The International Conferences on Engineering Sciences

E-ISSN: 3090-6733

*Research Article*

# Ductility Behavior of Laminated Hollow Section Bamboo Beam-Column Connections with Glue-in-Rod–Bracket System: An Environmentally Friendly Construction Material Solution

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**Abstract:** Wood consumption in Indonesia, which is expected to reach more than 64.84 million m³ by 2025, is putting enormous pressure on forests, as evidenced by the reduction in forest area through the clearing of 96,230 hectares of forest in 2023. To reduce dependence on wood as a building material, alternative materials with comparable physical and mechanical properties are needed. Bamboo, especially laminated bamboo, was chosen because it has high tensile strength, a short harvest time, and abundant availability. This study examines the behavior of hollow section laminated bamboo beam-column connections with a glue-in-rod-bracket system to determine the ductility of the connection under unidirectional (static) loads. An experimental method was used with the independent variables of diameter and number of bolts, while the dependent variables included the moment-rotation of the connection, stiffness, strength, and ductility. The results show that the average ductility values for 4 and 6 thread rods D6, D8, and D10 mostly meet the SNI 1729 ($\geq$1.25) and AISC 360 (rotation >0.03 rad) standards, with classifications ranging from "partially ductile" to "fully elastic." However, the 10-diameter 6-thread rod only achieved a ductility of 1.2, thus failing to meet the SNI standard. Based on the Handbook of Structural Steel Connection Design and Details, all connections fall into the non-seismic category because their ductility values are less than 3. These findings confirm the potential of laminated bamboo as an environmentally friendly construction material, while also providing technical guidelines for the design of non-seismic beam-column connections.

**Keywords:** Beam-Column; Bracket; Ductility; Environmentally; Laminated.

**Received:** December 22, 2025
**Revised:** January 11, 2026
**Accepted:** January 28, 2026
**Published:** January 31, 2026
**Curr. Ver.:** January 31, 2026

## 1. Introduction

Roundwood consumption in Indonesia in 2024 is recorded at 64.84 million m³,an increase from 42.28 million m³ previously, according to Statistics Indonesia 2025 (BPS, 2025). Forests are shrinking, with data showing 96.23 thousand hectares of forest area cleared in 2023 (BPS, 2025). The highest consumption of wood is for construction, followed by furniture (Abdullah et al., 2020). Due to environmental impacts and sustainability concerns, there is a need for alternative construction materials to replace wood. Currently, alternative materials to wood in the construction sector include wood plastic composites (WPC), galvalume, aluminum, steel, and laminated bamboo (Arifin et al., 2023). Laminated bamboo is a product that closely resembles the mechanical and physical properties of wood, one example being the orthotropic properties of wood (Obara, 2028) (Arifin et al., 2025). Another advantage of bamboo is that it is a fast-growing plant with a harvest age of approximately 3.5 years and a diameter at breast height (DBH) of 2.5 cm (Guerra et al., 2016).

DOI : https://doi.org/10.61132/iconfes.v3i1.185

Laminated bamboo is made from a collection of bamboo that is cut into squares and glued together using phenol formaldehyde (PF) or urea formaldehyde (UF) glue into various shapes (Muhammad Suandi et al., 2022). The bamboo used in this study is petung bamboo (Dendrocalamus Asper). This bamboo was chosen because it has better strength than other types of bamboo. The properties of Dendrocalamus Asper bamboo are 52.82% moisture content, 10.88% dry matter content, and 0.539 g/cm3specific gravity (Rini, 2018).

The current research focuses on laminated bamboo in the form of boards, solid beams, and hollow beams. The results of the research show that the hollow form is the most efficient (Karyadi et al., 2020). This form of laminated bamboo is intended as a construction element. The limitation of laminated bamboo as a construction unit is the need for connecting tools (Eratodi et al., 2014) (Syafi'i, 2019).

Based on the preliminary description, this study aims to develop laminated bamboo joints to form a unified construction. The connecting tools to be studied are brackets and glue-in rods. The purpose of the study is to determine the capacity of the main connection in terms of ductility. Experimental testing methods are used to determine whether the connection type meets the SNI 1729 (SNI 1729:2020, 2020) and AISC 360 standards (AISC 360-16, 2016).

## 2. Literature Review

### 2.1. Laminated Bamboo

Laminated bamboo is a combination of bamboo strips that are arranged and glued together to form laminated bamboo elements. This study created laminated petung bamboo from bamboo strips with a cross-section of 5 mm x 20 mm, which were glued with UF glue with an application of 268 g/m2 and pressed with a force of 2 MPa for 4 hours (Karyadi K et al., 2014). The shape of the slats (a) and the arrangement of the laminated bamboo (b) can be seen in Figure 1.

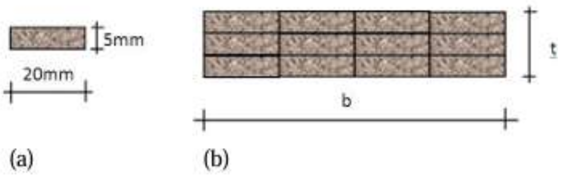

**Figure 1.** (a) Bamboo strips and (b) laminated bamboo arrangement.

The development of the laminated bamboo shape began with a solid beam shape with an average strength of 55.59 kN (Karyadi et al., 2020). The shapes developed in I, papa, and hollow profiles had an elastic modulus (MOE) of 11.537 GPa (Karyadi K et al., 2014). Further studies found that an optimum thickness of 1/3 of the hollow shape provided an increase in strength (Karyadi et al., 2019) . Further research related to the hollow shape showed that the cross-sectional dimension between b:h of 1.5 was the most efficient with an MOE of 14.504 GPa and a Modulus of Rupture (MOR) of 106.5 MPa (Karyadi & Susanto, 2017). The formula for the bending moment of beam-shaped elements in laminated bamboo is as follows.

$$M = S_x \times \sigma_b, \tag{1}$$

$$S_x = \frac{I_x}{y}, \tag{2}$$

$$I_x = \frac{1}{12}\left(bd^3 - ah^3\right), \tag{3}$$

**Theorem 1.** $M =$ Flexural Moment (N.m); $S_x =$ Elastic Modulus (mm$^3$); $\sigma_b =$ Cross-sectional Stress (N/mm$^2$);
**Theorem 2.** $I_x =$ Moment of Inertia (mm$^4$ ); $y =$ Center Point (mm);
**Theorem 3.** $b =$ Cross-sectional Width (mm); $a =$ Hollow Width (mm); $d =$ Cross-sectional Height (mm); $h =$ Hollow Height (mm).

### 2.2 Glue-in Rod and Bracket Joints

Furthermore, in order for the elements to form a unified building structure, connection tools are required. The connection tools selected are glue-in rods and brackets. Glue-in rods are embedded connections consisting of threaded rods and adhesive glue with an embedding distance from the edge of 3d (Karyadi K et al., 2014). The formula approach uses ASTM D1761-88 (ASTM D 1761-88, 2002).

$$F = f_v \times S, \tag{4}$$

$$S = L_x \times \pi \times d_x, \tag{5}$$

**Theorem 4.** $F =$ Strength (N);$f_v =$ Shear Stress (N/mm$^2$);$S =$ Embedment Area (mm$^2$); **Theorem 5.** $Lx =$ Embedment Length (mm);$d_x =$ Thread Rod Diameter (mm).

Bracket is a connecting device that facilitates the connection of thread rods. The bracket is shaped like a square bowl with a thread rod hole at the edge. The plate thickness is 10 mm, which is the maximum thickness of the thread rod used, referring to the SNI 03-1729 steel connection plate standard (SNI 1729:2020, 2020). The shapes of the glue-in rod and bracket are as follows.

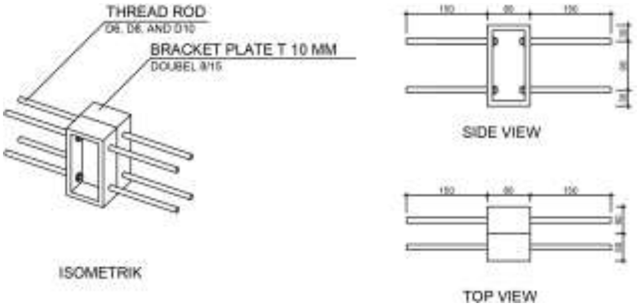

**Figure 2.** Glue-in Rod and Bracket Connection Model.

### 2.3 Ductility of Column-Beam Joints

Ductility, symbolized by D, is the ability of elements in a building structure to experience large post-elastic deflections when loaded, causing initial yielding while the structure still retains sufficient strength and stiffness. A high ductility value indicates that the building maintains its position when collapse is imminent. Ductility at the joint is defined as the distribution of energy at the angle of rotation.

The ductility factor value is taken from the moment-rotation relationship graph of the joint. The ductility factor is the ratio of the first yield deflection and before the joint receives the maximum load. The first yield rotation, referred to as the elastic rotation ($\theta y$), is taken from the intersection of the Ks and Kp slope lines, Figure 3. The maximum rotation ($\theta u$) is derived from the peak point of 0.8 Mu or $\theta u$ , which is 0.03 rad based on AISC 2016 (AISC 360-16, 2016).

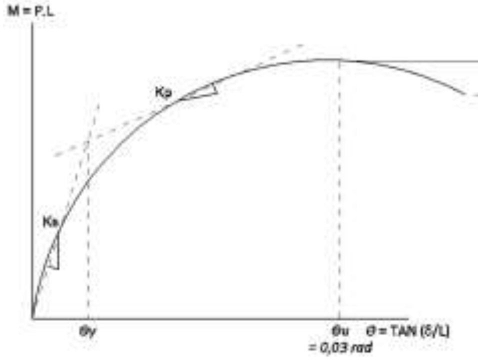

**Figure 3.** Determining the Ductility Value from the Moment and Rotation Relationship.

The references for the Wakasima ductility equations (J. P. Jaspart et al., 2019) and SNI 1762 (SNI 1729:2020, 2020) are as follows:

$$D = \frac{\theta u}{\theta y}, \tag{6}$$

**Theorem 6.** $D =$ Joint Ductility; $\theta y =$ Elastic Rotation; and $\theta u =$ Maximum Rotation.

The D value results are classified into connection ductility groups based on SNI 1762 (SNI 1729:2020, 2020). These performance levels will be used as a reference for planning the type of structural system. There are various structural systems in SNI 1762, namely: Bearing wall system, Frame system, moment-resisting frame system, cantilever column structural system, and double structural system. A summary of the grouping parameters is provided in Table 1.

**Table 1.** Ductility Parameters

| Structural Performance Level | D Value |
|---|---|
| Fully Elastic | 1.0 |
| | 1.5 |
| | 2.0 |
| | 2.5 |
| Partial Daktail | 3.0 |
| | 3.5 |
| | 4.0 |
| | 4.5 |
| | 5.0 |
| Full Daktail | 8.5 |

*SNI 03-1726-02*

## 3. Proposed Method

### 3.1. Research Design and Phases

Experimental research by creating laminated bamboo test specimens. The testing method was used to observe the ductility of laminated bamboo beam column joints measuring 10 cm x 15 cm x 100 cm. The control performed was damage to the joint. The variables are described as follows: The independent variables are the diameter and number of embedded treadrods; the dependent variable is the ductility value of the joint; and the control variables are the thickness of the 10 mm bracket, UF glue, epoxy glue, and Dendrocalamus asper bamboo. The research flowchart is shown in Figure 4.

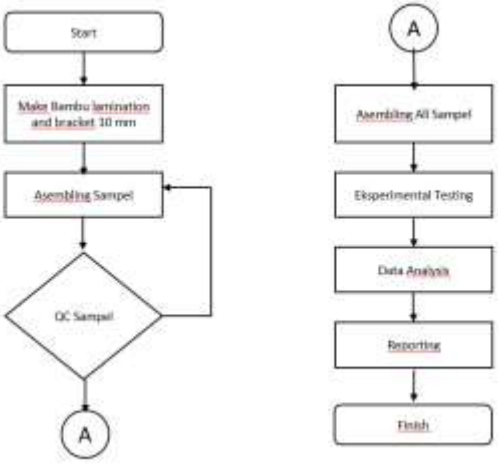

**Figure 4.** Research Flowchart.

### 3.2. Sample

The test object consists of 3 components that are combined and will be tested experimentally. The laminated bamboo column beam component measuring 10 cm x 15 cm x 100 cm will be connected to form a T. The bracket is shaped like a double bowl with holes for connecting the thread rods embedded in the column and laminated bamboo beam, with the bracket measuring 5 cm x 8 cm x 15 cm. The threaded rod components embedded in the laminated bamboo consist of D6, D8, and D10, which are configured in 4 and 6 arrangements. The assembly diagram of the sample is shown in Figure 5, and the sample details are shown in Table 2.

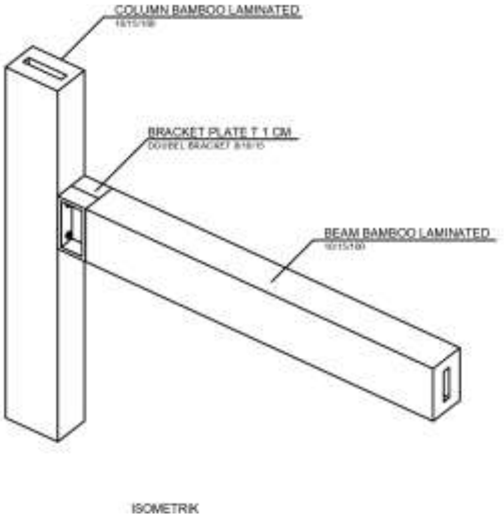

**Figure 5.** Sample Assembly.

**Table 2.** List of Test Object Samples.

| No | Thread Rod Diameter (mm) | Column/Beam Dimension (cm) | Thread Rod Configuration | Sample Code |
|---|---|---|---|---|
| 1 | 6 | 10x15x100 | 4 | 6.4.1 |
| 2 | | | | 6.4.2 |
| 3 | | | | 6.4.3 |
| 4 | | | 6 | 6.6.1 |
| 5 | | | | 6.6.2 |
| 6 | | | | 6.6.3 |
| 7 | 8 | 10x15x100 | 4 | 8.4.1 |
| 8 | | | | 8.4.2 |
| 9 | | | | 8.4.3 |
| 10 | | | 6 | 8.6.1 |
| 11 | | | | 8.6.2 |
| 12 | | | | 8.6.3 |
| 13 | 10 | 10x15x100 | 4 | 10.4.1 |
| 14 | | | | 10.4.2 |
| 15 | | | | 10.4.3 |
| 16 | | | 6 | 10.6.1 |
| 17 | | | | 10.6.2 |
| 18 | | | | 10.6.3 |

### 3.3. Data Analysis

Analysis to determine the ductility of connections. Ductility data analysis refers to SNI 1762 and AISC 360 when the angle rotation exceeds 0.03 rad, which is classified as ductile. The analysis categorizes the results of experimental testing according to SNI and AISC standards. The earthquake category is based on the Handbook of Structural Steel Connection Design and Details with a ductility of 3. The data was obtained through flexural testing. The experimental sample placement is shown in Figure 6.

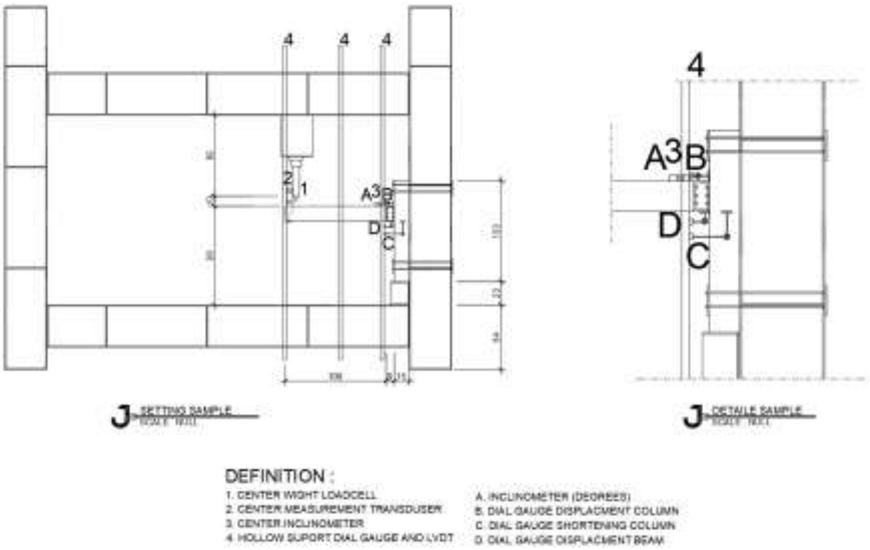

**Figure 6.** Placement for Experimental Testing.

## 4. Results and Discussion

### 4.1. Results

$D$ are derived from the $\theta y$ and the$\theta u$ , which in this case is 0.03 rad. The ductility values from the tests will be included in the AISC 360 standard (AISC 360-16, 2016), SNI 1729 (SNI 1729:2020, 2020), and the Handbook of Structural Steel Connection Design and Details (Akbar & P.E., 2010). AISC 360 states that a connection meets the ductile category when the rotation is greater than 0.03 rad. SNI 1729 has ductility parameters described in Table 1. A building is considered earthquake-resistant if the ductility is 3. The results of the 4 ThreadRod configuration are shown in Table 3 and the 6 Thread Rod configuration in Table 4.

**Table 3.** Configuration of 4 ThreadRods with Diameters of 6 mm, 8 mm, and 10 mm.

| No | Code Sample | Rotation Yield ($\theta y$ ) | Rotation Ultimate ($\theta u$ ) | Ductility (D) | Standard Ductility | |
|---|---|---|---|---|---|---|
| | | | | | SNI | AISC |
| 1 | 6.4.1 | 0.020 | 0.03 | 1.5 | Fully Elastic | Meets |
| 2 | 6.4.2 | 0.008 | 0.03 | 3.7 | Partial Daktail | Meets |
| 3 | 6.4.3 | 0.019 | 0.03 | 1.6 | Partial Daktail | Meets |
| | Average | | | 2.3 | Partial Daktail | Meets |
| | Standard deviation | | | 1.2 | - | - |
| 4 | 8.4.1 | 0.028 | 0.03 | 1.1 | Fully Elastic | Meets |
| 5 | 8.4.2 | 0.013 | 0.03 | 2.3 | Partial Daktail | Meets |
| 6 | 8.4.3 | 0.017 | 0.03 | 1.7 | Partial Daktail | Meets |
| | Average | | | 1.7 | Partial Daktail | Meets |
| | Standard deviation | | | 0.6 | - | - |
| 7 | 10.4.1 | 0.014 | 0.03 | 2.1 | Partial Daktail | Meets |
| 8 | 10.4.2 | 0.018 | 0.03 | 1.7 | Partial Daktail | Meets |
| 9 | 10.4.3 | 0.020 | 0.03 | 1.5 | Partial Daktail | Meets |
| | Average | | | 1.8 | Partial Daktail | Meets |
| | Standard deviation | | | 0.3 | - | - |

**Table 4.** Configuration of 6 ThreadRods with Diameters of 6 mm, 8 mm, and 10 mm.

| No | Code Sample | Rotation Yield ($\theta y$ ) | Rotation Ultimate ($\theta u$ ) | Ductility (D) | Standard Ductility | |
|---|---|---|---|---|---|---|
| | | | | | **SNI** | **AISC** |
| 1 | 6.6.1 | 0.016 | 0.03 | 1.9 | Partial Daktail | Meets |
| 2 | 6.6.2 | 0.010 | 0.03 | 3.1 | Partial Daktail | Meets |
| 3 | 6.6.3 | 0.012 | 0.03 | 2.5 | Partial Daktail | Meets |
| | Average | | | 2.5 | Partial Daktail | Meets |
| | Standard deviation | | | 0.6 | - | - |
| 4 | 8.6.1 | 0.014 | 0.03 | 2.2 | Partial Daktail | Compliant |
| 5 | 8.6.2 | 0.037 | 0.03 | 1.0 | Fully Elastic | Meets |
| 6 | 8.6.3 | 0.020 | 0.03 | 1.5 | Partial Daktail | Meets |
| | Average | | | 1.6 | Partial Daktail | Meets |
| | Standard deviation | | | 0.6 | - | - |
| 7 | 10.6.1 | 0.029 | 0.03 | 1.0 | Fully Elastic | Meets |
| 8 | 10.6.2 | 0.018 | 0.03 | 1.7 | Partial Daktail | Meets |
| 9 | 10.6.3 | 0.030 | 0.03 | 1.0 | Fully Elastic | Meets |
| | Average | | | 1.2 | Fully elastic | Meets |
| | Standard deviation | | | 0.4 | - | - |

## 4.2. Discussion

Further discussion of the data on the results of processing the standard deviation data from the experimental tests. The data is presented in the graph in Figure 7:

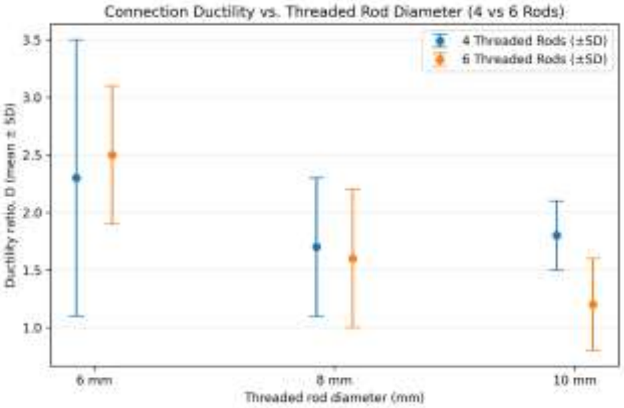

**Figure 7.** Standard deviation data processing graph.

Based on the test results of laminated bamboo beam-column connections with steel brackets and threaded rods, all specimens reached an ultimate rotation θu = 0.03 rad (AISC), while the yield rotation θy varied, resulting in a rotation ductility range D = θu/θy between 1.0 and 3.7. In terms of performance, the 4 thread rod configuration showed relatively consistent average ductility at all diameters (D6: 2.3; D8: 1.7; D10: 1.8), while the 6-threaded rod configuration showed a tendency for decreased ductility at larger diameters, especially Ø10 mm (average 1.2), which approached "nearly elastic" behavior (small post-yield deformation reserve) (SNI). This pattern indicates that increasing the number/diameter of rods can increase the stiffness and tensile capacity of the fastening system, but at the same time has the potential to reduce the length of the post-yield inelastic phase, so that the energy dissipation obtained from indicator D becomes smaller. However, all connections are categorized as non-seismic connections because the ductility value is less than 3.

The ductility results show that the 4-threaded rod configuration produces an average ductility of 1.7–2.3 (mostly partial ductility), while the 6-threaded rod configuration shows a downward trend in ductility at larger diameters, especially D10 mm with an average $D = 1.2$ (approaching fully elastic behavior). This pattern indicates that increasing the number/diameter of rods in a predominantly tensile bracket does not always improve ductile performance. Instead, the connection can become stiffer, resulting in shorter post-yield inelastic deformation and reduced energy dissipation potential. These findings are in line with the SNI's emphasis that connections must be able to provide the rotational capacity required for inelastic deflection demands.

## 5. Comparison

The results obtained from the testing meet the AISC standard that ductile connections have a rotation of more than 0.03 rad at ultimate rotation. AISC serves as the primary specification for the strength design of steel components and connections. The connecting devices used are brackets and threaded rods made of steel, so the regulatory standards are appropriate and met.

Based on SNI, the experimental test results show that the most ductile connection is configuration 6 with D6 mm of 2.5, which falls into the partial ductile category. The smallest result is configuration 6 with D10 of 1.2, which is fully elastic. Referring to SNI 1729 in Table 2.6, the building structure system is only close to a conventional moment-resisting frame system for configuration 6 with D6 mm.

Research by Adisukma (Emanuel Fadjari Gumelar Adisukma et al., 2017), created beam-column connections from kruing wood using 12.5 mm thread rod connectors in configuration 4. Sample 1 used only 4 thread rods directly embedded between the kruing wood beams and columns, while Sample 2 used 4 thread rods with an additional 4 mm angle plate at the bottom. The ductility value of sample 1 was 1.43 and sample 2 was 2.33. Based on this, the use of additional brackets affects the ductility of the connection in line with experimental bamboo research conducted with a maximum ductility value of 2.5. It should be noted that increasing the diameter of the thread rod and the number of configurations has the potential to reduce ductility.

Further research related to joints with angle plates was conducted by Asmoro, Susanto & Suswanto, B (2020) (Asmoro & Suswanto, 2020). 2 without stiffeners (TSJ-1 and TSJ 3) and 2 with lower stiffeners (TSJ-H and TSJ-R). The ductility values without stiffeners were smaller at 2.711 and 2.075, while the addition of stiffeners with angle plate spacing yielded values of 7.160 and 4.176. Based on the experimental results and references, the addition of angle plates did not have a significant impact; what did affect the results was the installation distance from the center point of the load. It’s like BIM to next research (Arifin et al., 2025).

Based on the findings, the ductility testing of all samples has met the AISC 360 standard and the highest value according to SNI 1729 in the 6 D6 mm size configuration is 2.5. The results of a comparison with previous studies show the potential for increasing ductility by adding angle plates. However, a significant increase in ductility is achieved by the shape of the bracket and the support point to determine the amount of ductility increase.

## 6. Conclusions

Based on SNI, the experimental test results show that the most ductile connection is configuration 6 with D6 mm at 2.5, which falls into the partial ductility category. The smallest result is configuration 6 with D10 at 1.2, which is fully elastic. Referring to SNI 1729 in Table 2.6, the building structure system is only close to a conventional moment-resisting frame system for configuration 6 with D6 mm. The AISC 360 standard is met because all joints have an angular rotation greater than 0.06 rad. In general, laminated bamboo joints with bracket-threadrod connectors have been experimentally tested to meet SNI and AISC standards. Based on the Handbook of Structural Steel Connection Design and Details, all joints fall under the non-seismic category because their ductility value is less than 3.

Follow-up experimental testing does not stop at testing column beam brackets. Other connection elements such as columns or beams need to be studied to create a complete structural unit. Further research can be conducted through cyclic (back-and-forth) loading to simulate an earthquake.

**Author Contributions**: The author's contributions are as follows. Conceptualization: Karyadi and Nindyawati; Methodology: Arifin, A.S.; Software: Qomaliyah,E.N.; Validation: Karyadi; Formal analysis: Mustofa, I.; Writing-original draft preparation: Arifin, A.S.; Writting-review: Karyadi.

**Funding**: This research was funded by DRPM Internal LPPM Universitas Negeri Malang, grant number 21.2.51/UN32/KP/2005.

**Data Availability Statement**: We provide limited data disclosure by contacting us via email achmad.arifin.fv@um.ac.id

**Acknowledgments**: Thank you to the members of the Civil Engineering and Planning Department Lab and fellow lecturers at the Vocational Faculty.

**Conflicts of Interest**: The author declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

## References

Abdullah, L., Suhendang, E., Purnomo, H., & Matangaran, J. R. (2020). Pendugaan konsumsi kayu dalam mendukung pengelolaan hutan lestari. *Jurnal Penelitian Hutan dan Konservasi Alam, 17*(1), 99–112. https://doi.org/10.20886/jphka.2020.17.1.99-112

AISC. (2016). *AISC 360-16: Specification for structural steel buildings*. American Institute of Steel Construction.

Akbar, R. T., & F., P. E. (2010). *Handbook of steel connection design and details* (2nd ed., Vol. 2).

Arifin, A. S., Karyadi, K., & Nindyawati, N. (2023). Experimental study on the failure of bamboo laminated hollow section beam–column joints using glue-in-rod bracket. *Reka Buana: Jurnal Ilmiah Teknik Sipil dan Teknik Kimia, 8*(2), 116–127. https://doi.org/10.33366/rekabuana.v8i2.4638

Arifin, A. S., Mustofa, I., & Azhari, F. M. (2025). Sosialisasi penerapan teknologi BIM sebagai solusi efisiensi material tulangan di Tulungagung. *Community Development Journal: Jurnal Pengabdian Masyarakat, 6*(3), 4890–4897. https://doi.org/10.31004/cdj.v6i3.48733

Arifin, A. S., Ramadhani, V. M., Amin, R., Nurhida, I. S., Rekayasa, T., & Perawatan, D. (2025). Transformasi ketrampilan furniture tukang kayu: Program pelatihan smart furniture di bengkel kayu mitra Kota Malang. *JAST: Jurnal Aplikasi Sains dan Teknologi, 9*(1), 99–107. https://doi.org/10.33366/jast.v9i1.7129

Asmoro, S. H., & Suswanto, B. (2020). Studi analisis sambungan semi rigid balok-kolom baja dengan modifikasi friction damper dengan metode elemen hingga. *Jurnal Aplikasi Teknik Sipil, 18*(1), 61–72. https://doi.org/10.12962/j2579-891X.v18i1.5446

ASTM International. (2002). *ASTM D1761-88: Standard test methods for mechanical fasteners in wood.*

BPS. (2025). *Statistics of forestry production 2024* (Vol. 13). Badan Pusat Statistik.

Eratodi, I. G. L. B., Triwiyono, A., & Awaludin, A. (2014). Tahanan lateral bambu laminasi dengan konektor pelat disisipkan menggunakan sambungan baut. *Dinamika Rekayasa, 10*(1), 14–19. https://doi.org/10.20884/1.dr.2014.10.1.60

Guerra, S. P. S., Oguri, G., de Jesus Eufrade, H., Xavier de Melo, R., & Spinelli, R. (2016). Mechanized harvesting of bamboo plantations for energy production: Preliminary tests with a cut-and-shred harvester. *Energy for Sustainable Development, 34*, 62–66. https://doi.org/10.1016/j.esd.2016.07.005

Jaspart, J. P., Corman, A., & Demonceau, J. F. (2019). Ductility assessment of structural steel and composite joints. In *Proceedings of the International Colloquium on Stability and Ductility of Steel Structures* (pp. 1–9).

Karyadi, K., & Susanto, P. B. (2017). Mechanical characteristics of box-section beam made of sliced-laminated Asian bamboo (*Dendrocalamus asper*) in bending failure mode under transversal load. *AIP Conference Proceedings, 1887*. https://doi.org/10.1063/1.5003545

Karyadi, K., Basuki, E. W. A., Susanto, P. B., & Nindyawati, N. (2019). Sidewall thickening as strengthening for box-section laminated bamboo beam under transverse load in shear failure mode. *Research Journal of Applied Sciences, Engineering and Technology, 16*(3), 129–134. https://doi.org/10.19026/rjaset.16.6008

Karyadi, K., Dewi, M., Soehardjono, S., & Agoes. (2014). Characteristics of mechanics of box-section beam made of sliced-laminated *Dendrocalamus asper* under bending. *Australian Journal of Basic and Applied Sciences, 8*(16).

Karyadi, K., Putri, O. P., Susanto, P. B., & Nindyawati, N. (2020). Strength and stiffness of segmented compression part beam made of sliced laminated bamboo due to transverse load on shear failure mode. In *Proceedings of the 4th International Conference on Vocational Education and Training (ICOVET 2020)* (pp. 278–283). https://doi.org/10.1109/ICOVET50258.2020.9230108

Muhammad Suandi, M. E., Amlus, M. H., Hemdi, A. R., Abd Rahim, S. Z., Ghazali, M. F., & Rahim, N. L. (2022). A review on sustainability characteristics development for wooden furniture design. *Sustainability, 14*(14), Article 8748. https://doi.org/10.3390/su14148748

Obara, P. (2028). *Verification of orthotropic model of wood.*

Rini, D. S. (2018). Sifat fisika bambu petung (*Dendrocalamus asper*) dari KHDTK Senaru berdasarkan posisi aksial. *Jurnal Belantara, 1*(2), 101–106. https://doi.org/10.29303/jbl.v1i2.83

SNI. (2020). *SNI 1729:2020: Spesifikasi untuk bangunan gedung baja struktural*. Badan Standardisasi Nasional.

Syafi'i, M. I. (2019). Pengaruh variasi panjang sambungan bibir lurus dan baut pada kuat lentur balok bambu petung laminasi. *Jurnal REKATS: Rekayasa Teknik Sipil, 7*(4), 1–5.