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Study on Mechanical Properties of Moso Bamboo in Jian'ou City, Fujian Province, China

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Abstract

The original bamboo material of 3 to 4-year-old moso bamboo in Jian'o City, Fujian Province, was used as the research object. Study the change of mechanical properties such as axial compressive strength, bending strength, tensile strength, shear strength, and hardness test. The main work and results of this paper include:Forty-five longitudinal compression specimens on moso bamboo tubes were tested to investigate the effects of different sizes and bamboo knots on the axial compressive strength of the moso bamboo tubes. The mean tensile strength of moso bamboo was found to be 165.13 N/㎜². A total of 27 shear specimens of 5cm moso bamboo tubes were tested, and their average shear strength was 2.61Mpa; he average flexural strength of moso bamboo was 172.48N/㎜². The hardness of moso bamboo specimens was tested using the Janka hardness method. The hardness of each part of Moso bamboo was significantly different.Comparing the mechanical properties of moso bamboo with other wood timber, moso bamboo showed better mechanical properties, the research hoped to provide a theoretical basis and scientific evidence for a comprehensive understanding of the complex mechanical properties of Fujian moso bamboo and the use of moso bamboo in high value-added applications.

Keywords: *Moso Bamboo, Original Bamboo, Mechanical Properties, Jian'ou City, Fujian Province, China;Processing Application.*

INTRODUCTION

Bamboo is a significant forest resource, with its fast growth, high yield and the performance advantages of lightweight and high toughness. With the development of bamboo processing technology, bamboo in the construction, furniture production, bamboo weaving crafts and other areas of use are more extensive. Yang in [1], bamboo instead of wood has become the best way to solve the lack of wood resources. The distribution of moso bamboo is mainly from the south of the Yangtze River Basin and Fujian and Jiangxi Provinces in China, and it is the bamboo species with the largest distribution area in China. Ai in [2], the mechanical characteristics of bamboo material are the definitive reference for the utilisation of bamboo. This research measured the longitudinal compressive strength, tensile strength, bending strength, shear strength, and hardness of different parts of Fujian moso bamboo aged 3 to 4 years and analyzed the failure mode.

The purpose of this research is to reveal the variation of various mechanical property parameters and mechanical properties of Fujian moso bamboo, to provide crucial mechanical property data for the industrial utilisation of moso bamboo, and to promote its application.

Moso Bamboo Materials and Mechanical Properties Test

The moso bamboo in Jian'ou City, Fujian Province, China selected for this experimental study was harvested in late September 2023 and taken from the bamboo forest of Cikou Village, Jianou City. Yu in [3], Cikou Village has an altitude of 258 meters, the region's annual mean temperature is between 15℃ and 25℃. And the selected site conditions are the same. Su in [4], the samples were 3 to 4 years old and harvested in late September, when bamboo has low moisture and sugar content, stable mechanical properties, and is less susceptible to pests, diseases, rot, and mould. The selected bamboo had a similar diameter at breast height (5cm to 8cm), each sample about 2.0 m long section was cut from the bamboo knot upwards to be used as the test material for the bottom, middle, and top parts of the plant, and a total of 50 pieces of the sample were felled and transported back to the plant, as shown in Figure 1. The bamboo culms were selected, labelled, cut, treated, and dried, and

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the specimens were transported and placed after a long period of outdoor storage to control their moisture content to 10% to 12%.

Figure 1 .The site of moso bamboo sample felling (Taken by the author)

Compression Strength Test

The method used to test the compressive strength of moso bamboo, concerning the standard ISO 22157-1:2004, moso bamboo tubes were chosen as the research object. In the experiment, five moso bamboo tubes were randomly selected, the whole bamboo tubes were divided into three sections, namely the bottom, the middle and the top section, and the 5cm bamboo tubes without bamboo knots and the neighbouring 10cm tubes with and without bamboo knots intercepted from each section, which made a total of 45 compression test specimens, and compared the strength changes of the bamboo tubes in different sample parts and discussed the effect of bamboo knots on the compressive strength, as shown in Figure 2.

The experiment uses the fully automatic flexural and compressive testing machine produced by Wuxi Emino Testing Machine Co., Ltd, model DYE-300, the maximum experimental force is 300KN. Yang in [5], the bamboo tube specimen was placed on the upper and lower steel plates and checked the flatness of the upper and lower sections of the bamboo tube. The load is holded at the same speed of 0.1 mm/s and the maximum load value that invalidates the specimen is recorded. Formula for calculating the compressive strength of bamboo tubes：

$$\sigma_{ult} = \frac{F^{ult}}{A} \qquad (1)$$

In the compressive strength formula, σ_{ult} is the compressive strength of bamboo tube specimens (MPa))；F^{ult} is the maximum compressive load of bamboo tube specimens(N)；A is the cross-section area of bamboo tube specimen (mm^2)；

Figure 2 . The compression test process of bamboo (Taken by the author)site of

Bending Strength Test

Bending strength test experiments with the previous chapter of the experiment for the same batch of moso bamboo, select three moso bamboo, each moso bamboo top, middle, and bottom of each of the three experimental specimens, a total of 27 specimens, specimen processing size of 250mm long, 12mm wide. Jin in [6], ensures the accuracy and consistency of the test data, all take the bamboo yellow face up for the bending test and the specimen avoids the bamboo knot in the middle position. The bending strength of moso bamboo

specimens was measured using the Shimadzu Precision Microcomputer Controlled Electronic Universal Testing Machine, model CMT6104, with a maximum load of 10KN, as shown in Figure 3.

The standard and data processing method performed is the determination of static bending strength of wood-based panels GB/T17657-1999, and the loading speed of the load is 10.0mm/min.

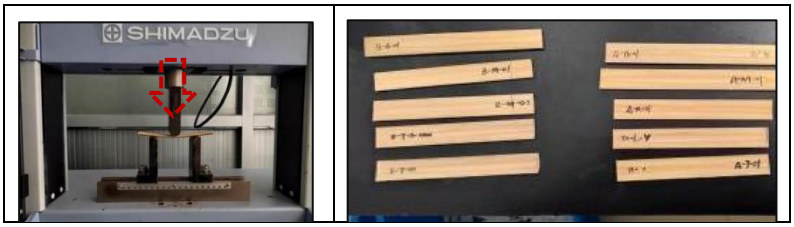

Figure 3 . The flexural strength test process and specimens(Taken by the author)

Tensile Strength Test

The dimensions of the tensile specimen refer to the standard of JGT 199-2007. The specimen length is 33 cm, the length of the clamping part at both ends is 8 cm, as shown in Figure 4. Tensile specimens were taken from A to C numbered moso bamboo to study the difference in tensile strength of different parts of moso bamboo. Szeto in [7], three comparison specimens are ensured for each segment, and the intersection of the material to ensure that there is no bamboo knot in the middle of the specimen.

Figure 4. Processing of tensile specimens (Taken by the author)

The tensile test of moso bamboo was carried out using a Shimadzu precision microcomputer-controlled electronic universal testing machine, model CMT6104, with a maximum load of 10 KN, loaded at a constant speed of 0.1 mm/s, and to record the maximum load. The formula for calculating the tensile strength of bamboo specimens：

$$\sigma_{ult} = \frac{F_{ult}}{b \times t}; \quad (2)$$

In the tensile strength formul, σ_{ult} is tensile strength of moso bamboo specimens(MPa)；F_{ult} is maximum tensile load of moso bamboo specimen (N)；b is width of tensile specimen of moso bamboo (mm)；T is thickness of bamboo wall in tensile specimen of moso bamboo(mm)；

Shear Test

The shear test method of moso bamboo refers to "ISO 22157-1: 2004", choosing the moso bamboo bottom, middle and top segments, respectively, taking the material adjacent to a group of 10 cm specimens, comparing the difference in shear strength of different parts of the bamboo. Bamboo shear test using Wuxi Emino Testing Machine automatic flexural compression testing machine, model DYE-300, with the maximum experimental force of 300KN, Yu in [8], measure the wall thickness at four positions and the height of the specimen, multiply, and add to get the total shear area of the specimen. Li in [9] , the upper and lower loading plates were customized according to the standard, and the shear position of the plates was aligned with the markings on the samples and downward at the same speed of 0.1 mm/s, as shown in Figure 5.

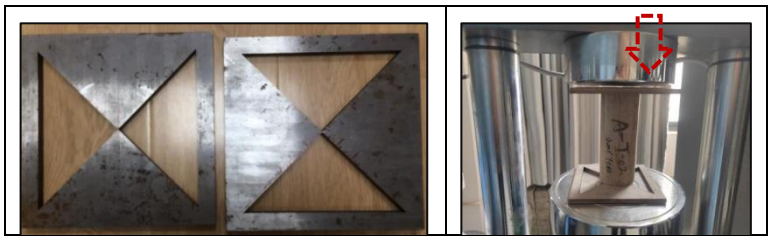

Figure 5. Progress of bamboo shear test (Taken by the author)

Calculation formula for shear strength of moso bamboo specimens：

$$\tau^{ult} = \frac{F^{ult}}{\sum t \times L} ; \quad (3)$$

τ^{ult} is shear strength of moso bamboo specimens(MPa) ; F^{ult} is maximum shear load of moso bamboo specimen(N) ; t is width of wall thickness at shear face of moso bamboo specimen(mm) ; L is length of bamboo tube at shear surface of moso bamboo specimen(mm);

Hardness Test

According to the moso bamboo parts of the bottom, the middle, and the top of the sawing adjacent to the three specimens, a total of 27 specimens. The specimen size is 20mm (length) × 15mm (width) × t (wall thickness) mm.

According to GB/T 1941-1991 "Wood Hardness Test Method", the experiment test uses the Shenzhen Wance production of microcomputer control universal testing machine, the model is TSE504C, the maximum experimental force is 50KN. The specimen was placed on the tester mount and the Janka pressurized ball was loaded on the test surface of the specimen. The hardness of the bamboo material measured in this study is the hardness of the bamboo yellow surface facing upwards. Chen in [10] , the Janka hemispherical indenter was pressed into the test surface of the specimen at a speed of 5mm/min until it was pressed into a depth of 2.82mm, and the load reading at this time was recorded as the hardness test value ,as shown in Figure.6.

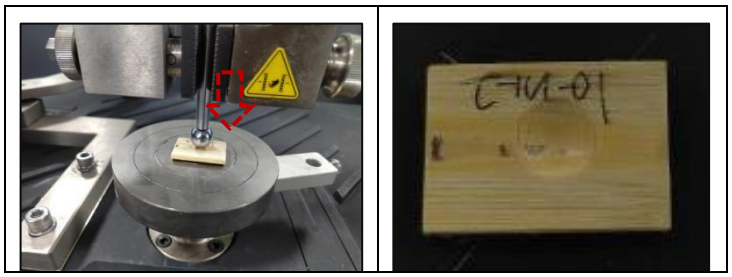

Figure 6. Loading method of bamboo yellow surface

Result of Mechanical Properties of Moso Bamboo Test

Compression Strength

The compressive test of 5cm bamboo tube only uses the sample without bamboo knots, with the increase of pressure value, the initial crack pattern appears and makes a loud sound at the point of expansion. The 10cm bamboo tube specimen without bamboo knots was deformed under compression by swelling on the green side of the bamboo. Then cracks appeared in the area where the bulging deformation was more serious, and the 10cm bamboo tube with bamboo knots had significant deformation near the upper part, as shown in Figure 7.

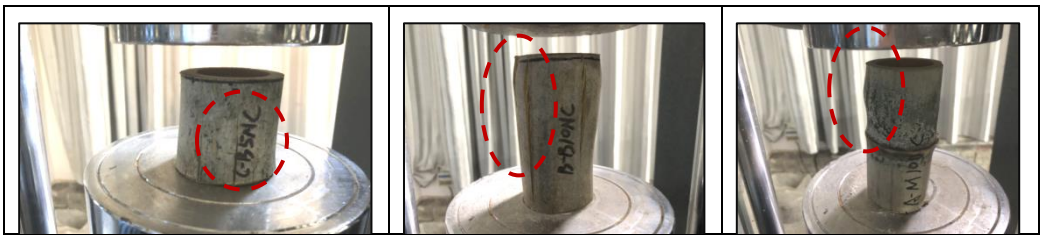

Figure 7. Failure mode of compression specimen(Photo taken by the author)

The compressive strength results of five 5cm bamboo tubes without bamboo knots are shown in Table 1. The compressive strength ranged from 40.32Mpa to 61.84Mpa, and the top of the moso bamboo was higher than the middle and the bottom, the coefficient of variation of the middle part of the specimens was small, which indicated that the middle part of the specimens was relatively stable in terms of compressive strengths.

The axial compressive strength of 10cm moso bamboo tube go up with the elevation of bamboo, the compressive strength results are shown in Table 2 .

Table 1 Results of 5 cm compressive strength （without bamboo knots）

Moso bamboo position	Compressive strength / AVG(N/㎟)	SD	CV(%)
Top	54.93	6.11	11.1
Middle	49.60	2.54	5.1
Bottom	48.30	6.22	12.87

Note: AVG:The average value;SD:The standard deviation;CV:The coefficient of variation;

Table 2 Results of 10 cm compressive strength （with bamboo knots）

Moso bamboo position	Compressive strength / AVG(N/㎟)	SD	CV/%
Top	46.78	3.25	6.95
Middle	43.53	4.22	9.67
Bottom	41.35	3.30	7.98

Note: AVG:The average value;SD:The standard deviation;CV:The coefficient of variation;

The 10 cm top and middle specimens without bamboo knot were not only stronger than those with bamboo knots but also showed better ductility, howeve the bottom specimens were the opposite of the ends, and the compressive strength of the 10 cm specimens with bamboo knots was less than that of the specimens without bamboo knots in the overall view. The compressive strength of 5 cm bamboo tubes is greater than that of 10 cm tubes, indicating that axial the compressive strength of bamboo tubes tends to reduce slightly with the increases of the length of the tubes.

Bending Strength

The test results of bending strength and bending modulus of different parts of moso bamboo are presebted in Table 3:

Table 3 Flexural strength of moso bamboo

Moso Bamboo position	Flexural strength / AVG(N/㎟)
Bottom	151.96
Middle	172.40
Top	193.08
AVG	172.48
SD	20.56
CV(%)	11.92

Note: AVG:The average value;SD:The standard deviation;CV:The coefficient of variation;

Based on the test results, it can be concluded that the mean bending strength of the top sample was the highest at 193.08 N/㎟, followed by 172.4 N/㎟ in the middle, and lastly 172.4 N/㎟ at the bottom.

Overall, the bending strength of the top of the moso bamboo was much higher than the middle than the bottom. The coefficient of variation is within 12%, which is in line with the standard required variation and the test results are reliable. These data are of great significance in guiding the selection and design of moso bamboo materials for engineering applications.

Tensile Strength

Moso bamboo tensile test loading initially can hear a tiny tearing sound, then a loud sound is heard, and the fibre tear on the yellow side of the specimen produced an obvious fracture, with the continuous increase of the load, the fibre on the side of the bamboo green was completely broken and the tensile test data of moso bamboo presented in Table 4. From the experimental data statistics, the mean tensile strength of the top is 185.03 N/㎟, which indicates that the top of the moso bamboo has better tensile strength and better durability. The mean tensile strength of the middle part was 161.88 N/㎟. The average tensile strength of the bottom was 148.49 N/㎟, indicating that the bottom of the moso bamboo was relatively weak in terms of tensile properties. The coefficient of variation of the tensile strength of moso bamboo was 11.24%, indicating that the degree of variation of the data was moderate and the data were relatively stable.

Table 4 Results of tensile strength and tensile modulus of moso bamboo

Moso Bamboo position	Tensile strength / AVG(N/㎟)	Tensile modulus / AVG(N/㎟)
Top	185.03	5773.39
Middle	161.88	4945.11
Bottom	148.49	4219.66
AVG	164.37	4979.38
SD	18.48	777.43
CV(%)	11.24	15.61

Note: AVG:The average value;SD:The standard deviation;CV:The coefficient of variation;

Shear Strength

The test results of longitudinal shear resistance of 3-4 years old moso bamboo and parts are shown in Figure8. The shear strength of moso bamboo specimens ranged from 12.09MPa to 16.10MPa.When the bending force of moso bamboo is applied, the lower part of the force surface and the upper part are compressive, from the beginning of the force to the destruction.,as shown in Figure 8. The longitudinal shear strengths of different parts of the same age of moso bamboo were lower than that of the middle part of the tube and lower than that of the top part of the tube, and the difference between the strengths of the three parts of the tube was relatively homogeneous.

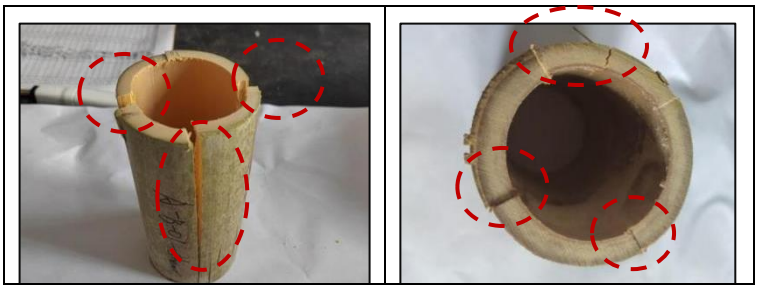

Figure 8. Progress of bamboo shear test (Taken by the author)

Hardness Strength

The results of the hardness experiments on moso bamboo showed that there were significant differences in the hardness of the root, middle and tip of the bamboo.With the increase of bamboo stem height, the hardness of moso bamboo increases linearly, Figure 9 indicates this trend. This is because as the height of the bamboo stem increases,and the content of fibre bundles per unit area gradually increases, leading to an increase in hardness. Due to the special structure of bamboo different from wood, in the existing research method can only carry out the hardness test of bamboo yellow surface, also affected by the diameter of the loading ball.

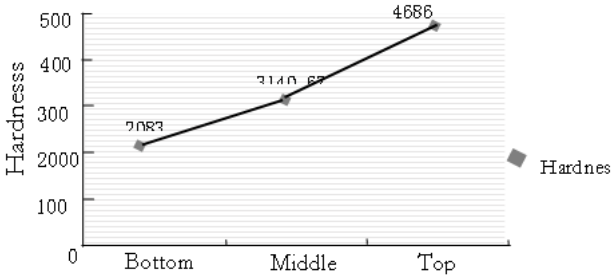

Figure 9. Hardness of different positions of moso bamboo (Taken by the author)

DISCUSSION

Comparison of the mechanical properties of moso bamboo with those of wood and other bamboo materials available in the literature, as shown in Table 5:

Table.5 Comparison of mechanical properties between moso bamboo, wood, and other bamboo materials

Species	Compressive strength(Mpa)	Tensile strength(Mpa)	Bending strength (Mpa)	Bending modulus (Mpa)	Shear strength (Mpa)	Hardness (N)
Moso bamboo	50.93	165.13Mpa	172.4Mpa	8374.4Mpa	12.61Mpa	2609.83N
Light bamboo	36.0	162.2Mpa	136.5Mpa	~	~	~
Hemp bamboo	42.0	161.1Mpa	128.0Mpa	~	~	~
Shirt wood	35.1	78.0Mpa	73.60Mpa	10390Mpa	6.5Mpa	16.01Mpa
Pine wood	33.0	99.0Mpa	68.3Mpa	7750Mpa	6.5~9.5	15.73Mpa
Birch wood	42.6	103.5Mpa	85.75Mpa	8820Mpa	~	36.99Mpa

The data show that the tensile strength and the axial compressive strength and the bending strength of moso bamboo, compared with other common bamboo species, are higher than those of light bamboo and hemp bamboo. In the literature, Xian in [11], the shear strength of light bamboo and hemp bamboo uses bamboo slices as a specimen, so it is impossible to compare. Compared with wood materials, the mechanical characteristics of moso bamboo are excellent, and its tensile strength, axial compressive strength and bending strength are about 1.5-2 times higher. The mechanical characteristics of moso bamboo in Fujian province are amazing, and the development of the bamboo industry needs to determine the application field and scope of bamboo according to the different mechanical properties of bamboo.

CONCLUSIONS

By analysing and summarising the experimental test data, the mechanical characteristics of moso bamboo in Fujian province are as follows:

In the longitudinal compression test of bamboo tubes, the compressive strength of the moso bamboo was that bottom part less than the middle part and less than the top part; the compressive strength was approximately

inversely proportional to the length of the specimens. The tensile strength of the moso bamboo in the bottom part is lower than that of the middle and the top specimens. The shear strength of the bottom specimen was the lowest, and the shear strength of the top specimen was higher than that of the middle and bottom specimens by 11.5%~12.6%. The average values of the bending strength and bending modulus of the moso bamboo were 172.48 N/㎜²and 8374.45 MPa, respectively, the top bending strength being 11.2% and 12.7% higher than that of the middle and the bottom. The hardness values of moso bamboo were in the range of 4114N~5322N. The hardness of moso bamboo was significantly improved with the increase in the height of the bamboo tube.

In summary, the mechanical properties of moso bamboo showed better performance than other bamboo species and timber, the axial compressive strength, bending strength and tensile strength of moso bamboo were higher than other bamboo strength by about 13.5 %, 13.7 % and 17.5 %, the tensile strength and bending strength and the shear strength were higher than those of wood timber by about two times. The mechanical characteristics of moso bamboo are indisputably linked to the positions of the culm. He Ming in [12], comprehensive consideration of the differences in mechanical property parameters and mechanical properties of Fujian moso bamboo can provide important mechanical property data for the industrial utilisation of moso bamboo and promote its application.

REFERENCES

Yang Zhongqiang, Zhu Jinqi.,Physical and mechanical properties of eight kinds of bamboo lumber from plexus bamboo , Guangdong Building Materials, 6, pp.129-131, 2011.(Journal)

Ai Wensheng, Yang Ming., Research on timber properties of moso bamboo, Hunan Forestry Science and Technology, 36(4),pp.1-5,2009.(Journal)

Yu You-Ming,Fang Wei., Research on the physical and mechanical properties of bitter bamboo, Journal of Southwest Forestry College, 25(3),pp.64-67, 2005.(Journal)

Su Wenhui , Gu Xiaoping., Study on the mechanical properties of large woody bamboos, Forestry Science Research, 19(5),pp.621-624, 2006.(Journal)

Yang Yunfang,YU You-ming., Research on the physical and mechanical properties of red-shelled bamboo, Journal of Zhejiang Forestry College, 15(2), pp.158-163, 1998.(Journal)

Jin Yongming , Yu Youming., Study on the variation law of physical and mechanical properties of Lei Bamboo, Journal of Bamboo Research,23(2),pp. 50-54, 2004.(Journal)

Szeto Chunnan,Wang Jian.,Comparison of physical and mechanical properties of bamboo timber of different orientations and ages, Hubei Agricultural Science, 50(13),pp.2683-2684,2011. (Journal)

Yu Hua., Ecological impact mechanism of bamboo expansion on the tree layer of bamboo and evergreen broad-leaved forests, PhD dissertation, School of Geographic Sciencest., Fujian Normal University., Fuzhou, 2021. (Dissertation)

Li Jiqing., Research on new bamboo laminated furniture, PhD dissertation, School of Wood Industry., Nanjing Forestry University., Nanjing, 2005. (Dissertation)

Chen Yushu, Liao Guoqiang B., Furniture Historyitle, 2nd ed., China Light Industry, 85-89, 2018. (Book)

Xian Xingjuan, Xian Dingguo., The microstructure of bamboo and its relationship with mechanical properties , Bamboo Research Journal, 9(3),pp.10-23, 1990.(Journal)

He Ming, B., Research on Chinese bamboo culture, 2nd ed., People's Publishing House Press, 34-36, 2007. (Book).