Comparative Testing of Properties of Fraxinus Chinensis Rox and Rod Types Materials and Application in Furniture Design

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Abstract. Fraxinus chinensis roxb material is a rod material has excellent performance, fraxinus chinensis roxb, rattan, bamboo, willow wood four materials, have been used as wood furniture materials, but for its material performance comparison analysis, and how to accurately apply to the field of furniture design is relatively little discussion. In order to distinguish the mechanical properties of fraxinus chinensis roxb material and other pole materials, the tensile, compression and bending properties of the four woods were tested by using a universal mechanical testing machine to test the mechanical properties of fraxinus chinensis roxb, rattan, bamboo and willow wood. In turn, the mechanical aspects of fraxinus chinensis roxb as a furniture material were evaluated, so as to better guide its application in the field of furniture design, and the conclusion was drawn that fraxinus chinensis roxb materials are suitable for use in bentwood furniture and bentwood-type furniture parts.

Keywords: Faxinus chinensis roxb; Rod types materials; Performance experiments; Furniture design

1 Introduction

In the face of the lack of forest resources, artificial forest materials in short supply of the status quo, the previous curved wood furniture and its curved furniture parts, usually using elm, ash and other valuable species, the development of new materials is an important option for the current(Liu,Chen&Zhang,2008;Wang,2023)[1,2],The fraxinus chinensis roxb material has a white texture and is characterized by firmness but not hardness, softness but notfracture (Liu, Chen&Zhang, 2008; Wang, 2023; Ren, 2012; Chen&Xue, 2024; Tian, *Wu*&Qin, 2002)[1,2,3,4,5], However, fraxinus chinensis roxb have been developed and utilized as a new material for a relatively short period of time(Chen&Xue,2024)[4],There are a lot of reports on fraxinus chinensis roxb nursery, silviculture and ecological management methods, etc (Tian, *Wu*&Qin, 2002; Xu, 2025; Liu&Yang, 2022)[5,6,7],There have also been studies on the softening process, hygroscopicity, and drying of fraxinus chinensis roxb, showing that the density of fraxinus

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chinensis roxb is greater than that of other woods, and that the drying and wetting of fraxinus chinensis roxb lumber is greater when the moisture content is the same (Tang, 2007; WuLan, 2015)[8,9],fraxinus chinensis roxb furniture processing process is relatively complex, need to go through two steps, the first step is the raw material processing, including: peeling—bending and straightenin—anti—insect, antiseptic and softening treatment —drying treatment, the second step is the fraxinus chinensis roxb furniture processing, including: bending and shaping—assembling—cutting—grinding—straightening—storage (Li, 2014; Shi, Li&Zhang, 2023) [10,11],Completion of furniture made of Completion of furniture made of ash pole material material.

Rattan, bamboo and willow materials, because of their good compression, stretching and bending properties, have been used to make curved furniture or curved furniture link structure cases (Wu, Chen, Lian&Hu, 2021; Yu, Ding&Liu, 2023; Ren&Zhang, 2012)[12,13,14],In this paper, the compression, tensile and compressive strengths of four materials, namely, fraxinus chinensis roxb material, rattan, bamboo and willow, were measured using fraxinus chinensis roxbs from Ningling County, Henan Province, as the research object.To prove that fraxinus chinensis roxbs can be used to make bentwood furniture or bentwood-type furniture links, thus providing a reference for other researchers.

2 Materials and Methods

2.1 Collection of Raw Materials

Fraxinus chinensis roxb material is a kind of bending and flexible wood unique to Ningling County, Henan Province(Ren&Zhang, 2012)[14], In this study, we collected fraxinus chinensis roxbs materials from Ningling, Shangqiu, aged 4 to 5 years, with an average diameter of 30 mm:peeling—heating at high temperatures(heat fully enters the wood fibers and kills the larvae at high temperatures)—correction of bending—insect and corrosion protection—dry by the sun(enables water content to be: 25-30%)(Liu, Chen&Zhang, 2008;Li, 2014;Shi, Li&Zhang, 2023)[1, 10, 11].

Rattan: Collection of rattan material from Jiangmen, Guangzhou, aged around 6 years, with an average diameter of 30mm, and certain processing techniques are applied to the rattan material(Qiang&Yuan, 2008)[13], cleaning of the raw rattan—straightening of the bends—cutting to length—peeling—bleaching—microwaving—antiseptic treatment—packaging.

Bamboo: collection of bamboo material from Anji, Zhejiang Province, aged around 4 years, with an average diameter of 30mm, and certain treatments on the bamboo material: selection of bamboo material—peeling—truncation—splitting—preservative treatment—packaging(OU, 2022)[15].

Willow: willow material from Huaihua, Hunan Province was collected and cut from willow trees that had been in production for about 8 years with an average diameter of about 30 mm, and the willow material was subjected to certain treatments: Selection of willow wood—debarking—soaking (to a certain humidity)—sawing and cutting—storage(Wang, 2021)[16].

In the process of selecting the material, to ensure that the diameter of the material for the same value, are 30mm (as shown in Table 1), is in order to better accomplish the comparison between the Fraxinus chinensis roxb material and other materials, so that the data of the test is more accurate.

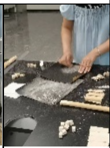
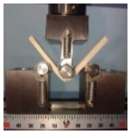
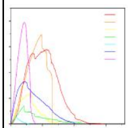
2.2 Methods

2.2.1 Equipment Selection.

Equipment name and model: Electronic universal material testing machine (Shimjin universal testing machine AGS-X10KN, Japan). Test methods refer ton ational standards: Compression test reference (GB/T3251-2006); Tensile test reference (GB/T228—2002); Three-point bending test reference (GB/T17657-2013).

2.2.2 Experimental Step.

Table 1. Experimental procedure

Sample selection and primary processing		**Sample Production**		**Deep Processing**		**Experiment**	**Analysis and summary**
							
Sample selection	Primary processing	Sample cutting	Sample polishing	Sample forming	Sample labeling	Shimjin universal testing machine AGS-X10KN, Japan	Visio software

In accordance with the national experimental standards, the experimental steps were carried out (as shown in table 1), including the selection and initial processing of samples, sample production, sample labeling, sample experimentation, and finally, the resulting data were analyzed and summarized.

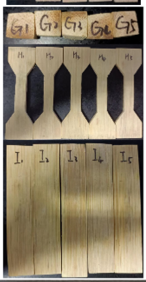
2.2.3 Sample Production.

Mechanical properties of fraxinus chinensis roxb, rattan, bamboo and willow were tested using an electronic universal testing machine.

The samples were left at room temperature for 24h before testing and all tests were conducted at room temperature. The samples for compression, tension and three-point bending were obtained by laser cutting process, the morphology of the samples ((n=5)) is shown in table 2 below and the samples were coded, the compression, tension and bending samples of fraxinus chinensis roxb were coded as: A1, A2, A3, A4, A5; B1, B2, B3, B4, B5; C1, C2, C3, C4, C5 The compression, tension and bending of rattan The samples were coded as: D1, D2, D3, D4, D5; E1, E2, E3, E4, E5; F1, F2, F3, F4, F5, compression, tensile and bending of bamboo materials The samples were coded as:

G1, G2, G3, G4, G5; H1, H2, H3, H4, H5; I1, I2, I3, I4, I5, compression, tensile and bending of willow materials The samples were coded as J1, J2, J3, J4, J5; K1, K2, K3, K4, K5; L1, L2, L3, L4, L5. compression, tensile and three-point bending tests were carried out on the specimens of the four types of wood, respectively.

Table 2. Mechanical test sample size

Types of materials	Experimental testing	Diameter (mm)	Height (mm)	Effective length(mm)	Strain (%)	Sample
Fraxinus Chinensis Roxb	Compressive	12	12	12	50%	
	Tensile	3	11	70	facture	
	Three-point bending	3	20	40	facture	
Rattan	Compressive	12	12	12	50%	
	Tensile	3	11	70	facture	
	Three-point bending	3	20	40)	facture	
Bamboo	Compressive	12	12	12	50%	
	Tensile	3	11	70	facture	
	Three-point bending	3	20	40	facture	
Willow	Compressive	12	12	12	50%	
	Tensile	3	11	70	facture	
	Three-point bending	3	20	40	facture	

3 Experimental Results and Analysis

3.1 Compression Experiment Results and Analysis

For the compression test, the universal mechanical testing machine was loaded at a compression rate of 2 mm/min, the stress and strain during loading were recorded, and typical stress-strain curves were plotted; the compressive elastic modulus of the material was obtained based on the stress ratio to the upper strain, and the compressive strength of the material was obtained by observing the curves. The apparent compressive elastic modulus of the stent was defined as the slope of the strain between 0% and 5%.

The modulus as well as the compressive strength of the materials observed that bamboo is superior in terms of compressive capacity, followed by fraxinus chinensis roxb, rattan and willow.

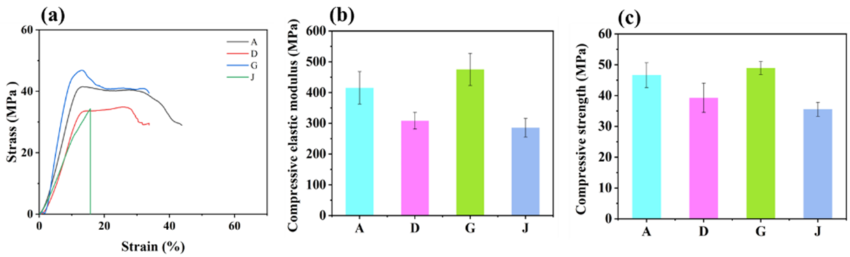


Fig. 1. Typical engineering stress-strain curves obtained from compression testing

Figure1 shows the typical engineering stress-strain curves of the four wood species, as well as their compressive modulus of elasticity and compressive strength statistics. The four woods were cut according to table 2, compression specimens were obtained and tested in compression on a universal testing machine, and the above curves were obtained as in fig. 1(a). Four kinds of wood in the compression process, the first elastic deformation, in the stage of the material stress with the increase of strain and rapid increase; to reach the highest point, in addition to willow all the rest of the wood appeared in the yield point, plastic deformation, with the compression load continues to be applied, the compressive strength of the material gradually decreased. Combined with the morphology of the material, the material in the elastic deformation region, the structure of the material is basically maintained, after reaching the plastic deformation region, a large number of cracks appeared in the wood block, the structure was damaged, and the compressive strength of the wood decreased. From the tests, as shown in fig.1(b),The compression modulus of fraxinus chinensis roxb is 415.25±52.96MPa, which is larger than 308.26±26.97MPa of rattan and much larger than 285.50±30.37MPa of willow, which indicates that fraxinus chinensis roxb is better than rattan and willow in compression and resistance to deformation, and it is more suitable for some structural parts to make weight-bearing furniture. Compared with bamboo's 475.03±52.35MPa, the compressive capacity offraxinus chinensis roxb is slightly lower than that of bamboo. In terms of material compression, as shown in fig.1(c), the compressive strength of fraxinus chinensis roxbis 46.62±4.02MPa, which is greater than that of garcinia mangostana's 39.27±4.75MPa and willow's 35.53±2.27MPa, and is slightly lower than that of bamboo's 48.93±2.11 MPa, indicating that fraxinus chinensis roxb have a certain compression resistance and are suitable for use as furniture.

3.2 Tensile Experiment Results and Analysis

The modulus of elasticity of fraxinus chinensis roxb is less than bamboo but greater than the remaining two materials, and the strength is higher in the elastic deformation range.

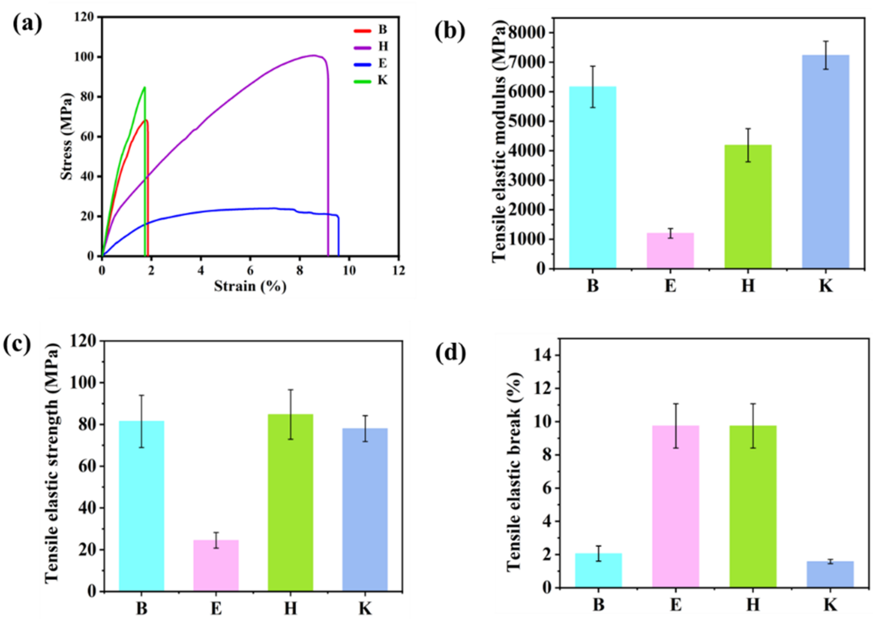


Fig. 2. Typical stress-strain curves obtained by stretching four types of wood

For the tensile test, the universal mechanical testing machine was loaded at a tensile speed of 2 mm / min, the stress and strain during loading were recorded, and typical stress-strain curves were plotted; the tensile modulus of elasticity of the material was obtained based on the ratio of stress to upward strain, and the tensile strength and elongation at break were obtained by observing the curves. The apparent tensile elastic modulus of the stent was defined as the slope of the strain between 0% and 1%.

The four wood materials were cut into dumbbell-shaped specimens according to the dimensions in table 2, and the materials were placed to be stretched at the fixture, and the typical engineering stress-strain curves of the four woods were obtained, from which the modulus of elasticity, the fracture strength, and the elongation at break of the materials were calculated. As shown in fig. 2(a), after being subjected to tensile force, the four materials immediately underwent elastic deformation, and because the fiber direction of the material was consistent with the tensile force direction, the material had a high elastic modulus and tensile strength, which indicated that the fiber direction of the material was good for mechanical strength, and the fiber played a good reinforcing role; with the loading of the force, the four types of wood fractured at different elongations, and the fracture was firstly started from the fracture of part of the wood fiber fracture began, until all the fracture, so there was an instantaneous strain reduction of 0. From the test, as shown in fig.2(b), the tensile modulus of fraxinus chinensis roxb was 6166.02±700.23 MPa, which was much larger than that of garcinia cambogia at 1200.83±163.51 MPa, and larger than that of bamboo at 4186.48±561.04 MPa, which indicated that fraxinus chinensis roxb, in terms of tensile properties, had a greater resistance to deformation due to rattan wood and bamboo, more suitable for some structural parts for making tensile furniture.The tensile capacity of fraxinus chinensis roxb was slightly lower than that of willow compared to 7235.29±475.24 MPa of willow. In terms of the material's tensile, as shown in fig. 2(c), the tensile strength of fraxinus chinensis roxb is 81.47±12.50MPa, which is greater than 24.48±3.74MPa of garcinia and 78.01±6.22MPa of willow, and slightly lower than 84.74±11.89MPa of bamboo, which indicates that fraxinus chinensis roxb has some tensile capacity and is suitable to be used as some components in furniture materials.Four materials in the bamboo material fracture has the longest elongation at break, which is related to the structure of bamboo, bamboo by many bamboo fiber arrangement, fracture is not at the same time when the fracture but gradually fracture a process of(W.Yin.*et al* 2015;Wang,2023;T.B.Vân Nguyen.2018)[17,18,19].The elongation at break of fraxinus chinensis roxb was 2.06±0.45%, which is similar to 1.58 ± 0.13% for willow, and 9.74±1.33% for bamboo is similar to that of rattan as shown in fig.2(d).The mechanical properties of the four wood materials were obtained from the observation that they have good mechanical properties, especially in the direction of the parafibers, due to the reinforcing effect of the fibers, so that they have good tensile strength and are suitable to be used in some furniture materials with tensile demand.

3.3 Three-Point Bending Experiment Results and Analysis

For the three-point bending test, the universal mechanical testing machine was loaded at a bending speed of 8 mm / min, the stress and strain during the loading process were recorded, and typical stress-strain curves were plotted. The bending modulus of elasticity of the material was obtained based on the ratio of stress to upward strain, and the flexural strength and elongation at break were obtained by observing the curves. The apparent bending modulus of elasticity of the stent was defined as the slope of the strain between 0% and 1%.

The four kinds of wood were cut into long rectangular strip samples according to the dimensions of table 2, and the typical engineering stress-strain curves of the materials were obtained by three-point bending experiments, and the elastic modulus, flexural strength and elongation at break of the materials were calculated. Observe fig.3(a) the material is initially in the elastic deformation zone, with the loading of force, the stress of the material increases rapidly with the increase of strain, and the four kinds of wood appeared to be different degrees of bending, until the wood bending fracture, at this time, most of the fibers of the material in the bending action of the fracture, with the continued increase in strain, the degree of bending of the material increases, the stress continues to decrease, until it completely fracture. Since wood is a microstructured material belonging to the multilayer, it has a large elongation at break and good toughness. From the test, as shown in fig.3(b), the bending modulus of fraxinus chinensis roxb is 19270.62±2620.84MPa similar to that of willow 21040.22±2089.07MPa, which indicates that the two kinds of bending resistance are comparable, both are much larger than that of rattan 2688.05±320.46MPa, and larger than that of bamboo 4913.13±619.39MPa. It shows that fraxinus chinensis roxb are better than rattan wood and bamboo in bending performance and resistance to deformation, which is more suitable for making some bending parts and used to make bending-resistant furniture.From fig.3(c), it can be seen that fraxinus chinensis roxb possessed the highest flexural strength of 285.37±35.08 MPa, followed by willow with a flexural strength of 221.36±22.63 MPa, which are both much greater than the flexural strengths of rattan of 63.72±4.92 MPa and bamboo of 153.20±16.44 MPa. The materials from the beginning of bending to the appearance of fracture, as shown in fig. 3(d), rattan possesses the largest bending deformation of 7.22±1.10%, followed by bamboo's elongation at break of 7.74±2.09%, which both materials have good toughness, and fraxinus chinensis roxb have intermediate bending performance with elongation at break of 3.16±0.77%, and the lowest one is willow with only 1.64±0.11% elongation at break. Fully demonstrated that the material has good bending resistance, good toughness, suitable for some bending processing, has the potential as furniture processing materials.

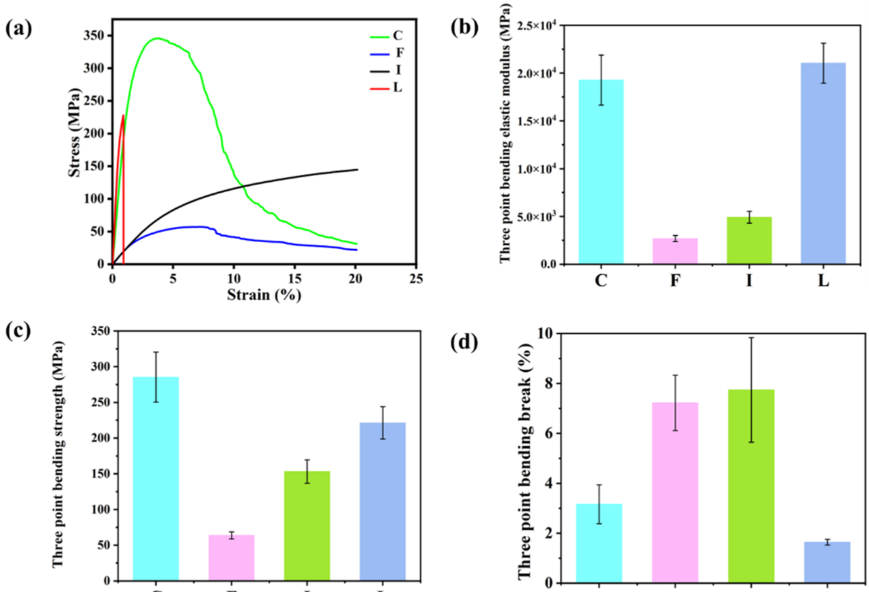


Fig. 3. Typical engineering stress-strain curves obtained from bending tests of four wood species

In summary, different woods show different properties in compression, tension and bending. In various tests, fraxinus chinensis roxb have better mechanical properties and can resist tensile, compression and bending, with the most prominent being the bending properties, indicating that fraxinus chinensis roxb are suitable for making furniture with strong bending and furniture connectors, as well as furniture with high strength and strong tensile properties.

4 Conclusions

The following conclusions were drawn from the compression, tensile, and three-point bending experiments on fraxinus chinensis roxb material, rattan material, bamboo material, and willow material using a universal mechanical force measuring machine:1)Fraxinus chinensis roxb is better than rattan wood and willow wood, in terms of compression performance and resistance to deformation, and slightly lower than bamboo, which is more suitable for some structural parts and used to make load-bearing furniture.2)Fraxinus chinensis roxb is better than rattan wood and bamboo in tensile properties and resistance to deformation, and slightly lower than williow, which is more suitable for some structural parts to be used to make tensile resistant furniture.3)Fraxinus chinensis roxb have the highest bending strength of 285.37 ± 35.08 MPa, followed by willow bending strength of 221.36 ± 22.63 MPa, both much greater than the bending strength of 63.72 ± 4.92 MPa for rattan and 153.20 ± 16.44 MPa for bamboo. It fully indicates that the material has good bending resistance, good toughness, suitable for some bending processing, and has the potential to be used as furniture processing material.

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