WORLD CONFERENCE ON TIMBER ENGINEERING 2025
BRISBANE, AUSTRALIA

Advancing Timber for the Future Built Environment

BASIC STUDY OF GLUED LAMINATED BAMBOO (GLB)

Haruto MITSUZONO[1], Atushi TAKANO[2]

ABSTRACT: The material and joint properties of Glued Laminated Bamboo(GLB) made of Moso bamboo harvested from Japan were verified. The results showed that the basic material strength of the GLB in bending, shear, and compression. The characteristics of the joints were evaluated, which GLB to GLB or GLB to plywood with screws, and skeleton curves were drawn.

KEYWORDS: glued laminated bamboo, material strength, joint strength

1 – INTRODUCTION

GLB have been studying as a structural material for permanent buildings since 2021, and obtained an individual certification to construct a one-story building (hereafter referred to as "model building") in 2023 for us. In this process, several types of structural test were conducted and acquired some result. The present study reports some basic results.

2 – BACKGROUND

In recent years, the wood has been attracting interest as a renewable resource, and is actively used as building material and fuel. As a result, it has been pointed out that wood resources will be depleted in the future due to a rapid increase in the amount of wood used and inadequate reforestation after logging. Against this background, bamboo is attracting attention as an alternative renewable resource in Japan. For example, cedar, which is commonly used as material, however, which takes more than 30 years to reach maturity, while bamboo becomes mature bamboo in 3 to 5 years, making it a highly available resource[1],[2]. There are previous academic studies on bamboo that have represent the material strength studies on the material strength of split bamboo[3],[4],[5] , the material strength of glued laminated bamboo (GLB) [6] , and the effect of manufacturing methods on the strength of structural materials made from bamboo[7],[8]. These previous studies have shown that the strength of bamboo materials is affected by the bending strength and the tensile strength of bamboo. In addition, these previous studies have reported the excellent mechanical properties of bamboo, namely high bending, tensile performance, and toughness. The manufacture methods change the characteristic of bamboo on the property values. However, all of these studies have been limited to reports on the effects of basic material strength, joint characteristics, and manufacturing methods. The purpose of this study is to determine the material standard strength and joint standard strength required for the use of GLB as a structural material. In this paper, the material and joint strength properties are examined based on the material strength tests using the test methods of timber.

3 – MATERIAL

Glued Laminated Bamboo (GLB) is the laminated strips; stand bamboo split into 8~12 equal pieces cut rectangular in cross section, drying and dry distillation. Direction of GLB is exhibited on *Fig. 1*.

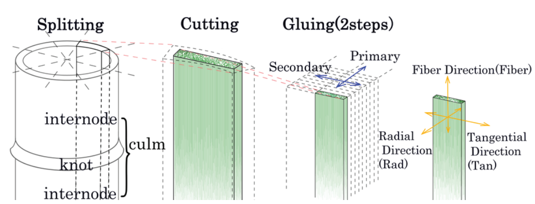


Fig. 1 Manufacturing outline and Definition of fiber direction (GLB)

[1]Haruto MITSUZONO, Kagoshima University Graduate School of Science and Engineering, Kagoshima, Japan, k7418774@kadai.jp

[2] Atushi TAKANO, Assoc. Prof., Kagoshima University Graduate school of Science and Engineering, Kagoshima, Japan, takano@aae.kagoshima-u.ac.jp

https://doi.org/10.52202/080513-0505

4 –Test protocol

Tests and Assessments were based on “Japanese Agricultural Standards[9]”, “Japanese Industrial Standards [10]” and Test manual in Japan[11]. Tests were conducted in 2021 and therefore do not refer to ISO 23478[12] in 2022, ISO 5257[13] in 2023 and ISO 7567[14] in 2024. *Talbe1* provides a summary of material tests and *Talbe2* provides a summary of joint tests. More Details are exhibited in the next section.

4 .1–Material strength test

All specimens patterns of material test are exhibited in *Table 1*. The material test is monotonic load. After the maximum load, the load was applied until the load dropped to 80% of the maximum load. Each characteristic: strength and modulus of elasticity, value is calculated following each standard and manual.

4.1.1 – Bending test (material)

Bending specimen plan is exhibited in *Fig. 2*. Each six, 40mm wide x 150mm high x 1500mm long beams, were made. Four-point bending tests were performed on two types with different fiber directions. Loading speed is 30mm/min. Bending strength and modulus of elasticity in bending are calculated by reference No.[9]

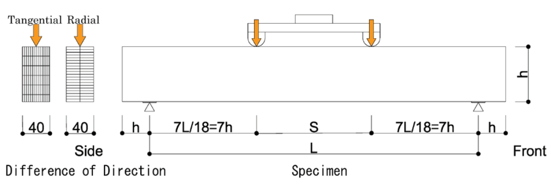


Fig. 2 Bending specimen plan

4.1.2 – Shearing test (material)

Two shearing tests, “Block scale shearing test” and “Real scale shearing test”, were performed. Shearing specimen plan is exhibited on *Fig. 2* and *Fig. 3.* Block scale; each six, 40mm wide x 30mm depth x 40mm high (including 10mm chip) and Real scale; 40mm wide x 150mm high x 800mm long, were made on each two types with different fiber directions. Block shearing test by chair shear test and real shearing test by asymmetric four-point bending test were performed. Shear strength parallel to the grain is calculated by reference No.[10], [11]

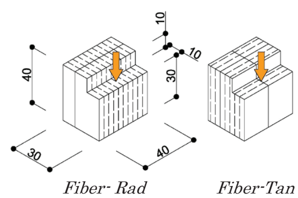


Fig. 3 Block scale shearing specimen plan

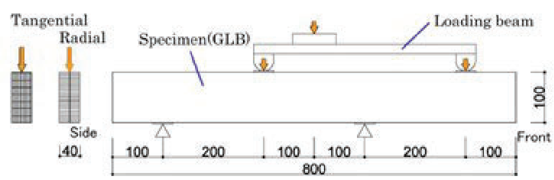


Fig. 4 Real scale shearing specimen plan

4.1.3 – Compression test (material)

Two Compression tests, “Compression parallel to the grain test” and “Compression Perpendicular to the grain”, were performed. Compression specimens plan is exhibited in *Fig. 5 and Fig. 6*. Compression parallel to the grain; each six, 40 x 40mm (d=40) cross section x 40(1d), 80(2d), 120(3d) mm high, and Compression Perpendicular to the grain; each six, 40 x 40mm (d=40) cross section x 200mm long, specimens were made. Loading speed is 1 mm/min.

Table 1 List of material strength specimen pattern

Test	method	Specific value	Dimension[mm]	Standards
Bending	4-point bending	Bending strength modulus of elasticity in bending	W40-H150-L2000	Reference by [2]
Shear	Block scale	shear strength parallel to the grain	40-30-L40	Reference by [1]
	Real scale		W40-H100-L800	Reference by [3]
Compression	longitudinal compression	compression strength parallel to the grain	40-40-h40~120	Reference by [3]
	partial transverse compression	yield strength in compression perpendicular to the grain	40-40-L240	Reference by [3]

Table 2 List of joint strength specimen pattern

Specimen				Main part size[㎜]; material	Outer part size[㎜]; material	Center part size[㎜]; material	Screw	Relation of fiber and load directions(Main/ Outer/ Center)
Sin-gle	Parallel		-A/-B	40×40×250; GLB*	40×40×250; GLB	-	P5-80II+ -4	Parallel/ Parallel/-
	Vertical		-A/-B*	40×40×250; GLB*	40×100×250; GLB	-	P5-80II+ -4	Parallel/ Vertical/-
Double	Parallel	-ply	-A/-B*	28×40×200; plywood	40×40×200; GLB*	-	P6-100II+ -2	Parallel/ Parallel/-
		-glb	-A/-B*	40×40×200; GLB*	40×40×200; GLB	-	P6-120II+ -2	Parallel/ Parallel/-
	Vertical	-ply	-A/-B*	28×60×130; plywood	40×40×200; GLB*	-	P6-100II+ -1	Vertical/ Vertical /-
		-glb	-A/-B*	40×40×200; GLB*	40×100×200; GLB	-	P6-120II+ -2	Parallel/ Vertical /-
Quadr-uple	Parallel		-A/-B	40×100×200; GLB	40×100×200; GLB	28×100×200; GLB	P6-185II+ -2	A: Parallel/ Parallel/ Parallel B: Vertical / Vertical / Vertical
	Vertical		-A/-B*	37×40×200; GLB*	40×100×200; GLB	34×100×200; GLB	P6-185II+ -2	Parallel/ Vertical / Vertical

*: The difference between A and B is fiber direction of GLB. Different part is indicated by “ * “ in ‘Main’ or ‘Outer’.

https://doi.org/10.52202/080513-0505

Compression strength parallel to the grain and yield strength in compression perpendicular to fiber is calculated by reference No. [11]. At the time of compression parallel to the grain test, using the platen with spherical bearing is defined. However, GLB is prone to buckling even with a short specimen. So, the platen which are parallel to each other to avoid early buckling.

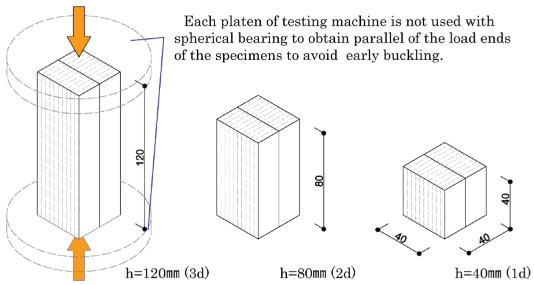


Fig. 5 Compression parallel to the grain test specimen plan

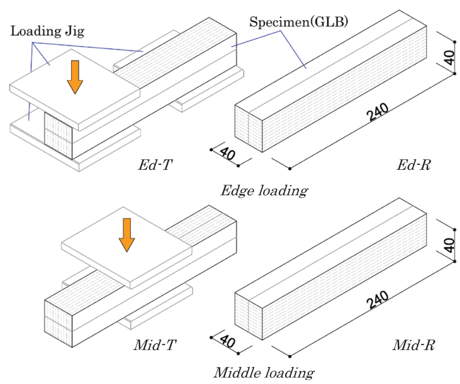


Fig. 6 Compression Perpendicular to the grain test specimen plan

4.2 –Joint shearing test

All specimen patterns of joint shearing test are exhibited in *Table 2*. Three types of tests were conducted: Single shearing, Double shearing, and Quadruple shearing. The joint test is evaluated seven specimens of each type, with the first specimen subjected to monotonic load and the second to seventh specimens subjected to repetitive load follow schedule. Schedule is 1/2, 1, 2, 4, 6, 8, 12, 16 times primary yield displacement(P_{y1}). After the maximum load, the load was applied until the load dropped to 80% of the maximum load or until the main part was pushed all the way through. Each characteristic: primary and secondary yield load(P_{y1} and P_{y2}), ultimate load(Pu), primary and secondary yield displacement(δ_{y1} and δ_{y2}) and ultimate displacement(δu) is assessed following the manual and draw the skeleton curb.

4.2.1 – Single shearing test (joint)

Single shearing specimen plan is exhibited in *Fig. 7*. One main part and two outer parts fasten with screws to set up four patterns. Parallel; main part, 40mm wide x 40mm depth x 250mm high, and outer part(GLB), 40mm wide x 40mm depth x 250mm high(GLB), and Vertical; main part, 40mm wide x 40mm depth x 250mm high and outer part(GLB), are combined so that vertical to the main and outer part. They are made in each two types (-A and -B) with different fiber directions.

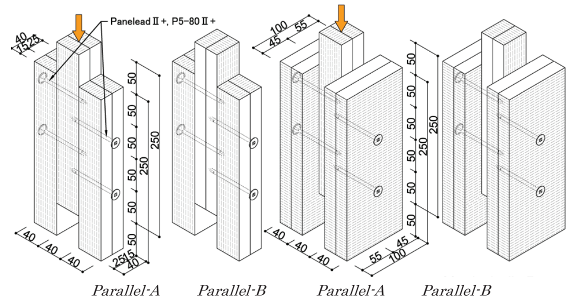


Fig. 7 Single Shearing specimen plan

4.2.2 – Double shearing test (joint)

Double shearing specimen plan is exhibited in *Fig. 8* and *Fig. 9*. One main part and two outer parts fasten with screws to set up four patterns. Parallel-ply; main part(plywood), 40mm wide x 40mm depth x 200mm high, and outer part(GLB), 40mm wide x 40mm depth x 200mm high, and Parallel-glb; main part(GLB), 40mm wide x 40mm depth x 200mm high, and outer part(GLB), 40mm wide x 40mm depth x 200mm high, are combined so that parallel to the main and outer part. Vertical-ply; main part(plywood), 60mm wide x 28mm depth x 130mm high, and outer part(GLB), 40mm wide x 40mm depth x 200mm high, and Vertical-glb; main part(GLB), 40mm wide x

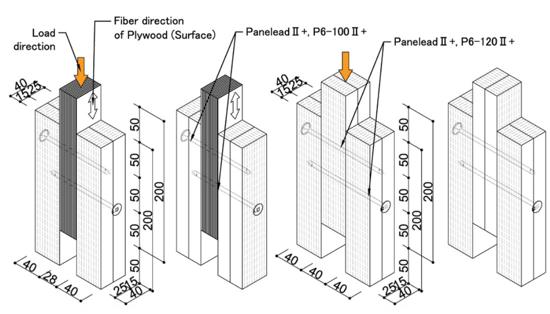


Fig. 8 Double Shearing specimen plan(Parallel)

40mm depth x 200mm high, and outer part(GLB), 100mm wide x 40mm depth x 200mm high, are combined so that vertical to the main and outer part. They are made in each two types (-A and -B) with different fiber directions.

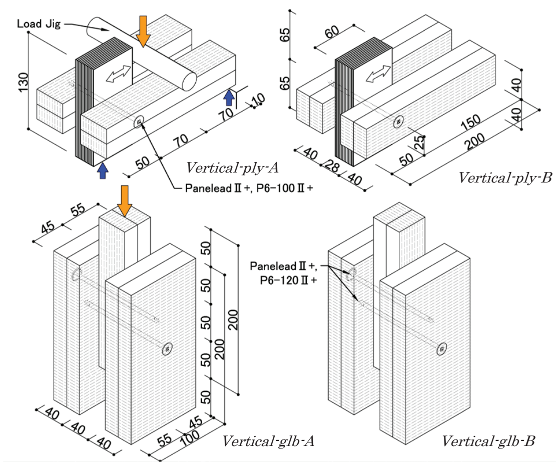


Fig. 9 Double Shearing specimen plan(Vertical)

4.2.3 – Quadruple shearing test (joint)

Quadruple shearing specimen plan is exhibited in *Fig. 10*. One main part, two outer parts and one center part fasten with screws to set up four patterns. Parallel; main part(GLB), 100mm wide x 40mm depth x 200mm high, outer part(GLB), 100mm wide x 40mm depth x 200mm high, and center part(GLB) 100mm wide x 28mm depth x 200mm high, are combined so that parallel to All part. Vertical; main part(GLB), 40mm wide x 37mm depth x 200mm high, outer part(GLB), 100mm wide x 40mm depth x 200mm high, and center part(GLB) 100mm wide x 34mm depth x 200mm high, are combined so that Vertical to the main and other part. They are made in each two types (-A and -B) with different fiber directions.

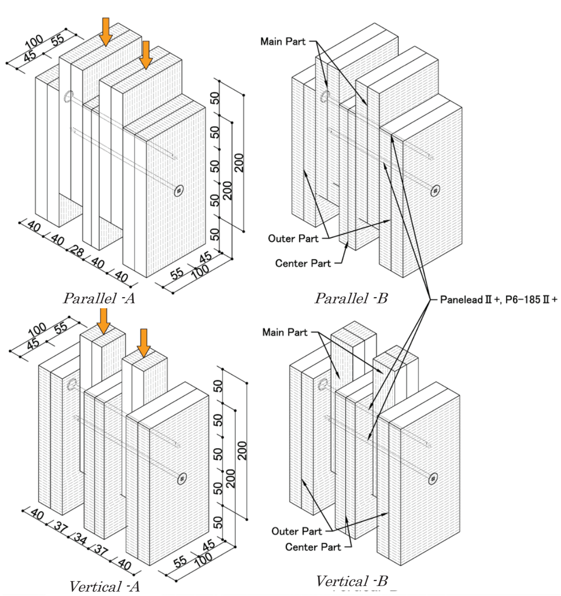


Fig. 10 Quadruple Shearing specimen plan

5. –Test result

5.1 –Material test

5.1.1 – Bending test

Bending test result is exhibited in *Table 3*. Bending strength and Modulus of elasticity of bending exhibited similar values regardless of direction. And standard deviation is about twice as large in Radial direction than in Tangential direction. This is because the properties of individual laminas are averaged out in the tangential direction where the number of laminae is greater relative to the width of the piece, and thus standard deviation is presumably smaller.

Table 3 Bending Characteristic value

Load direction	Radial direction		Tangential direction	
	Fb	Eb	Fb	Eb
unit	[N/㎟]	[kN/㎟]	[N/㎟]	[kN/㎟]
Mean	84.28	10.11	86.17	10.26
Max	90.04	10.88	88.45	10.70
Min	73.99	9.41	81.84	9.86
SD	5.51	0.56	2.45	0.29
n	6		6	

Fb: Bending Strength Eb: Modulus of elasticity of bending

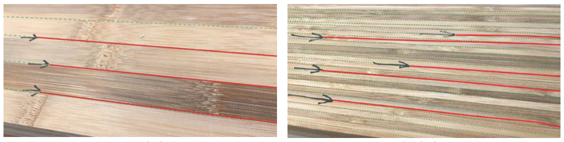
5.1.2 – Shearing test

Shearing test result is exhibited in *Table 4*. Shearing strength varied greatly depending on the scale and fiber direction of the specimens. And, shearing strength by real scale shearing test is smaller than that of block scale. This may be because there are some parts that were preceded by fracture of the adhesive rather than the culm part. In the future, improving adhesives and bonding methods are expected. Furthermore, it is necessary to consider the use of a method that assumes that the destruction of the adhesive part precedes the destruction of the adhesive part.

Table 4 Shearing characteristic value [N/㎟]

	Block scale		Real scale	
	Fiber- Rad	Fiber-Tan	Radial	Tangential
Mean	15.67	18.75	13.72	11.83
Max	16.77	20.32	15.31	12.81
Min	14.79	16.47	12.25	10.22
SD	0.73	1.28	1.07	1.14
n	6	6	6	6

https://doi.org/10.52202/080513-0505



※Green dashes: Gluing surface, Red line: Failure surface

Fig 1 Destruction Property (Real scale Shearing)

5.1.3 – Compression test

Compression test results are exhibited in *Table 6* and

Table
7
.

Compression strength parallel to the grain is almost the same regardless of specimen high(equal d). This is because of the buckling during the loading process. So, compression strength parallel to the grain obtained in this paper is not PURE compression strength parallel to the grain, hereinafter referred to as *compression strength parallel to the grain (presumptive)*.

In compression, it yields strength perpendicular to the grain, although the difference of load by load-point is small, a difference of load-by-load direction is not small. In particular, the tangential direction specimen showed 1.5 times higher load than the radial direction specimen. In the case of Laminated Veneer Lumber (LVL), the vertical using (perpendicular to the load direction laminated direction) has greater resistance to compression than the flat using (parallel to the load direction and laminated direction) [15]. This is because in the flat using, the earlywood and veneers with low strength are selectively deformed, while in the vertical using, the latewood and veneers with high strength that are aligned in the direction of load resist deformation and compensate for the low strength areas. The same characteristic is thought to have been observed in GLB with structure like LVL.

Table 6 Compression strength parallel to the grain (presumptive) [N/㎟]

h	120 ㎜(3d)	80 ㎜(2d)	40 ㎜(1d)	All
Mean	42.51	44.90	47.87	45.09
Max	45.51	47.48	54.77	54.77
Min	40.57	42.83	43.74	40.57
SD	1.93	1.55	3.72	3.31
n	6	6	6	18

Table 7 Compression yield strength perpendicular to grain [N/㎟]

	Middle loading		Edge Loading	
	Radial	Tangential	Radial	Tangential
Mean	9.68	12.87	7.66	12.59
Max	12.32	16.03	8.42	15.28
Min	8.09	8.64	6.16	10.12
SD	1.98	2.94	1.01	1.74
n	6	6	6	6

Fig 2 Destruction Property (compression parallel to the grain test (1d))

5.2 –Joint shearing test

All results of joint tests are exhibited in *Table 5*. Details are given in the next section.

5.2.2 – Single shearing test

Single shearing test results(skeleton curb) is exhibited in *Fig. 11* and *Fig. 12*. The thin orange and blue lines in the graphs show the P-δ curves of each specimen based on actual measurements, and the orange and blue thick lines show the skeleton curves evaluated for each specimen type. The load decreases gradually after the maximum load is reached, indicating that there is little difference in bearing

Table 5 Assessment results of the joint test per one screw

Specimen	Single shear				Double shear (GLB)				Double shear (Plywood)				Quadruple shear			
	Parallel		Vertical		Parallel		Vertical		Parallel		Vertical		Parallel		Vertical	
	-A	-B$	-A	-B$	-A	-B$	-A	-B$	-A	-B$	-A	-B$	-A	-B	-A	-B$
Specimen type	Rocket		Rocket		Rocket		Rocket		Rocket		Bridge		Rocket		Rocket	
Screw	P5-80II+		P5-80II+		P6-120II+		P6-120II+		P6-100II+		P6-100II+		P6-185II+		P6-185II+	
Assessment method	Tri-linear		Tri-linear		Tri-linear		Tri-linear		Offset method (0.3mm)		Tri-linear		Tri-linear		Tri-linear	
Valid specimens number Yield / Ultimate	4/4	5/5	5/5	5/5	5/5	4/4	5/3	5/4	6/4	6/5	6/6	5/5	6/6	4/4	6/6	6/6
Yield Load Py[kN]	2.61	2.68	2.57	2.54	5.62	5.98	6.51	6.23	4.83	4.00	4.29	4.21	11.4	17.5	11.2	12.0
Yield Load SD [-]	0.39	0.78	0.99	0.75	0.45	0.66	0.50	0.54	0.42	0.11	0.47	0.37	1.23	2.98	0.81	1.27
Displacement of First Yield point(δy_1)[mm]	0.23	0.18	0.45	0.42	0.95	1.03	1.80	1.39	1.76	0.88	1.02	0.87	1.61	4.48	1.42	1.75
Displacement of Second Yield point(δy_2)[mm]	7.12	6.09	7.27	7.24	4.48	6.43	7.27	7.02	9.13	10.6	3.96	3.04	5.43	13.9	5.50	6.24
Ultimate Load Pu[kN]	5.52^{*2}	5.52^{*2}	5.45^{*2}	5.41^{*2}	10.5^{*3}	11.8^{*3}	13.6^{*3}	14.0^{*3}	7.41	7.91	6.62^{*3}	6.41^{*3}	19.6^{*3}	28.1^{*3}	20.7^{*3}	21.8^{*3}
Ultimate Load SD [-]	0.97^{*2}	1.97^{*2}	1.92^{*2}	1.58^{*2}	1.50^{*3}	2.26^{*3}	0.75^{*3}	1.42^{*3}	1.11	0.40	0.71^{*3}	0.64^{*3}	1.45^{*3}	2.65^{*3}	1.31^{*3}	1.35^{*3}
Displacement of ultimate point(δu)[mm]	21.4^{*2}	21.2^{*2}	27.1^{*2}	27.4^{*2}	10.8^{*3}	10.7^{*3}	9.76^{*3}	9.14^{*3}	30.0	30.0	8.56^{*3}	8.30^{*3}	24.0^{*3}	37.6^{*3}	9.53^{*3}	10.0^{*3}

$: The difference between A and B is fiber direction of GLB. Different part is indicated by "$". *1: Standard Deviation
*2: In some specimen ultimate characteristics was observed cleavage destruction by screw.
*3: Ultimate characteristics was observed cleavage destruction by screw.

capacity depending on the shape of the specimen and the fiber direction. The main cause of the load drop was the pulling out of screws, and the load drop due to splitting of the part was small. This is because the screws were applied from the outer parts to the main part, so the pulling out of the screws preceded the cracking of the part, and the bearing capacity of the specimens depended on the bending and pulling out of the screws.

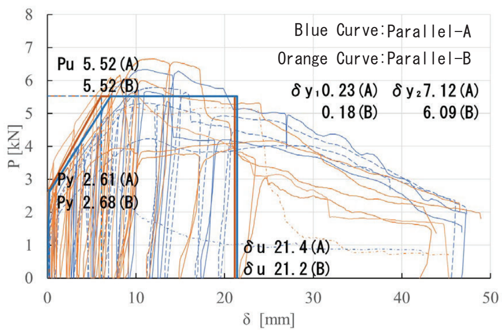


Fig. 11 P-δ curve (Single Shear test(Parallel))

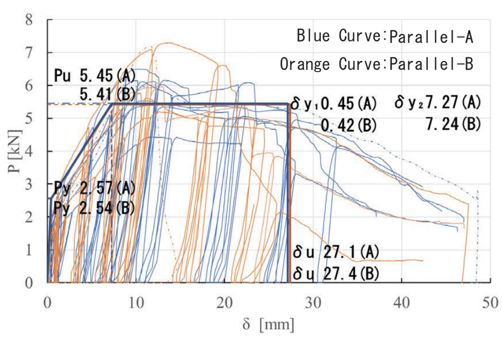


Fig. 12 P-δ curve (Single Shear test(GLB)(Vertical))

5.2.2 – Double shearing test

Double shearing test results(skeleton curb) is exhibited in *Fig. 13* to *Fig. 16*. All specimens showed similar skeleton curve and specimens with parallel-glb and vertical-glb showed a significant load drop after reaching the maximum load. This is thought to be because the screws during loading apply load in the direction that tries to split the bamboo fibers (fiber direction), which makes the main and outer parts more prone to cracking. In addition, the standard deviation of yield load in the same shape is small, but the standard deviation of ultimate load is large. This is thought to be mainly due to the standard deviation.

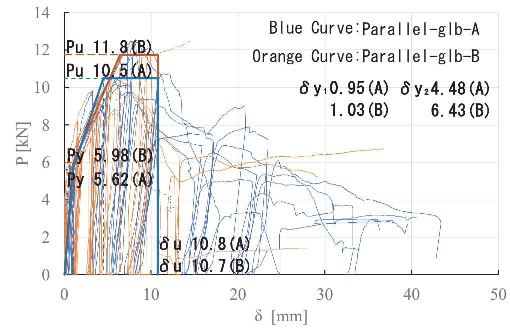


Fig. 13 P-δ curve (Double Shear test(GLB)(Parallel-glb))

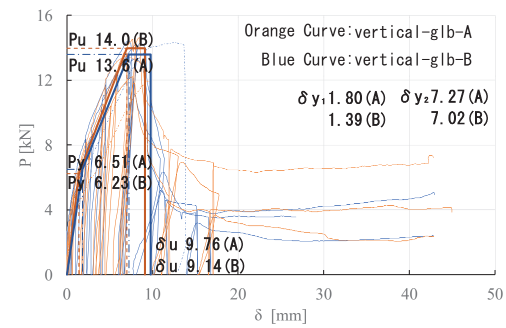
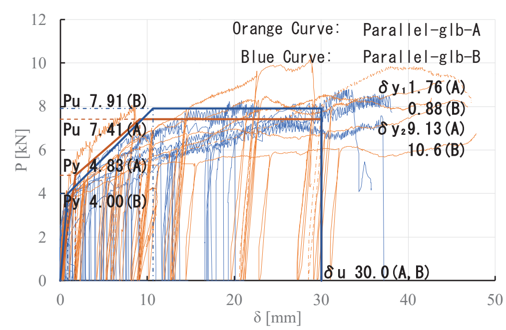


Fig. 14 P-δ curve (Double Shear test(GLB)(Vertical-glb))



** Parallel-ply-A and B didn't reach ultimation and were evaluated using the following methods(Offsets method).*
Yield point: Offset method(δ=0.3mm) Ultimate point: Point of δ(30.0mm)
Primary Stiffness: Slope of line passing 0.1Pmax and 0.4Pmax
Secondary Stiffness: Slope of line passing 0.4Pmax and 0.9Pmax
Fig. 15 P-δ curve (Double Shear test(parallel-ply))

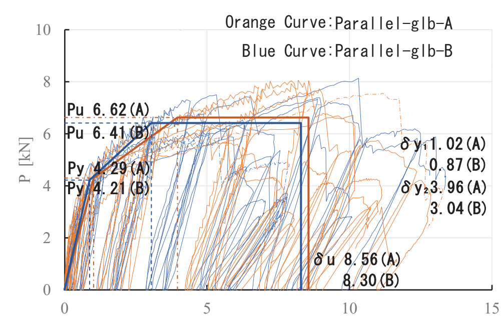


Fig. 16 P-δ curve(Double Shear test(Plywood)(Vertical-ply))

https://doi.org/10.52202/080513-0505

in the physical properties of bamboo, since the ultimate load depends on the cracking of the culm. Compared to specimens with similar geometry in the single shearing test, the values for each bearing capacity are generally about twice as high, confirming the effect of the increase in the number of shear faces per screw. On the other hand, the ultimate displacement was less than half that of the single shearing test, suggesting that the difference in ultimate properties was mainly due to the pullout of screws in the single shearing test and the cracking of part in the parallel-glb and vertical-glb.

In Parallel-glb, many of the tests did not cause load drop in the plastic region, and the endpoint could not be determined in many cases. This is largely because of friction on the shear surface caused by the attraction of the outer parts to the main part during loading. Fracture properties showed that, unlike in the parallel-ply and vertical-ply, there was little cracking of the specimen. This may be because the veneers that were perpendicular to the direction of the fiber and the direction of the stress were cracked or pulled inward, indicating that the cracks were caused by the plywood rather than the GLB.

On the other hand, in the vertical-ply, the edge cracking of the outer parts at the end of the shear test induced a significant load drop. Compared to the parallel-ply and vertical-ply, the overall bearing capacity was lower. This is thought to be because when the main part is plywood, the bearing capacity against penetration is smaller.


Parallel(side) Parallel(bottom) Vertical(upper) Vertical(bottom)
Fig. 17 Destruction property(Double Shear test(GLB))


Parallel(side) (front-after) (front-before) Vertical(front)
Fig. 18 Destruction property (Double Shear test(Plywood))

5.2.3– Quadruple shearing test

Quadruple shearing test results(skeleton curb) is exhibited in *Fig. 19* and *Fig. 20*. In all specimens, cracks parallel to the fibers were observed, regardless of the load direction, and were the main cause of the load drop in the Parallel-A specimens. This is because the cross section of the main part of Vertical is smaller than that of Parallel-A, and cracking is more likely to occur. On the other hand, in Parallel-B, although some specimens showed a load drop, the drop was significantly slower than in Parallel-A Vertical-A and -B. This is because the load drop in Parallel-B was slower than in Parallel, Vertical-A and -B. This may be because in Parallel-B, unlike the other tests, the screws were significantly embedded in the GLB, and the fiber direction of the GLB and the direction of the applied load were perpendicular, making it difficult to crack, and thus increasing the toughness.

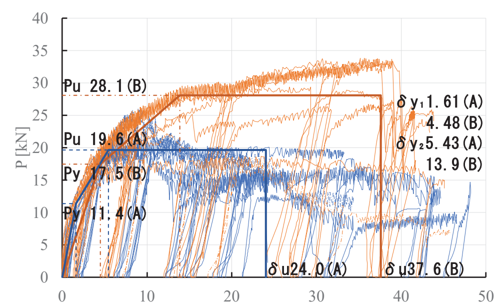


Fig. 19 P-δ curve (Quadruple Shear test(Parallel))

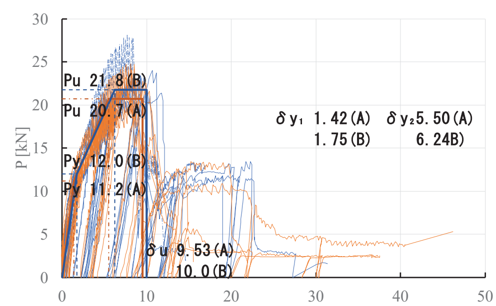
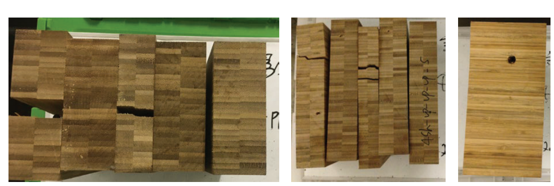
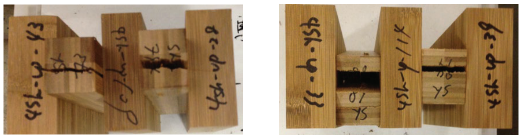


Fig. 20 P-δ curve (Quadruple Shear test(Vertical))


Parallel-A(Bottom) Parallel-B(Front) -B(Side)



Vertical(Top) Vertical(Bottom)

Fig. 21 Destruction property(Quadruple Shear test)

6 – CONCLUSION

In this paper, the following findings and issues were obtained.

Table 8 Material Characteristic value

	n	Mean±SD
Bending Strength(h=100)	6	84.28±5.51 N/㎟
Modulus of elasticity of Bending	6	10.11±0.56 kN/㎟
Compression strength parallel to grain	18	45.09±3.31 N/㎟
Compression strength perpendicular to grain	6	7.66±1.01 N/㎟
Shearing Strength (Real-Rad)	6	13.72±1.07 N/㎟

a) The basic material strength and joint strength property of GLB were obtained *Table 5* and *Table 8*. In the future, material standard strength by increasing the number of specimens were expected.
b) The main cause of load reduction in material tests is cracking the gluing surface. In the future, by improving the adhesion performance, high material strength can be expected to develop.
c) When a screw joins two members, the difference in bearing capacity due to fiber direction is small for specimens of the same shape. This may be because the bearing capacity depends on the yield and pullout failure of the screws.
d) When screws are used over three or more members, load reduction is observed due to cracking in the fiber direction of the GLB. This cracking always occurs in the fiber direction, regardless of the direction of the applied force.

7 – REFERENCES

[1] Lou Yiping, Li Yanxia, et al：Bamboo and Climate change Mitigation, Technical Report No.32, INBAR 2010

[2] Forestry Agency：[Toward Increased Utilization of Bamboo, Forestry Agency]Take no rikatsuyou zoshin ni mukete rinyacho(in Japanese), 2018

[3] Obataya Eiichi, et al.：Bending characteristics of bamboo (Phyllostachys pubes-cents) with respect to its fiber-foam composite structure, Wood sci Technical, 2007.2

[4] Nariaki Hondayama, Hirokazu Toki, Kenji Naruo, Shuntaro Chiba: [Studies on Formulation of Bamboo Form and Material Strength (Part 1) Results of Bamboo Form Survey, Formulation and Material Strength Tests] takno no kejo no teishikika oyobi zairyokyodo ni kansuru kenkyu (sono 1) takeno kejochosakekka to teisikika oyobi zairyokyodo sikenkekka, Architectural Institute of Japan, Summaries of technical papers of annual meeting (Tohoku) (in Japanese), pp.1387-1388, 2018

[5] Shuntaro Chiba, Hirokazu Toki, Kenji Naruo, Nariaki Hondayama: [Studies on Formulation of Bamboo Form and Material Strength (Part 2) Consideration of Determining Factors of Tensile and Shear Strength of Bamboo] Take no kejo no teishikika oyobi zairyokyodo ni kansuru kenkyu (sono 2) take no hippari kyodo oyobi sendan kyodo no kettei insi no kosatsu, Architectural Institute of Japan, Summaries of technical papers of annual meeting (Tohoku) (in Japanese), pp.1389-1390 2018

[6] Hidekazu Yamamoto, Tishihiro Kusunoki, Hidetoshi Hayashida, Hajime Taniguchi：Experimental Study on Bending Creep Behaviour of Glued Lamindated Bamboo Member, Architectural Institute of Japan, Summaries of technical papers of annual meeting (Kyusyu) (in Japanese), pp.37-38, 2007

[7] Kent A. Harries: Material characterisation of bamboo for glued-laminated products, Advances in Bamboo Science, vol. 3, 2023. 3.

[8] B. U. Kelkar, et al.: Review, Structural bamboo composites: A review of processing, factors affecting properties and recent advances, Advances in Bamboo Science, vol. 3, 2023. 3.

[9] Japanese Agricaltual Standards, Glued Laminated Timber (JAS1152), (Public Notice of the Ministry of Agriculture, Forestry and Fisheries No. 475 of June 27, 2019)

[10] Japanese Industrial Standards, JIS Z 2101:2009 Methods of thest for woods, 2009

[11] Japan Housing and Wood Technology Center [Manual for Strength Testing of Structural Wood] Kozoyo mokuzai no kyodo siken manyuaru (in Japanese), 2011.3

[12] ISO 23478: 2022 Bamboo structures-Engineered bamboo products -Test methods for determination of physical and mechanical properties-

https://doi.org/10.52202/080513-0505

[13] ISO 5257:2023 Bamboo structures-Engineered bamboo products-Test methods for determination of mechanical properties using small size specimens-

[14] ISO 7567:2024: Bamboo structures — Glued laminated bamboo — Product specifications

[15] [Ippan shadan hozin Zenkoku LVL kyokai] Nationai LVL association, General incorporated association: [kozoyo tanban sekisouzai no merikomi seino siken hokokusho] Structural Laminated Veneer Lumber Caving-in Performance Test Report, 2010