Analysis of Mechanical Properties of Timber Materials

Darmono, Faqih Ma’arif, Slamet Widodo, Sidik Pamungkas

Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

Abstract. This study aims to conduct the value of modulus of rupture (MOR) and modulus of elasticity (MOE) where the flexural strength is one of the highest mechanical properties compared with other mechanical properties. The method used is a flexural strength test using a three-point loading test, whereas for specific gravity and moisture content using the drill method. The materials used in this study are Bangkirai, Teak, Camphor, Sukun, and Coconut wood. The results of this study indicate that the moisture content is directly proportional to the value of MOR and MOE, except for the MOE of Coconut wood. The specific gravity is linear with MOE, except for MOR and MOE (coconut and teak wood).

1. Introduction

To preserve wood, complying the needs of wood, engineering and development of technology in the field of timber are necessary. It gives the consequence that there must be an appropriate method to streamline and optimize the use of wood, especially in the application of building structures, without ignoring the construction requirements. For this reason, data needed on the characteristics of wood, especially its mechanical properties.

Wood originating from various types of trees has different properties. Even wood from one tree has different properties compared to the end with its base. In timber technology, deep knowledge is needed in the use of wood as a structural component. Therefore, the use of wood must be truly effective and optimal with high efficiency, namely using low-quality wood which is varied with high-quality wood.

Flexural strength is one of the highest mechanical properties when compared to other mechanical properties such as tensile strength, compressive strength, and shear strength. Due to the high flexural strength and small density, it widely used for bending elements in structures such as beams and girders [1].

The flexural strength and elastic modulus of each type of wood are different. By considering the physical and mechanical aspects, it is necessary to have experimental research on the performance of flexural strength on timber to obtain the value of flexural strength and modulus of elasticity of each type of wood so that the community can choose the variety of wood more accurately and efficiently.

2. Method

Following the provisions of [2], testing is carried out using the three-point loading, it is a test with a single load, specifically mind-span, while for testing specific gravity and moisture content using the drill method.
In this study, the specimens used were variations in the types of Teak, Yellow Ballau, Camphor, Coconut, and Sukun with 50 mm x 50 mm x 760 mm in dimensions. The specimens are 15 pieces of 5 different types of wood. The tools used in this study were calipers, split saws, planers, cut saws, vertical saws, drilling machines, chisels, ovens, scales, and tensile strength testing instruments namely Universal Testing Machine (UTM).

3. Results and Discussions

3.1. Modulus of Rupture (MOR)

The test results for modulus of rupture are presented in Figure 1 below.

![Figure 1. Comparison of MOR values between variants](image)

The test results of a modulus of rupture for Teak, Yellow Ballau, Camphor, Coconut, and Sukun were 91.31 N/mm², 115.22 N/mm², 76.65 N/mm², 32.89 N/mm², and 65.90 N/mm² respectively. Yellow Ballau has the largest modulus of rupture meanwhile Sukun has the smallest MOR value. According to [3] regarding the classification of strength on wood can be seen in Table 1 as follows:

| Wood type    | MOR (N/mm²) | Strength classes |
|--------------|-------------|------------------|
| Teak         | 91.31       | II               |
| Yellow Ballau| 115.22      | I                |
| Camphor      | 76.65       | II               |
| Coconut      | 32.89       | III              |
| Sukun        | 65.90       | V                |

From Table 1 it is known that Yellow Ballau is included in the Strength class I, while Teak and Camphor included in the Strength class II. Coconut involved in the Strength class III, and Sukun involved in the Strength class V.

Based on [3] Bangkirai is included in class II, because it has class I. This material is good for heavy construction, resistant to bad influences, such as continuous on the ground, or heat from the sun, rain, and wind.

Teak and Camphor are used in class II because they have strength class II, they are good for heavy construction, are always badly affected, such as: continuously in the ground or exposed to the sun, rain, and wind.
Coconut with strength III class included in class III usage, the wood is good for heavy protected construction under the roof and not related to wet soil. Sukun with a strength class V entered in class V; the wood is good for non-permanent construction.

3.2. Modulus of Elasticity (MOE)

The test results of modulus of elasticity are presented in Figure 2 below.

![Figure 2. Modulus of elasticity each variant](image)

The modulus of elasticity of Teak, Yellow Ballau, Camphor, Coconut, and Sukun were the results 9316.47 N/mm², 12925.95 N/mm², 5865.52 N/mm², 8839.75 N/mm², and 3039.94 N/mm², respectively. Yellow Ballau has the largest modulus of elasticity while Sukun has the smallest one. According to the [4], the strength value (MPa) based on mechanical sorting at 15% moisture content in the variation of the specimen [4]. The modulus of elasticity based on [3] is presented in Table 2.

| Type of wood | MOE (experiments) | Code | Ew | Fb/MOR |
|--------------|-------------------|------|----|--------|
| Teak         | 9316.47           | E10  | 9000 | 20     |
| Yellow Ballau| 12925.95          | E13  | 12000| 27     |
| Camphor      | 5865.52           | -    | -   | -      |
| Coconut      | 8839.75           | -    | -   | -      |
| Sukun        | 3039.94           | -    | -   | -      |

Table 2. Modulus of elasticity based on RSNI 2002 [4]

Based on Table 2 show that the class of Teak and Yellow Ballau are E10 and E13 with the modulus of rupture of 20 MPa and 27 MPa. Nevertheless, the class of Camphor, coconut, and Sukun not included in the [4].

Table 2 used 15% moisture content, whereas the moisture content in the experiment used under 15%. Therefore, the strength of the references was different. [4] was use as a reference through experimental testing. The test results of the experimental presented in Table 3.

| E/MOE from experiment (N/mm²) | Fb/MOR (N/mm²) |
|-------------------------------|---------------|
| 9316.47                       | 91.31         |
| 12925.95                      | 115.22        |
| 5865.52                       | 76.65         |
| 8839.75                       | 32.89         |
| 3039.94                       | 65.9          |

Table 3. MOE and MOR value from experiment test
Table 2 used 15% moisture content, whereas the moisture content in the experiment used under 15%. Therefore, the strength of the references was different. [4] used as a reference through experimental testing. The preliminary test of the specimen presented in Table 3.

3.3. Effect of physical properties on mechanical properties

The modulus of rupture (MOR) and modulus of elasticity (MOE) will influence to the physical characteristics of wood such as moisture content and specific gravity — physical properties and modulus of rupture presented in Table 4.

| Type of wood | Moisture content (%) | Specific gravity | MOE (N/mm²) | MOR (N/mm²) |
|--------------|-----------------------|------------------|-------------|-------------|
| Teak         | 7.22                  | 0.45             | 9316.47     | 91.31       |
| Yellow Ballau| 7.62                  | 0.76             | 12925.95    | 115.22      |
| Camphor      | 6.67                  | 0.44             | 5865.52     | 76.65       |
| Coconut      | 5.02                  | 0.69             | 8839.75     | 32.89       |
| Sukun        | 5.81                  | 0.29             | 3039.94     | 65.90       |

From Table 4, it can be explained the effect of moisture content and specific gravity on the mechanical properties as follows.

3.3.1 Effect of specific gravity on Modulus of Rupture (MOR)

The effect of the specific gravity versus MOR is shown in Figure 3 below.

![Figure 3. Relationship between Specific Gravity versus MOR](image)

Based on Figure 3, there are variations of specific gravity in the types of wood have been tested. Its because each species of wood has different characteristics. In general, the value of specific gravity influenced by the structure of timber composition, extractive content, and water content.

The value of Modulus of Rupture in different specific gravity conditions affects the MOR value. The increase in density is directly proportional to the value of MOR by [5] who declares that the higher the density of wood, the more substances in the cell wall, which means the thicker the cell wall.

Because the strength located on the cell wall, the thicker the cell wall is the stronger the wood. But for coconut is inversely proportional or contradictory because of the large density, but small modulus of
rupture that is in line with [6], the strength which has a greater specific gravity, does not necessarily have greater strength, because of the strength also determined by the chemical content in the cell walls.

It can be proven from the specific gravity and MOR values from the largest to the lowest as follows: Yellow Ballau (0.76 and 115.22 N / mm²), Teak (0.45 and 91.31 N / mm²), Camphor (0.44 and 76.65 N / mm²), Sukun (0.29 and 65.90 N / mm²), and Coconut (0.69 and 32.89 N / mm²), respectively. The data shows that the greater of density, the MOR value will increase, whereas Coconut wood is inversely proportional to the density and value of MOR.

That proves in line with [7] That the density of wood varies between different types of trees and among trees of one species. This variation also occurs in several positions from one tree. The difference in wood density is due to differences in the number of substances that make up the cell wall and the extractive content per unit volume.

3.3.2  The Effect of specific gravity on Modulus of Elasticity (MOE)

The relationship between specific gravity and MOE as presented in Figure 4 below.

![Figure 4. Relationship between specific gravity versus MOE](image_url)

In this study flexural testing was carried out with different moisture content conditions in five types of wood variation. Based on Figure 4, there are variations in the value of specific gravity on the variety of wood species tested — the amount of density influenced by the constituent structure of wood, extractive content, and water content.

The increase in density is directly proportional to the value of MOE by [5] which states that the higher the density of wood, the more wood substances in the cell wall, which means the thicker the cell walls. The strength of wood located on the cell wall, the thicker the cell wall, the stronger the wood.

However, for teak wood it is inversely proportional because the density is small, but the MOE value increase, in line with [6] that the strength of wood which has a greater specific weight does not have greater strength, because the strength of wood also determined by the chemical components of wood that are inside the cell wall.

Based on Figure 9 shows that the greater the density of wood, the value of MOE of wood will also increase, whereas teak with the value of density and MOE (0.45 and 9316.47 N / mm²) is inversely proportional to density and MOE value.
The results of the study are in line with [7] that the density of wood varies between different types of trees and among trees of the same species. This variation also occurs in different positions from one tree. The variation in wood density is due to differences in the number of substances that make up the cell wall and the extractive content per unit volume.

4. Conclusions

Based on the results of data analysis, the following conclusions are obtained.

- MOR values of Teak, Bangkirai, Camphor, Coconut, and Sukun were 91.31 N / mm², 115.22 N / mm², 76.65 N / mm², 32.89 N / mm², and 65.90 N / mm², respectively.
- The specific gravity has a linear relationship with MOR, while coconut wood is inversely proportional to the large specific gravity but the MOR value is small.
- The value of specific gravity is linear with MOE, however for teak with values of density and MOE (0.45 and 9316.47 N / mm²), inversely proportional to the other four types of wood.

References

[1] Mulyati 2014 Bahan Ajar Struktur Kayu Pertemuan I, II, III, Fakultas Teknik Sipil dan Prancanaan, Institut Teknologi Padang, Padang
[2] ASTM-D 198-05, Standard Methods Static of Limber in Structural Size, In Annual Book of ASTM Standard United State, Philadelpia
[3] Anonymous 2018, NI-5 PKKI 1961 Peraturan Konstruksi Kayu Indonesia, Jakarta
[4] Revisi Standar Nasional Indonesia 2002 Tata Cara Pelaksanaan Konstruksi Kayu Indonesia PPKI NI-5-2002, Departemen Pekerjaan Umum, Jakarta
[5] Haygreen J G and Bowyer J L 1989 Forest Products and Wood Science, Iowa State University Press /Ames, 213-226 pp
[6] Panshin A J and de Zeeuw 1980 Textbook of Wood Technology, McGraw-Hill Book Co, New York. 288-308 pp.
[7] Brown H P, Panshin A J and Forsaith C G 1952 Textbook of Wood Technology, McGraw-Hill Book Co. New York.