



Assesing compressive strength variations of galam wood in construction: A study of different sections and ratios

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ARTICLE INFO

Article history:

Submitted 7 September 2023

Received 11 September 2023

Received in revised form 12 October 2023

Accepted 15 November 2023

Available online on 30 November 2023

Keywords:

Galam wood, compressive strength, ratio H/D.

Kata kunci:

Kayu galam, uji tekan, rasio H/D.

ABSTRACT

Due to of its inherent strength and durability, wood is a valuable and abundant natural resource that is frequently used in the construction industry, road infrastructure, and bridge architecture. Notably, Galam Wood stands out as a distinct possibility for construction applications, as it may be used in its natural state without the need for specialist treatments. The current research digs into an examination of several areas of Galam Wood, including the bottom, middle, and higher regions. This inquiry integrates distinct ratios (1, 2, 3, 4, and 5) to investigate their respective influences on the material's strength. The chosen diameter of the specimens, varying between 5 cm and 10 cm, emerges as a critical element impacting compressive strength. In the size conditions of 10 cm diameter specimens, differences in section reveal a minimal influence on compressive strength, contrasting significantly with the considerable effect reported in the 5 cm diameter test items. The observable dissimilarity in compressive strength readings for the 10 cm diameter specimens remains below the threshold of 10%. Nevertheless, the careful selection of diverse ratios distinctly modifies the compressive strength outputs, underlining the critical function of this parameter in the behavior of Galam Wood under compressive loads.

ABSTRAK

Keberadaannya yang sangat melimpah menjadikan kayu sebagai salah satu bahan material yang sering ditemukan dalam dunia konstruksi bangunan, jalan bahkan jembatan. Dipilihnya kayu sebagai salah satu bahan material konstruksi karena kayu memiliki karakteristik yang kuat dan tahan lama. Beberapa jenis kayu memiliki sifat fisika dan mekanika yang cukup baik untuk digunakan dalam kegiatan konstruksi, salah satunya adalah kayu galam. Kayu galam yang dimanfaatkan sebagai material konstruksi digunakan dalam kondisi alami tanpa adanya perlakuan khusus. Variasi benda uji dalam penelitian ini adalah variasi pengambilan zona bagian pada kayu galam yaitu zona bagian bawah, bagian tengah dan bagian atas. Adapun variasi rasio yang digunakan yaitu rasio 1, 2, 3, 4 dan 5. Variasi pada benda uji ini digunakan untuk mengetahui pengaruhnya terhadap kekuatan yang mampu diterima oleh kayu galam diameter 5 cm dan diameter 10 cm. Variasi zona bagian pada benda uji kayu galam diameter 10 cm tidak berpengaruh besar terhadap kuat tekan namun variasi zona bagian berpengaruh pada benda uji diameter 5 cm. Perbedaan nilai kuat tekan pada setiap zona bagian benda uji diameter 10 cm hanya dibawah 10%. Namun variasi rasio yang digunakan cukup mempengaruhi hasil nilai kuat tekan kayu galam.

Available online at <http://dx.doi.org/10.36055/tjst.v19i2.21934>

1. Introduction

Wood is one of the natural resources easily found in Indonesia. Its abundance makes wood one of the materials that are often found in the world of building construction, roads and even bridges. Wood was chosen as one of the construction materials because wood has strong and durable characteristics. Besides that wood also has fairly lightweight [1], [2], is resistant to earthquakes and is also relatively cheaper in price [3]. Some types of wood have physical and mechanical properties that are good enough to be used in construction activities, one of which is galam wood. According to Ridwan, galam wood has been



used as a house niche for many years because galam wood has good durability [4]. The use of galam wood as a niche can last for more than 30 years in swamp soil [5]. In addition to its use as a house spout, galam wood is also very easy to find use as scaffolding in construction [6].

The original habitat of galam trees is in peat swamp forests. Plants with the Latin name *Melaleuca Cajuputi* are found in Central Kalimantan, South Kalimantan and coastal South Sumatra [5]. Galam trees can grow up to 10-25 meters in height and 30-350 mm in diameter. Galam wood used as a construction material is used in natural conditions without any special treatment. The use of galam wood as a niche or as scaffolding is a conventional method that does not have definite strength so that its use is only installed as much as possible to withstand the load [7], [8]. According to Susilo, the use of galam wood is also costly because it is only installed as much as possible, and some are still not organized so its use is not efficient and optimal [6], [9].

Testing the compressive strength of galam wood in natural conditions using leather conducted by Arha with a test piece height of 15 cm obtained a compressive strength of 23,24 MPa, while a test piece with a height of 10 cm obtained a compressive strength of 18,16 MPa [8]. From the test results it can be seen that galam wood is included in the E25 quality class. Research on the quality of galam wood conducted by Siregar in natural conditions obtained compressive strength results above 18 MPa [10]. Also obtained are the results of specific gravity testing according to PUBI 1982 that galam wood with skin is included in strength class IV. While the moisture content of galam wood is found to be above 20% [11].

In addition to the compressive strength experiment, Basyaruddin et al (2019) performed flexural strength testing on galam wood specimens with dimensions of 5 x 5 x 76 cm [12]. The study found that galam wood had a 20 % higher average flexural strength value than sengon wood. As a result, flexural testing on wood generally complies with the requirements established by SNI 03-3959-1995 and ASTM D 143-94 [13], [14].

The size of the wood test object used in the compressive strength test based on SNI 03-3958-1995 is 5×5×20 cm with a square prism shape. However, galam wood in natural conditions does not yet have standardization [15], [16]. So this research is expected to be used as a reference to standardize the size of galam wood test objects in natural conditions.

The variation of test specimens in this study is the variation of taking the section part of the galam wood, namely the lower, middle and upper sections. There is also a ratio variation which will also be used to determine the height of the test specimen. The ratio variations used are 1, 2, 3, 4 and 5. The determination of the variation of taking the section part and the ratio variation determines to find out whether the strength of this galam wood is influenced by taking the section part and the large variation in the ratio.

2. Research Methodology

2.1. Research Location

Research on the standardization of galam wood in natural conditions was conducted at the Materials and Structures Laboratory, Faculty of Science and Technology, Muhammadiyah University of East Kalimantan. Galam wood specimens were obtained from a wood shop located on street Rapak Indah, Samarinda City, located at coordinates 0°30'11.7 "S 117°06'25.9" [7]. Galam wood obtained from this woodshop is the result of cultivation located in Teluk Waru Village, Paser Regency, East Kalimantan Province [10].



Figure 1. Location of Galam Wood Shop
(Source: Google Earth)

2.2. Preparation of Test Objects

According to the SNI 03-3958-1995 standard, the compressive strength test on wood specimens uses a size of 5×5×20 cm [15], [16]. However, in this study, the natural size of galam wood with a diameter of 5 cm and 10 cm was used and there was no special treatment of the test specimens. With the condition of the galam wood trunk which is irregular or perfectly round, the average diameter measurement is carried out in three parts, namely the top, middle and bottom. Measurement of the average diameter on both sides is also carried out on each side of the galam wood section. In research conducted by Siregar, also measured the average diameter of the galam wood cross section obtained by measuring the upper, middle and lower diameters [10]. The cross-section of the inner wood test object is obtained from the area equation as follows:

$$A = 0.25 \times \pi \times D^2 \quad (1)$$

Description:

A = Cross-sectional area (mm²)

π = 3,14

D² = Average diameter (mm)

The height of galam wood in one trunk obtained under natural conditions from a wood shop is 4 meters. In one trunk, galam wood is divided into 3 sections, namely the lower, middle and upper parts. The number of 5 cm diameter galam logs used in this study was 5 pieces. One galam log was divided into three sections, namely the bottom, middle and top. One section part of the 5 cm diameter galam wood requires a height of 75 cm with a total height of 2.25 meters for the 5 cm diameter test object. After obtaining the size of each section of the test piece, the height measurement is obtained from the average

diameter multiplied by the ratio. In this study, a variety of ratios were used, namely 1, 2, 3, 4 and 5. So that the total number of 5 cm diameter galam wood test objects was 75 pieces.

The number of 10 cm diameter galam logs used as test specimens in this study was 10 logs divided into 5 groups of test specimens. Each section required a rod height of 150 cm. Since one galam wood trunk only has a height of 4 meters, the first trunk was only divided into 2 sections, namely the lower section and the upper section. The middle section in the first test specimen was taken on the next rod. The same was done for the second, third, fourth and fifth test specimens. After obtaining the section on each test specimen, the next measurement of the galam wood test specimen with the size was obtained from the ratio variation multiplied by the average diameter. So that the following results are obtained:

$$H = D_{average} \times R \quad (2)$$

Description:

- D = Average diameter
- R = Ratio
- H = Height

The galam wood specimens that have been measured are then cut using a circular saw. The number of test specimens in 1 ratio is 15 pieces, of which in each section amounts to 5 test specimens. The total number of test specimens from the five ratios with 3 section sections is 75 pieces of galam wood test specimens. So that the total number of galam wood test objects is 150 pieces.

2.3. Specific Gravity, Moisture Content and Absorption Testing

Some types of wood have natural properties such as high moisture content, which is influenced by wood's low specific gravity and density. High moisture content will affect the mechanical strength of wood [17]. As a supporting material for building construction, galam wood must have good strength to withstand loads. The high level of moisture content and low density of wood will affect the strength of the wood in receiving loading. Testing the physical properties of galam wood in this study includes testing the specific gravity, moisture content and absorption. The test objects used in testing water content, specific gravity and absorption are taken from the remaining part of the cut on the galam wood trunk which is used the same as for compressive strength testing. The number of 5 cm diameter galam wood test specimens used in testing the physical properties of each section amounted to 3 pieces and in the 10 cm diameter galam wood test specimens each section section amounted to 3 pieces so the total number of galam wood test specimens in testing physical properties amounted to 6 pieces. In testing physical properties, the height obtained from the average diameter of the cross-section multiplied by a ratio of 2 is used.

After preparing the galam wood test specimens, the next step is to weigh each test specimen to determine the volume of the test specimen. Weighing is carried out in 3 conditions, namely natural weight (W_a), oven dry weight (W_{ko}) and wet weight (W_b). To find out the specific gravity and the level of moisture content in galam wood can use equations that refer to the SNI 03-6848-2002 standard as follows [18], [19], [20], [21]:

$$Bj = \frac{W_{ko}}{V} \quad (3)$$

Description:

- BJ = Specific gravity
- W_{ko} = Oven dry weight (kg)
- V = Volume of galam wood (m³)

The volume of the test specimen uses the following equation:

$$V = 0.25 \times \pi \times D_{Average}^2 \times H \times 10^{-9} \quad (4)$$

Description:

- V = Volume of galam wood specimen (m³)
- π = 3,14
- D_{Average} = Average diameter of galam wood test specimens (mm)
- H = Height of galam wood specimen (mm)

$$\text{Moisture Content} = \frac{(W_a - W_{ko})}{W_{ko}} \times 100\% \quad (5)$$

Description:

- W_a = Natural dry weight of galam wood specimen (grams)
- W_{ko} = Oven dry weight of galam wood test specimen (grams)

$$p = \frac{(W_b - W_{ko})}{W_{ko}} \times 100\% \quad (6)$$

Description:

- W_b = Wet weight of galam wood specimen (grams)
- W_{ko} = Oven dry weight of galam wood test specimen (grams)

2.4. Testing The Compressive Strength of Galam Wood

After cutting, the galam wood test specimens were first weighed to determine the weight of each test specimen. Furthermore, the test specimens were tested for compressive strength using a compressive testing machine. The test specimens were placed centrally on the compressive testing machine. The loading speed is given constantly and the maximum test load until the test piece experiences destruction or collapse. The maximum load (P_{maks}) received by the test specimen and visible on the dial of the press test machine is recorded so that the maximum compressive load value of galam wood is known.

The load value read on the press test equipment is converted into a compressive strength value using a formula equation that refers to SNI 03-3958-1995 as follows [15]:

$$f'_c = \frac{P_{Max}}{A} \quad (7)$$

Description:

f'_c = Compressive Strength (MPa)

A = Average cross-sectional area (mm²)

P_{Max} = Maximum load (N).

Which of the results of the compressive strength value is then given an analysis and discussion related to the effect of the section and ratio on compressive strength.

2.5. Destruction Patterns in Galam Wood

Galam wood tested for compressive strength will receive the maximum load given by the compressive testing machine. When the galam wood test specimen receives the maximum load from the compressive testing machine, the reaction seen in the galam wood test specimen is the occurrence of destruction or collapse. For comparison, there is a pattern of destruction that occurs in the concrete according to SNI 1974: 2011, namely cone destruction, cone and split destruction, cone and shear destruction, shear destruction and upright axis parallel destruction [22].

Crack patterns that occur in wood according to SNI 03-3958-1995 there are 6 forms of cracking [15]. The first is a horizontal crack shape, the second is a wedge-shaped crack, the third is a shear crack, the fourth is an elongated shape, the fifth is a compression and shear crack shape and the sixth is an end crack. In this study, the destruction that occurs in galam wood test objects is divided into 3 destruction patterns: bending, breaking and shortening.

3. Result and Discussion

3.1. Characteristic Physique

Galam wood, which has been weighed under three different conditions, was then subjected to calculations to determine its specific gravity, moisture content, and absorption.

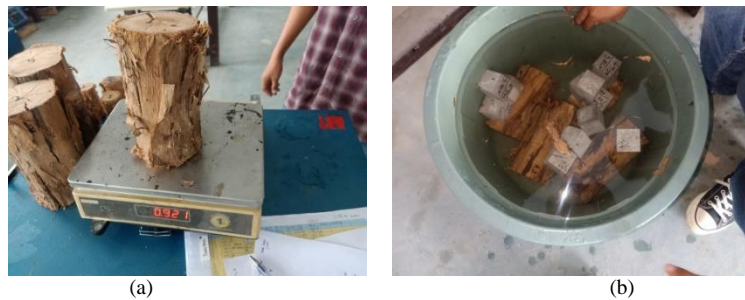


Figure 3. Weighing of Oven-Dried Specimen of Galam Wood.; (b) Immersion of Galam Wood Specimen to Determine Wet Weight

The results of the physical property calculations for galam wood with a diameter of 5 cm are presented in Table 1 below.

Table 1. Data of Galam Wood Physical Property Test Results for 5 cm Diameter.

No	Specific Gravity (g/cm ³)	Moisture Content (%)	Absorption (%)
1	0,47	73,44	40,63
2	0,45	81,48	50,00
3	0,42	69,86	49,32

The results of the physical property test for galam wood with a diameter of 5 cm are as follows:

- Average air-dried specific gravity : 0.45 g/cm³
- Average moisture content : 74.93%
- Average absorption : 46.65%

Table 2. Data of Galam Wood Physical Property Test Results for 10 cm Diameter.

No	Specific Gravity (g/cm ³)	Moisture Content (%)	Absorption (%)
1	0,81	37,13	32,03
2	0,90	22,28	27,66
3	0,93	23,14	27,50

Based on the test results, for galam wood with a diameter of 10 cm, the average air-dried specific gravity is 0.88 g/cm³, the average moisture content is 27.52%, and the average absorption is 29.06%. According to PUBI 1982, galam wood falls under the "wet wood" category because it has a moisture content above 20% [10].

3.2. Compressive Strength Test Results

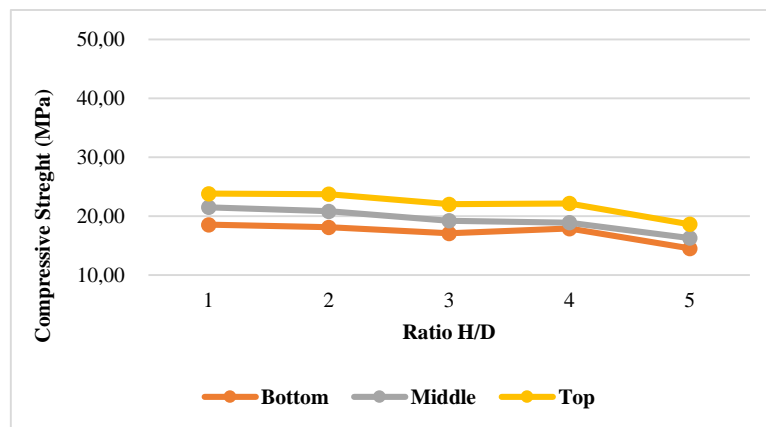
After conducting the compressive strength test on galam wood with a diameter of 5 cm using 75 specimens, the specimens maximum load values were converted into compressive strength. The compressive strength test results for galam wood with a diameter of 5 cm are presented in Table 3, showing the average compressive strength for each ratio in different sections.

Table 3. Average Compressive Strength Values of Galam Wood with 5 cm Diameter.

Ratio	Bottom (MPa)	Middle (MPa)	Top (MPa)
1	18,54	21,52	23,81
2	18,12	20,82	23,74
3	17,09	19,24	22,03
4	17,90	18,91	22,17
5	14,53	16,29	18,63

**Figure 4.** Compressive Strength Test of Galam Wood with 10 cm Diameter.

From the average compressive strength results that have been tabulated (Table 3), it can also be observed in the graph (Figure 4) that the compressive strength of galam wood with a diameter of 5 cm is influenced by the sampling sections of the test specimens. As seen in the graph, the compressive strength of galam wood from the bottom section has lower values than the compressive strength values from the middle and top sections. The higher the sampling section is, the higher the compressive strength values obtained. Additionally, it is evident that as the ratio increases, the compressive strength relatively decreases. When comparing the compressive strength deviations among the ratios, they are not significantly large, allowing for creating a linear regression graph (Figure 5) that yields a straight line. The percentage of strength for the three different sections from each ratio observed in galam wood with a diameter of 5 cm is shown on the regression graph (Figure 5).

**Figure 5.** Graph of Compressive Strength for 3 Sections with a Diameter of 5 cm.**Table 4.** Percentage of Compressive Strength for Galam Wood Specimens with a Diameter of 5 cm.

Ratio	Bottom (%)	Middle (%)	Top (%)
1	100,00	100,00	100,00
2	97,76	96,76	99,71
3	92,20	89,43	92,51
4	96,55	87,89	93,11
5	78,38	75,70	78,22

The results of the percentage of compressive strength for galam wood specimens with a diameter of 5 cm are presented as a linear regression graph (Figure 6), which shows the relationship between the ratio and the percentage of strength in the galam wood specimens. For the galam wood specimens with a diameter of 5 cm, the equation relating the ratio to the strength percentage is $y = -5.0695x + 107.09$ with an R-squared value of 0.8193. The linear regression equation $y = -5.0695x + 107.09$ represents the relationship between the ratio (x) and the percentage of strength (y) for the galam wood specimens. The R-squared value (0.8193) indicates the goodness of fit of the regression line to the data, with values closer to 1 indicating a better fit.

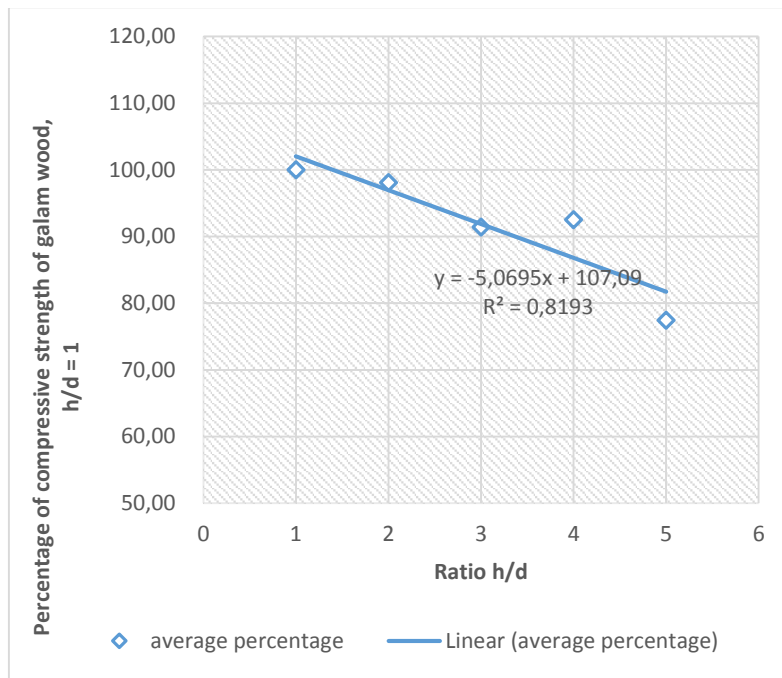


Figure 6. Linear Regression Graph for the Three Sections of Galam Wood with a Diameter of 5 cm.

When compared, the compressive strength at ratios 1 and 5 shows a decrease of 22.57% on the graph (Figure 5). According to the research conducted by Hidayatullah, the linear regression equation for long-sized mahogany columns is $\psi=1-(1.9164 \times 10^{-8}h^4)$, and for medium-sized columns, the equation is $\psi=3962.4/\lambda^2$ [23]. The average compressive strength values of galam wood with a diameter of 10 cm from the compressive strength test for each section and each ratio are presented in Table 5 below.

Table 5. Average Compressive Strength Values of Galam Wood with a Diameter of 10 cm.

Ratio	Bottom (MPa)	Middle (MPa)	Top (MPa)
1	40,10	39,87	38,50
2	39,54	38,53	35,88
3	39,10	35,73	34,26
4	38,41	35,64	33,97
5	34,25	34,09	32,17

From the average compressive strength results of the galam wood specimens with a diameter of 10 cm, as presented in Table 5, it is observed that the position of the sampled sections on the specimens does not significantly influence the compressive strength of galam wood. However, on the graph (Figure 7), it can be seen that there is a decrease in the compressive strength of the galam wood specimens, and the ratio influences this decrease.

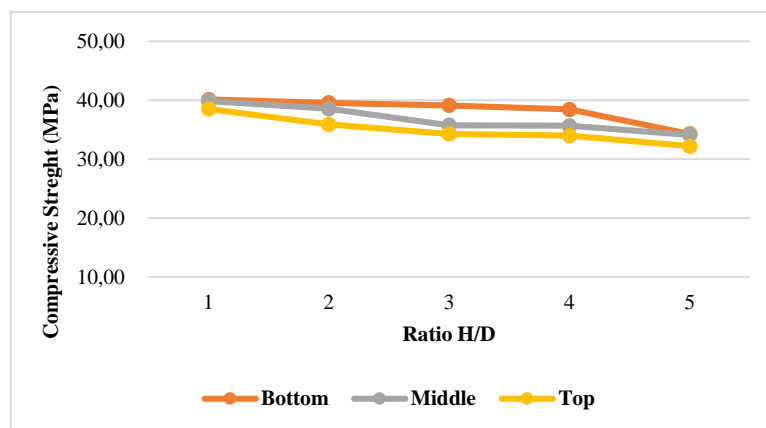
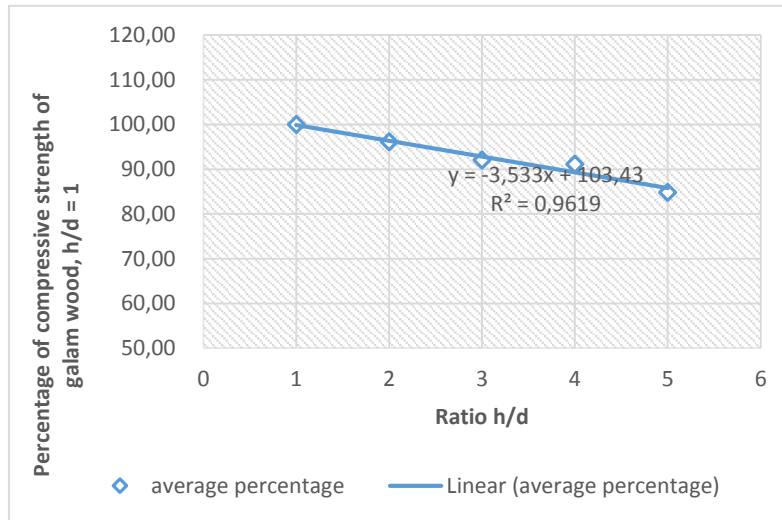


Figure 7. Graph of Average Compressive Strength of Each Section Section.

From the graph (Figure 7) it is known that there was a decrease in strength in the test specimens of 10 cm diameter of 15.16% of the galam wood. Galam wood specimens with a large ratio have a larger size. The galam wood specimen that is too tall cannot accept a large load from the compression testing machine so the higher the galam wood specimen, the smaller the strength contained in the galam wood test object. This can occur due to the influence of the slenderness of the test object. The slimmer the dimensions of a rod, the greater the bending factor [24]. The percentage strength of the test specimens of 10 cm diameter galam wood can be seen in Table 6 below.

Table 6. Percentage of Specimen Strength of Galam Wood with a Diameter of 5 cm.

Ratio	Bottom (%)	Middle (%)	Top (%)
1	100.00	100.00	100.00
2	98.60	96.64	93,19
3	97.51	89.61	88.99
4	95.81	89.39	88,23
5	85.43	85.51	83.57

**Figure 8.** Linear Regression Graph of the Three Sections of Galam Wood with a Diameter of 10 cm.

The results of the percentage strength of the galam wood test specimens at 10 cm in diameter are presented in the form of a linear regression graph (Figure 8) which shows a graph related to the influence of the ratio to the percentage of strength on the galam wood specimens. On the specimen of galam wood with a diameter of 10 cm, the equation for the relationship between the ratio and strength is obtained, namely $y = -3,533x + 103,43$ with $R^2 = 0,9619$.

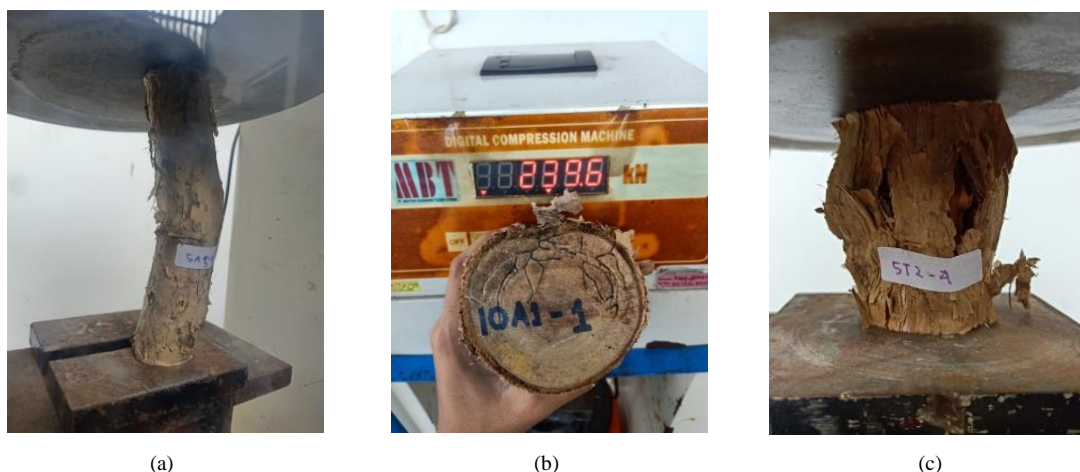
The graph of the relationship between the ratio and strength of the galam wood test specimens (Figure 5, Figure 7) shows that the graph almost forms a straight line, this is due to the difference in strength which is not too significant. Compared with the graph of the relationship between the height and diameter of the concrete cylinder test object to its compressive strength, the graph forms a curved line.

3.3. A pattern of Destruction on Test Objects

The damage that occurred in the galam wood specimen was caused by the dimensions of the specimen itself. The cross-sectional area of the slate influences this and also the height of the slate. The pattern of destruction in the compressive strength test commonly occurs in concrete cylinder specimens. When the compression testing machine gives the maximum loading to the concrete cylinder test object, the test object will cause a crushing reaction.

The destruction reaction received by this specimen also occurred in the galam wood during the compression test. The galam wood specimen which has received the maximum load from the compression testing machine also causes a crushing reaction.

There are 3 different types of destruction reaction patterns that occurred in this study. The first failure pattern is buckling, the second is breaking and the third is shortening. An example of the pattern of destruction that occurs in the compressive strength test of galam wood can be seen in Figure 9 (a), (b) and (c). The average pattern of destruction that occurred on the test specimens of 5 cm diameter galam wood was a C pattern, namely shortening. Meanwhile, the average pattern of destruction in the specimens of 10 cm diameter galam wood was buckling.

**Figure 9.** (a) First Crash Pattern; (b) Second Pattern of Destruction; and (c) Third Pattern of Destruction.

4. Conclusion

Based on the compressive strength test on the 5 cm diameter of the ca wood specimen and the 10 cm diameter of the calamus wood test object and the results of the analysis of the tests that have been carried out, it can be concluded that:

1. Sampling of the sections on the test specimens of 5 cm diameter of galam wood is very influential on the results of the strength of the galam wood. The test results found that the upper stem section has a higher strength than the lower stem section. However, the variation in the ratio of the galam wood specimens with a diameter of 5 cm did not significantly affect the strength of the specimens. From the results of the average strength of the 5 cm diameter of the test object, the average percentage of strength obtained from the ratio of the ratio to the part section on the galvanized test object was 91.88 %. The linear regression equation for the relationship between the ratio and the strength percentage on a 5 cm diameter galam wood sample is $y = -5.0695x + 107.09$.
2. The variation in the ratio of the 10 cm diameter of the saplings had a significant effect on the strength of the saplings. This happened because of the influence of the slenderness of the galam wood specimen. The higher the dimensions of the galam wood test object, the smaller the strength that the test object can accept. The galam wood test object can receive greater strength if the cross-sectional area of the galam wood test object is not too small with a small height dimension as well. From the test results on a 10 cm diameter galam wood specimen, the reduction results were obtained at a ratio of 5, which is below 10%. However, the variation in taking the sections of the test specimens of 10 cm diameter galam wood did not have enough effect on strength. Also obtained is a linear regression equation that relates the ratio to the percentage of strength of the 10 cm diameter galam wood specimen, namely $y = -3.533x + 103.43$.

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