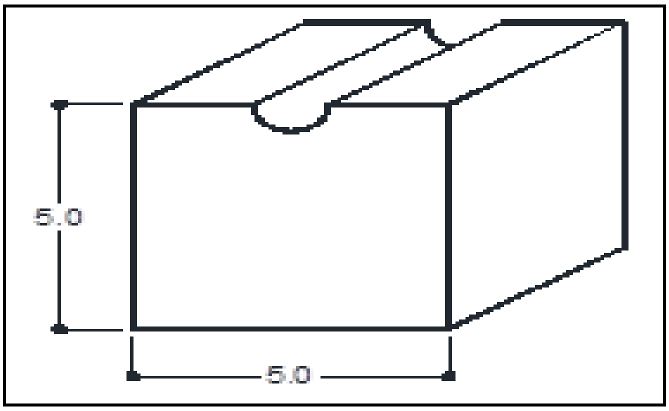

Fig 7 Half Hole Test Specimen

- *Flexural Test of Bolt Connection Tool*

The flexural strength of bolts is very important to ensure the safety and reliability of structures or components that use bolted connections.

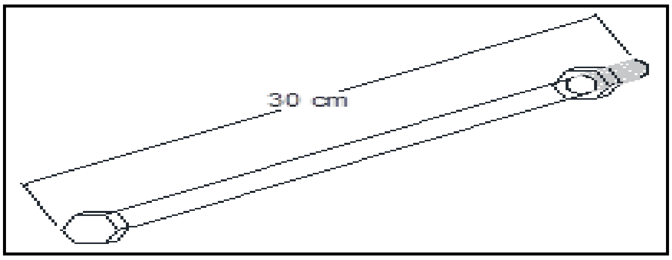

Fig 8 Bolts Diameter 16, 12 and 10 mm

$$F_{yb} = \frac{M_y}{S} \quad \text{……………………………………..} \quad (2)$$

Information:

Fyb = Flexural Strength of Bolt

My = Moment calculated based on the load obtained in the test (My= Py.L/4),

P = Load determined from load-deformation curve,
sbp =distance of support point)

S = Effective plastic section modulus for fully plastic hinge (S=D3/6, D=bolt diameter)

➢ *Testing Procedures*

The testing procedures carried out in this study are as follows:

- The test specimen is placed in the testing machine in a centric position and according to the set-up and the dial gauge is placed in its respective position.
- The load and measuring instrument are positioned at the initial load and measurement (zero)
- The load is applied at a specified point.
- The magnitude of the load and deflection is recorded at each loading stage.
- Load and deflection data are processed to determine the comparison of load capacity with variations in connection tools, percutaneous and loading.
- The processed results are presented in the form of tables, graphs and diagrams.

IV. RESULTS & DISCUSSION

➢ *Physical Properties of Palupi Wood*

- *Water Content and Density*

This formula shows the percentage of water mass contained in the wood relative to its oven-dry mass. For example, the calculation for sample U1, with a wet weight of 47.6g and a dry weight of 40.8g:

$$\mathbf{MC}(\%) = \frac{\mathbf{47.6-43.6}}{\mathbf{43{,}6}} \times \mathbf{100} = \mathbf{9{,}17\%} \quad \text{……………….} \quad (3)$$

Table 2 Results of Water Content and Density Tests

Sample	Wet Weight (g)	Dry Weight (g)	Volume (mm3)	MC Water Content (%)	Density
U1	47.60	43,60	125	9,17	0,35
U2	49.60	45,40	125	9,25	0,35
U3	46.60	43,00	125	8,37	0,33
T1	60.20	53,00	125	13,58	0,43
T2	66,00	59,00	125	11,86	0,47
T3	58.60	52,2	125	12,26	0,41
P1	60.60	55,00	125	10,18	0,44
P2	72.80	62.70	123	16.11	0,51
P3	72.80	62.60	118	16.29	0,55

- *The Range of Results Obtained is:*

✓ Lowest water level: 8.37%
✓ Highest water level: 16.29 %
✓ Lowest density: 0.33
✓ Highest density: 0.55

➢ *Mechanical Properties of Palupi Wood*

- *Shear Strength Parallel to Fiber*

The main parameters measured in this test are the fracture load (in Newtons) applied to the specimen until it cracks or splits at the shear plane, and the shear cross-sectional area (in mm²). The results of this calculation are expressed in megapascals (MPa), equivalent to N/mm². The shear strength (Fv) value is calculated using the formula:

$$Fv = \frac{P}{A} \quad (4)$$

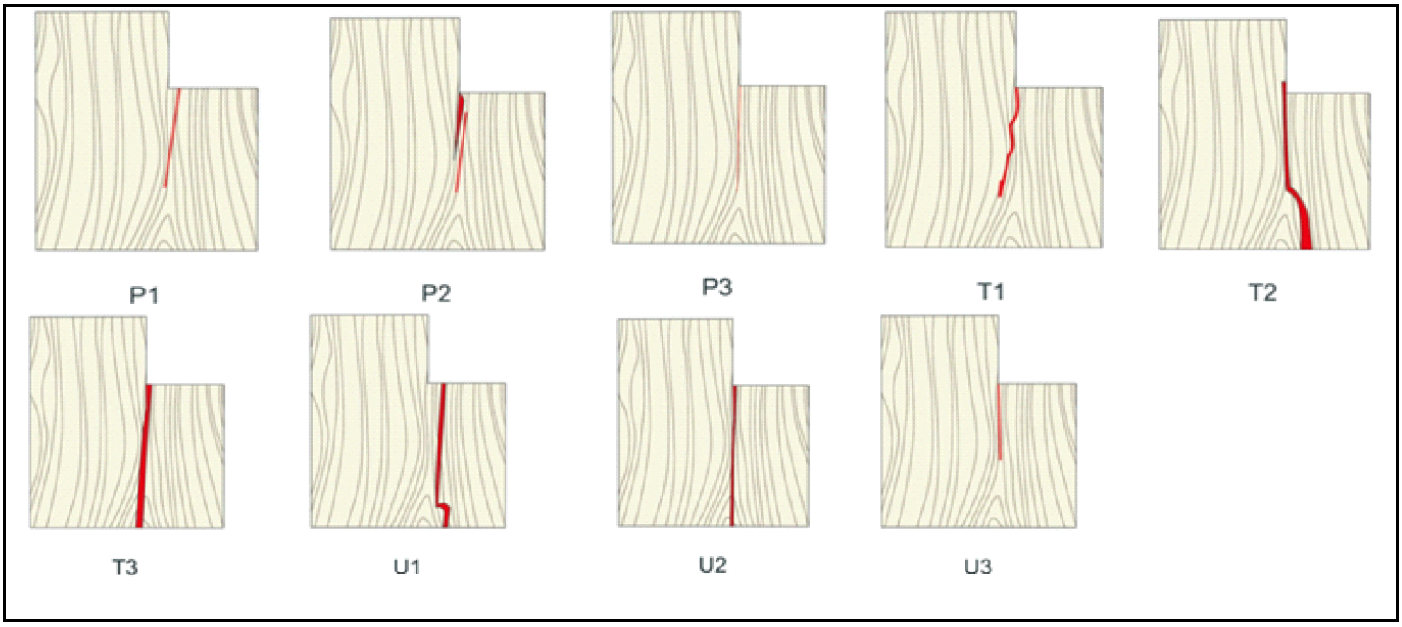

Fig 9 Crack Model on Shear Strength Test Sample

The following are the stages for calculating the results of the shear strength test:

Calculating the Shear Cross-Section Area (A) formula :

$$A = Lebar\ x\ Tinggi$$

$= 53 \times 49$

$= 2597$ mm²

Calculating the shear strength of wood against load:

$$F_v = \frac{Pembacaan\ Dial\ Beban\ pada\ Alat}{A} \quad F_v = \frac{5000}{2597}$$

$$F_v = 1{,}925 \text{ MPa}$$

Table 3 Results of data processing from wood shear strength testing.

Sample Code	Width (mm)	Height (mm)	Area (mm²)	Shear Load (N)	Shear Strength (MPa)
KGS U1	53	49	2597	5000	1,925
KGS U2	52	48	2496	5000	2,003
KGS U3	52	47,5	2470	5000	2,024
KGS T1	52	51	2652	5000	1,885
KGS T2	52	47	2444	5000	2,046
KGS T3	50,5	47	2373,5	5000	2,107
KGS P1	50	46	2300	10000	4,348
KGS P2	51	45	2295	10000	4,357
KGS P3	50,5	45	2272,5	10000	4,400

From the test results listed in the table above, varying shear strength values were obtained in nine wood samples grouped into three categories: U (U1–U3), T (T1–T3), and P (P1–P3). In the U group, the cross-sectional area ranged from 2470 to 2597 mm² with a relatively constant fracture load of 5000 N. The resulting shear strength values in this group ranged from 1.925 MPa to 2.024 MPa.

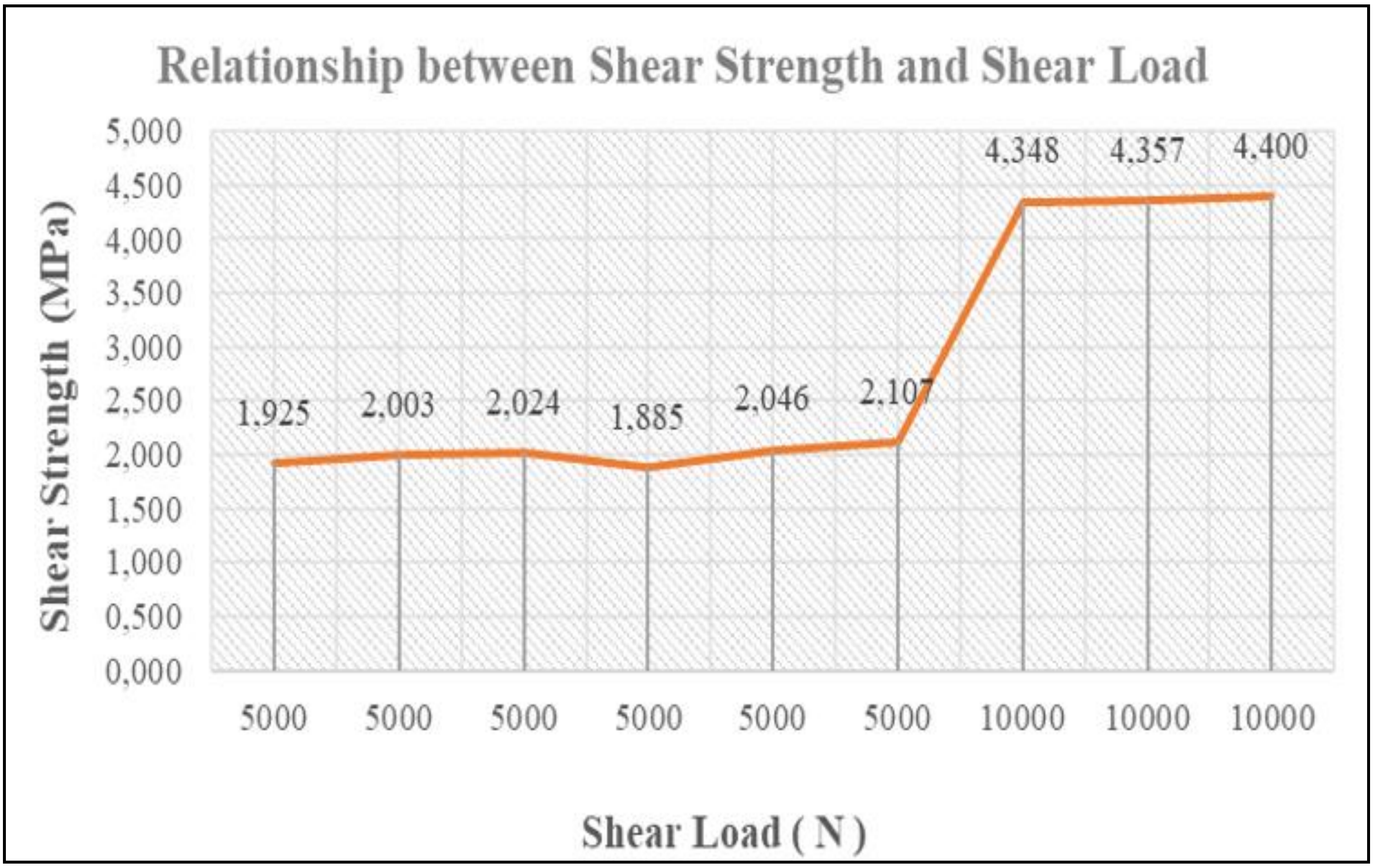

Fig 10 Graph of the Relationship Between Shear Strength and Shear Load

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25dec821

- *Strongly Press Along the Fibers*

Compressive strength parallel to grain according to*SNI 03-3958:1995*, the compressive strength parallel to the grain is calculated by the load per unit area of the compression surface.

$$f_c// = \frac{P}{b \times h}$$ .... (5)

Where:

fc// = compressive strength parallel to the fiber (MPa)

P = maximum compressive test load (N)

B = width of test object (mm)

H = height of test object (mm)

$$f_c// = \frac{Pembacaan\ Dial\ Beban}{b \times h}$$

$$= \frac{80000{,}00}{52{,}10 \times 50{,}00}$$

$$= \frac{80000{,}00}{2605{,}00}$$

$$f_c// = 30{,}71$$ N/mm²

After all the data is calculated using the same equation, it will then be arranged in a table to make it easier to read. In Table 4.4, you can see all the data processed from the data on the compressive strength test parallel to the wood fiber that has been carried out.

Table 4 Results of Data Processing from Compressive Strength Testing Parallel to Wood Grain

NO	Test Specimen Code	b (mm)	h (mm)	A (mm2)	Pressure P (N)	Voltage σ1 // (N/mm2)
				(b x h)		P/A
1	KTK P1 //	52,10	50,00	2605,00	80000.00	30,71
2	KTK P2 //	52,80	50,00	2640,00	80000.00	30,30
3	KTK P3 //	48,50	50,00	2425,00	55000.00	22,68
4	KTK T1 //	51,33	50,00	2566,67	65000.00	25,32
5	KTK T2 //	51,67	50,00	2583,33	70000.00	27,10
6	KTK T3 //	50,33	50,00	2516,67	60000.00	23,84
7	KTK U1 //	50,48	50,00	2524,00	50000.00	19,81
8	KTK U2 //	50,90	50,00	2545,00	70000.00	27,50
9	KTK U3 //	51,20	50,00	2560,00	60000.00	23,44

- *Compressive Strength Perpendicular to Fiber*

Perpendicular compressive strength of the fiber $\frac{P}{b \times h}$ According to SNI 03-3958:1995, the perpendicular compressive strength of the fiber is calculated using the load per unit of area of pressure area.

Fc ⊥ = …..................................... (6)

Where

fc⊥ = compressive strength perpendicular to the grain (MPa)

P = maximum compressive test load (N)

B = width of test object (mm)

H = height of test object (mm)

$$f_c\perp = \frac{Pembacaan\ Dial\ Beban}{b \times h}$$

$$= \frac{40000{,}00}{52{,}10 \times 50{,}00}$$

$$= \frac{80000{,}00}{2605{,}00}$$

$$f_c\perp = 15{,}36$$ N/mm²

After all the data is calculated using the same equation, it will then be arranged in a table to make it easier to read. In Table 4.5, you can see all the data from the processing results of the wood fiber perpendicular compressive strength testing data that has been carried out.

Table 5 Results of Data Processing from Perpendicular Compressive Strength Testing of Fibers

NO	Test Specimen Code	b (mm)	h (mm)	A (mm2)	P (N)	σ1 ⊥ (N/mm2)
				(b x h)		P/A
1	KTK P1⊥	52,10	50,00	2605,00	40000.00	15,36
2	KTK P2⊥	51,67	50,00	2583,33	20000.00	7,74
3	KTK P3⊥	51,13	50,00	2556,67	10000.00	3,91
4	KTK T1⊥	50,63	50,00	2531,67	5000.00	1,97
5	KTK T2⊥	51,00	50,00	2550,00	5000.00	1,96
6	KTK T3⊥	50,67	50,00	2533,33	5000.00	1,97
7	KTK U1⊥	52,10	50,00	2605,00	5000.00	1,92
8	KTK U2⊥	51,67	50,00	2583,33	5000.00	1,94
9	KTK U3⊥	51,13	50,00	2556,67	5000.00	1,96

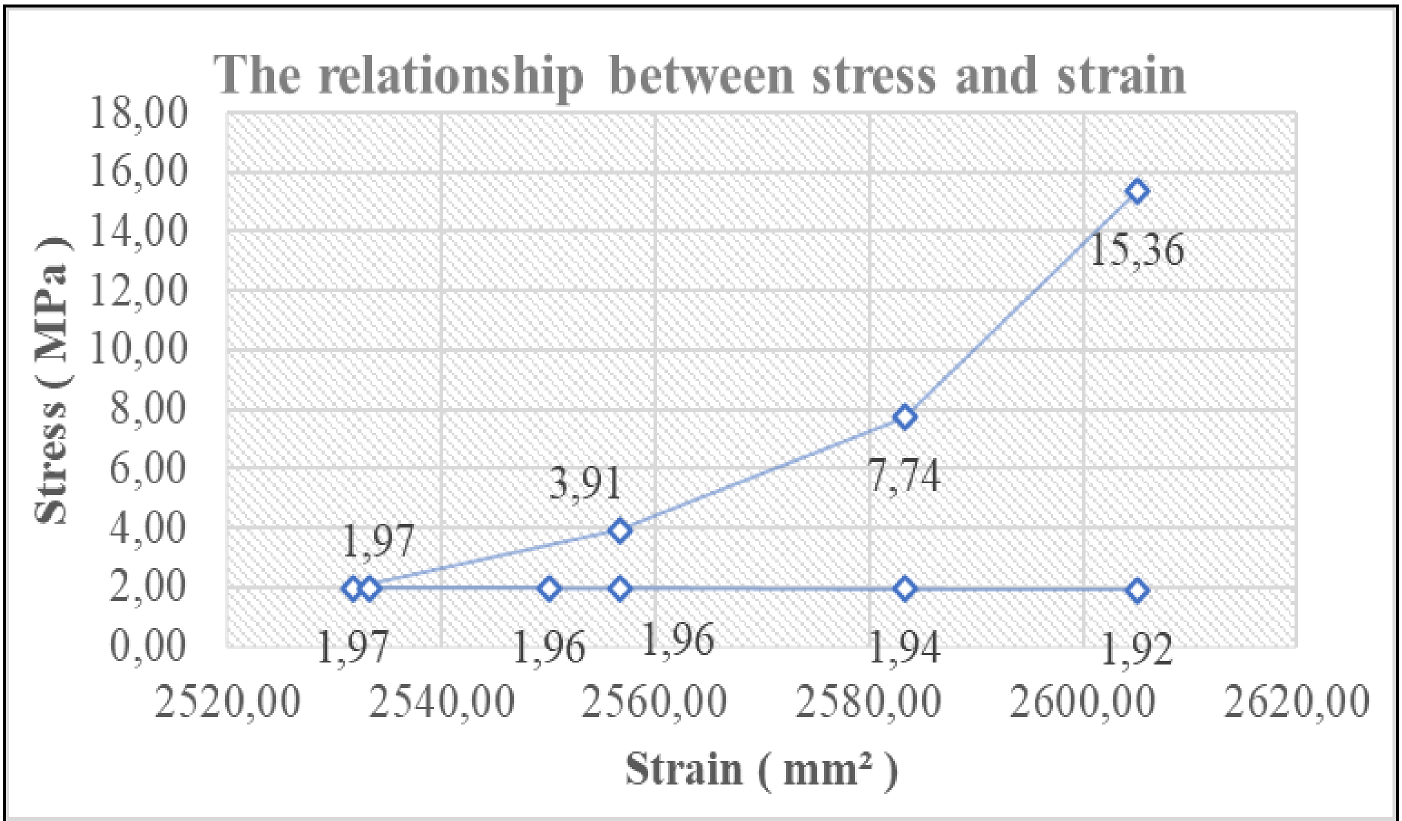

Fig 11 The Relationship Between Stress and Strain in Perpendicular Compressive Strength Testing

- *Wood Flexural Strength*

According to SNI 03-3959:1995, the flexural strength of the test object is calculated using the formula:

$$fb = \frac{3PL}{2b \ x \ h^2} \quad (7)$$

Where:

fb = flexural strength (MPa)

P = maximum flexural test load (N)

L = focal length (mm)

b = width of test object (mm)

h = height of test object (mm)

$$fb = \frac{3 \ x \ Beban \ uji \ x \ Jarak \ Tumpuan}{2b \ x \ h^2}$$

$$= \frac{3 \ x \ 8000 \ x \ 710}{2 \ x \ 51{,}78 \ x \ 51{,}78^2}$$

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25dec821

$$= \frac{18240000,00}{277661,7995}$$

$$fb = 61,37 \quad N/mm^2$$

After all the data is calculated using the same equation, it will then be arranged in a table to make it easier to read. In Table 4.6, you can see all the data from the processing results of the wood flexural strength testing data that has been conducted.

Table 6 Results of Analysis of Wood Flexural Strength Test Data

NO	Test Specimen Code	B (mm)	H (mm)	P (N)	L (mm)	σ_1 (fb) (N/mm^2)
1	KRL1 (P)	51,78	51,78	8000	710,00	61,37
2	KRL2 (P)	51,17	51,37	6600	710,00	52,05
3	KRL3 (P)	51,35	50,62	7000	710,00	56,66
4	KRL1 (T)	52,40	52,83	5500	710,00	40,05
5	KRL2 (T)	51,17	50,73	6400	710,00	51,76
6	KRL3 (T)	51,17	50,73	5500	710,00	44,48
7	KRL1 (U)	51,50	50,80	5700	710,00	45,68
8	KRL2 (U)	51,03	51,07	7500	710,00	60,01
9	KRL3 (U)	47,87	48,87	4600	710,00	42,85

Based on the results of the flexural strength test of wood on 9 specimens:

Flexural Strength (σ_1):

- ✓ Rate-rate = 50.55 N/mm^2
- ✓ Maximum = 61.37 N/mm^2
- ✓ Minimum = 40.05 N/mm^2

Overall, the test wood demonstrated a good average flexural strength of 50.55 N/mm^2, although there was variation between specimens due to differences in deflection. The maximum value of 61.37 N/mm^2 in the specimen at the base of the wood indicates the potential for selecting wood based on its quality class for structural applications.

- *Bearing Strength and Flexural Strength of Bolt Connection Tools*

Tests were conducted on wood samples drilled with varying hole diameters (10 mm, 12 mm, and 16 mm), and subjected to loads parallel to the surface but perpendicular to the grain. The bearing strength value was calculated using the following formula:

$$fe = \frac{P}{A} \quad \text{(8)}$$

$$fe = \frac{P}{d \times b}$$

with:

Fe = compressive strength (MPa)

P = maximum load during test (N)

A = cross-sectional area of contact between the test tool and the specimen (mm^2)

d = diameter (mm)

b = width (mm) (contact length/bearing area = d × b gives the bearing cross-sectional area in mm^2)

The cross-sectional area is calculated between the Width of the Test Specimen (l) times the Half Hole Diameter (d) and the maximum load is constant at 20000 N, with the Bearing Strength Unit MPa or N/mm.

The calculation is taken on the sample with code KTP-01:

$$fe = \frac{20000}{50 \times 10} = 40,00\ MPa$$

$$fe = \frac{20000}{500} = 40,00\ MPa$$

Meanwhile, in the flexural strength test of bolts*(Fyb)*obtained from primary data through experimental testing. Bolt flexural strength testing follows the standards*ASTM D189* (*ASTM*,2007). The standard span length is taken as 11.5 x D (bolt diameter). The bolt flexural strength testing method uses the three-point bending method. The bolt flexural strength testing and the various variations in bolt flexural yield are shown in Figure 4.11.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25dec821

Fig 12 Bolt Flexural Yield Strength Testing

Tests were conducted on wood joints with bolt diameter variations of 10mm, 12mm, and 16mm, each of which had a fixed length of 300mm, equivalent to 11.5 times the diameter (L = 11.5D). The purpose of this test was to determine the magnitude of the yield force (*Py*) and the yield moment (*My*) on each specimen, which is calculated using the formula:

$$My = \frac{1}{4}\ x\ Py\ x\ L \qquad (9)$$

- ✓ *Strong Bending Tool Diameter 16*

$$My = \frac{1}{4}\ x\ 5370\ x\ 184 = 247020{,}00\ N.mm$$

The yield moment value for a diameter of 16mm is in the range. Diameter 16mm produces a yield moment between 224480.00 – 257600.00N·mm.

- ✓ *Strong Bending Tool Diameter 12*

For a 12-diameter bolt (300mm length), the yield force is relatively uniform at 3240–3260N.

$$My = \frac{1}{4}\ x\ 3240\ x\ 138 = 111780{,}00\ N.mm$$

The 12mm diameter is in the range of 111780.00 – 112470.00N·mm.

- ✓ *Bending Strength of Connecting Tool Diameter 10*

A 10mm diameter bolt with a length of 300mm shows a yield force of about 1890–1970N.

$$My = \frac{1}{4}\ x\ 1950\ x\ 115 = 56062{,}50\ N.mm$$

Diameter 10mm in the range of 54337.50 – 56637.50N·mm.

- ➢ *Two-View Joint Testing*

The results show that the larger the bolt diameter, the higher the yield strength. Bolts with a diameter of 16 mm demonstrated the highest performance in resisting bending loads, followed by bolts with diameters of 12 mm and 10 mm.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25dec821

Fig 13 Testing the Joint of Two Wood Sections

The following is a calculation to obtain a value using a formula according to the failure mode.

Information :

D = diameter (mm)

Fyb = flexural strength of the post (MPa)

Rd = reduction condition

Re = Let's/ Let's do

Rt = lm /ls

Lm = length of the pin support on the main structural component (mm)

Ls = length of the dowel support on the side structural component (mm)

Five = bearing strength of the post on the main structural component (MPa)

Fes = bearing strength of the post on the side structural component (MPa)

- *The Calculation of the Lateral Value for the SKBU 16 Test Object is:*

Measured diameter = 16 mm

Main wood thickness (ℓ_m) = 15 mm

Thickness of side wood (ℓ_s) = 15 mm

$$Fe^{\perp} = 185 \times G^{1{,}45} / \sqrt{D}$$

$$= 185 \times 0{,}358^{1{,}45} / \sqrt{16}$$

= 10,45 MPa

Strong support for the main tree (F_{em}) = 10,45 MPa

Strong support for the main tree (F_{es}) = 10,45 MPa

$$R_e = \frac{F_{em}}{F_{es}} = \frac{10{,}45}{10{,}45} R_e = \frac{F_{em}}{F_{es}} = \frac{10{,}45}{10{,}45} = 1$$

Reduction value for SKBU 16 test specimen with measured diameter≤≤ 16 mm :

$$K_\theta = 1 + 0{,}25\left(\frac{\theta}{90}\right)$$

$$K_\theta = 1 + 0{,}25\left(\frac{90}{90}\right)$$

$$= 1{,}25$$

$$R_d = 4 \times R_\theta$$

$$= 4 \times 1{,}25$$

$$= 5$$

Im failure mode :

$$Z = \frac{D \ell_m F_{em}}{R_d}$$

$$Z = \frac{16 \times 15 \times 10{,}45}{5}$$

= 501,53 N

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25dec821

Table 7 Comparison of Failure Modes in Two-Face Wood Joints

Test Item Code	Diameter, D (mm)	Lateral Resistance, Fe (MPa)	Reduction Factor, Re	Fyb (MPa)	Z (N)	Failure Mode
SKBU 10	10	14,45	1	871,50	2005,88	IV
SKBU 12	12	13,20	1	845,49	2978,44	IV
SKBU 16	16	10,45	1	580,44	501,53	Im
SKBT 10	10	20,99	1	871,50	2417,47	IV
SKBT 12	12	21,15	1	845,49	3770,55	IV
SKBT 16	16	15,00	1	580,44	719,96	Im
SKBP 10	10	20,56	1	871,50	2392,48	IV
SKBP 12	12	25,11	1	845,49	4108,10	IV
SKBP 16	16	23,07	1	580,44	1107,52	Im

It is known that the theoretical value has been calculated and taken based on the EYM calculation and entered in table 5 Theoretical Shear Strength, and Experimental Shear Strength is taken from the maximum load value on the tool. The calculation of the difference in the comparison of theoretical and experimental values is:

Experimental Value =Maximum Load Value – Max Shear Test Value

= 20.700 – 10.000

= 10.700 N

Theoretical Value= Maximum Load Value – EYM Value

= 20.700 – 2392,48

= 18307,52 N

Percentage Calculation Using the Formula:

$$\text{Efficiency Ratio } (\%) = \frac{\textbf{Nilai Eksperimen/Teoritis}}{\textbf{Nilai Beban Maksimum}} \textbf{ x 100\%}$$

$$\text{Efficiency Ratio } = \frac{\textbf{10700}}{\textbf{20700}} \textbf{ x 100\%}$$

$$= \textbf{51.70 } \%$$

After all the data is calculated using the same equation, it will then be arranged in a table to make it easier to read. In Table 4.11, you can see all the data from the processing results of the test data that has been carried out.

Table 8 Theoretical and Experimental Comparison of Two-Section Joints

Code	Experimental Value	Theoretical Value (N)	Percentage of Experiments (%)	Theoretical Percentage (%)
SKBP 10	10700	18307,52	51.70%	81.30%
SKBP 12	12500	18391,90	55.60%	73.10%
SKBP 16	14500	23392,48	59.20%	95.10%
SKBT 10	15500	18082,53	75.60%	81.30%
SKBT 12	17000	18229,45	77.30%	74.70%
SKBT 16	21750	26030,04	81.70%	76.20%
SKBU 10	14500	17494,12	74.40%	83.40%
SKBU 12	23700	25721,56	80.70%	84.50%
SKBU 16	22600	27098,47	81.90%	98.20%

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25dec821

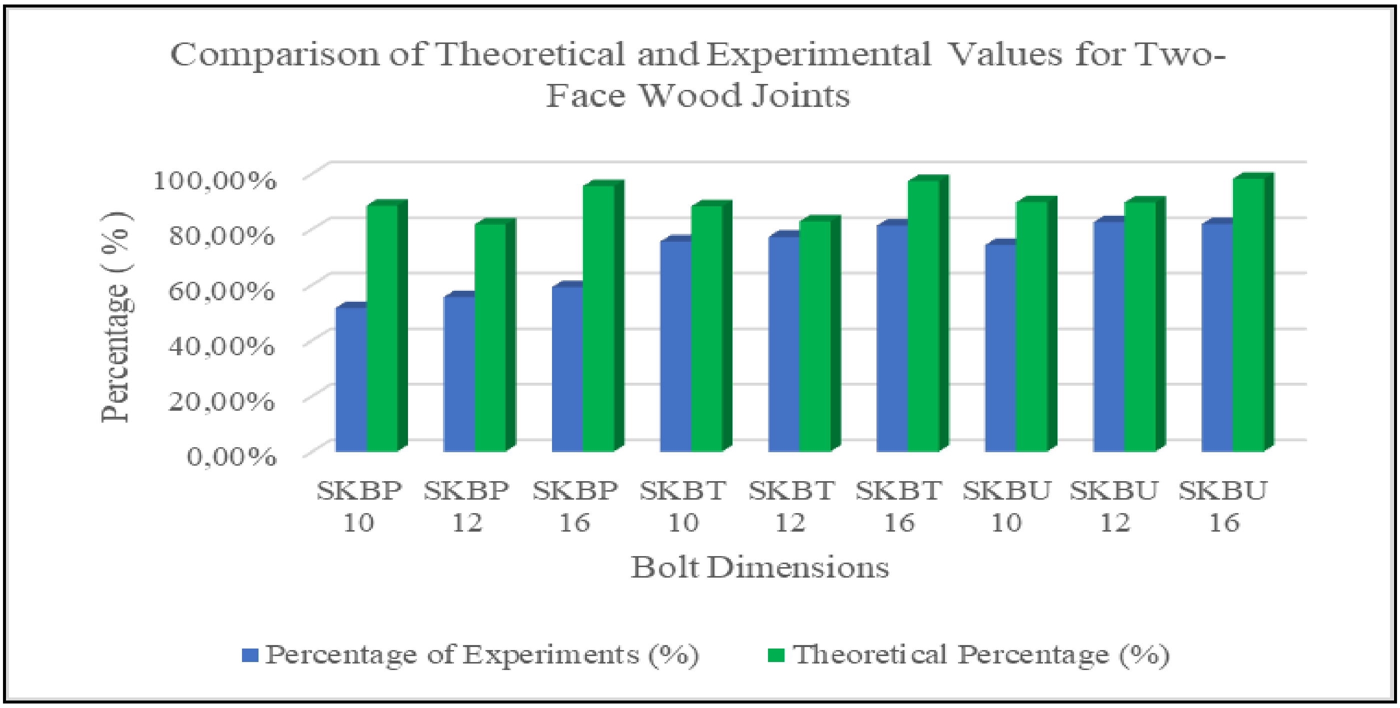

Fig 14 Comparison Chart of Theoretical and Experimental Values for Two-Face Wood Joints

The Percentage Difference of Theoretical and Experimental specimens shows that the percentage of experimental results is always lower than the theoretical value when compared to the maximum load considered as 100%. However, the average percentage difference between experimental and theoretical values ranges from 20% to 40%, which indicates the contribution of other factors beyond the theoretical assumptions of EYM—such as friction between wood surfaces, variations in stress distribution, or joint stiffness.

V. CONCLUSION AND SUGGESTIONS

➢ *Conclusion*

This study shows that Palapi wood has physical and mechanical characteristics suitable for light structural applications, with a moisture content of 8.37–16.29% and a density of 0.33–0.55 g/cm³. Its mechanical properties are in the range of medium-grade tropical woods, with a shear strength of 17.04–22.54 MPa and a bearing strength of 15–20 MPa. The results of the test of two-section joints indicate that the bolt diameter and the position of the member sections affect the joint capacity. The base section showed the strongest performance, while the middle and end sections were more susceptible to longitudinal crack failure. Comparison between the experimental results and the EYM calculations showed that the EYM model tends to be conservative with a difference of 20–40%. The SKBU connection type has the best force transfer efficiency, while the SKBP has the lowest capacity.

➢ *Suggestion*

The use of butt wood for structural connections is recommended due to its higher mechanical capacity. Larger bolt diameters can increase connection strength, but minimum edge spacing should still be considered to prevent longitudinal cracking. A correction of approximately 30–35% to the theoretical EYM results is recommended to bring the design predictions closer to the actual capacity. Additional drying is required for wood with a moisture content above 18%. Further research is needed to review multi-bolt connections, the influence of environmental conditions, and numerical modeling of Palapi wood connections.

REFERENCES

[1]. Fakhri., Satyarno, I., Haji Gusstafri., Yohanes, A., 2016, Increasing Shear Strength of Wooden Structure Joints Using a Combination of Glue-Bolts Connection Type, Jurnal Inertia Teknik Sipil, Vol. VIII No. 2, September 2016, Riau.
[2]. Eman Christianto, Budisetyono T., Ruslan Dj, Comparison of Wood Connection Planning with Bolts and Nails Based on SNI 7973:2013, Jurnal Dimensi Pratama Teknik Sipil, Surabaya, East Java.
[3]. Ayubi, K., A., A., 2020, Study of Bolt Usage on Teak Wood Plastic Composite (WPC) with Two Slice Shear Method, Thesis, Tidar University, Magelang.
[4]. Dahlan, M., S., 2013, Statistics for Medicine and Health, 5th Edition, 3rd Printing, Salemba Medika, Jakarta.
[5]. Darmawan, A., 2022, Lateral Resistance Capacity of Sengon Wood with Fiberglass Dowel Joint, Thesis, Tidar University, Magelang.
[6]. Ginting, A., 2007, The Effect of Water Content and Distance Between Nails on the Strength of Coconut Wood Joints, Department of Civil Engineering 3(1), Faculty of Engineering, Maranatha Christian University, Bandung.
[7]. Hazmi, H., A., 2018, Lateral Connection Capacity of Sengon Wood with Teak Wood Plastic Composite

(WPC) Dowel Connection Tool, Thesis, Tidar University, Magelang.
[8]. Megasari, S., W., Winayati, 2017, Analysis of the Effect of Adding Sikament-NN on Concrete Characteristics, Journal of Civil Engineering Cycle Vol. 3 No. 2, Lancang Kuning University, Pekanbaru.
[9]. Sucahyo Sadiyo, Imam Wahyudi, Fengky Satria Yoresta, Nurhasanah and Muhammad Sholihin, Analysis of Double Shear Joint Strength of Six Types of Wood at Various Faults According to Diameter and Number of Bolts., Perennial Journal, 2012 Vol. 8 No. 2: 52-61, Bogor Agricultural University, Bogor.
[10]. Elmi N. S Analysis of the Strength of Two-Face Connections on MDF Using WPC Dowel Jointing Tools, Teknisia scientific journal volume 27 number 2 pages 103-1122022
[11]. Wijanarko, Study of Bolt Usage in Wood Plastic Composite (WPC) with Double Shear Connections Method, Tidar University Thesis, Magelang.
[12]. I Ketut Sulendra, Study of retrofitting wooden roof truss joints, Dissertation, Tadulako University, Palu
[13]. (BSN) National Standards Agency (2013). SNI 7973:2013 Design specifications for wood construction.
[14]. (BSN) National Standards Agency (2002). SNI 03-6850-2002 Testing and Measurement of Water Content, Wood and Woody Materials.
[15]. (BSN) National Standards Agency (1994) SNI 03-3400-1994 Explains the method of testing the shear strength of wood in the laboratory.
[16]. (BSN) National Standards Agency (1995). SNI 03-3958-1995 Laboratory Method for Testing Wood Compressive Strength.
[17]. (BSN) National Standards Agency (1995). SNI 03-3960-1995 Testing Method for Flexural Elastic Modulus of Wood in the Laboratory.
[18]. ASTM D5764-97a. (2002). Standard Test Method for Evaluating Dowel-Bearing Strength of Wood and Wood Based Product. West Conchohocken: ASTM International.
[19]. National Design Specification for Wood Contruction (NDS) 2018 National Design Specification, Edition, Leesburg: America Wood Council.