

# Bamboo Conditions for Processing Bamboo Fiber with Combing Method

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**Abstract.** The bamboo fibre is a new kind of natural fibre from bamboo with machine method, and is in the frontier of bamboo timber processing, new composite and textile research field. The combing method is mainly one in processing bamboo fiber. The plasticity and strength of bamboo were required in processing bamboo fiber by machine method. The aim of this work is to explore changes of mechanical properties -lengthways tensile properties of bamboo after alkali treatment and focuses on a relation between lengthways tensile properties of alkali treated bamboo and the moisture content. Mechanism of plastic deformation of bamboo was initially revealed in this paper. Experiment shows that: above fibre saturation point, the lengthways tensile strength and elasticity modulus of bamboo decreased with increase of moisture content with 2.5%NaOH soaking for 24h, and bamboo plasticity is better when its moisture content is between 40% and 90%. According to the principle of bamboo fiber processing by combing, the moisture content of bamboo should be controlled from 50% to 70% after 24h soaked with 2.5%NaOH. Bamboo fiber processing test shows that the conclusion is correct.

## 1. Introduction

Bamboo is the ideal material used in composite material and structure material owing to its fast growing, wide distribution, excellent performance and renewable capability. The bamboo fiber is a new kind of natural fiber from bamboo with machine method, in recent years, the bamboo fiber gets more and more people's attention and is in the frontier of bamboo timber processing, new composite and textile research field[1~3]. According to the preparation process of bamboo fiber, bamboo pretreatment is required generally. Purpose of pretreatment is to improve plasticity and strength of bamboo is retained enough. The practice of making bamboo fiber showed that the qualities of fiber were closely related to bamboo conditions and main factor was humidity for alkali treated bamboo.

In the previous study, above fiber saturation point, mechanical properties of bamboo were basic unchanged. After alkali treatment, relation between mechanical properties of bamboo and moisture content were not been reported. Natural bamboo can be taken as unidirectional fiber reinforced composite, macro is anisotropic [2]. Bamboo is under tensile state parallel to the grain mostly in processing bamboo fiber by rolling method and combing method[3]. Therefore, lengthways tensile properties of bamboo were studies in the paper.

According to pretreatment process of bamboo with 2.5%NaOH solution for 24h [4], the properties were compared between untreated bamboo and softening-treated bamboo under stretching parallel to the grain, a relation between the mechanical strength and moisture content under stretching parallel to the grain were discussed. Due to the large yield and wide distribution of *Phyllostachys pubescens*, this paper chooses moso bamboo as the research object.

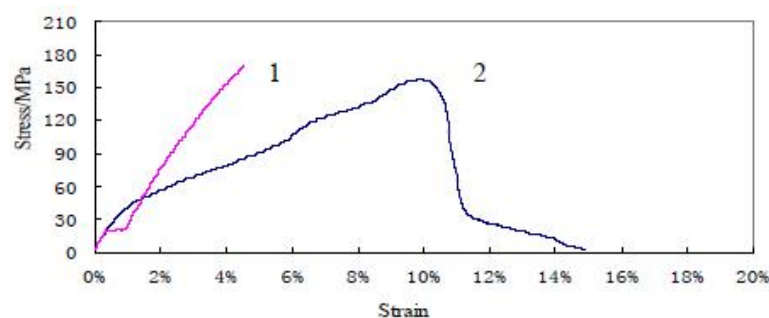


## 2. Bamboo conditions for processing bamboo fiber

### 2.1 Experiments material and method

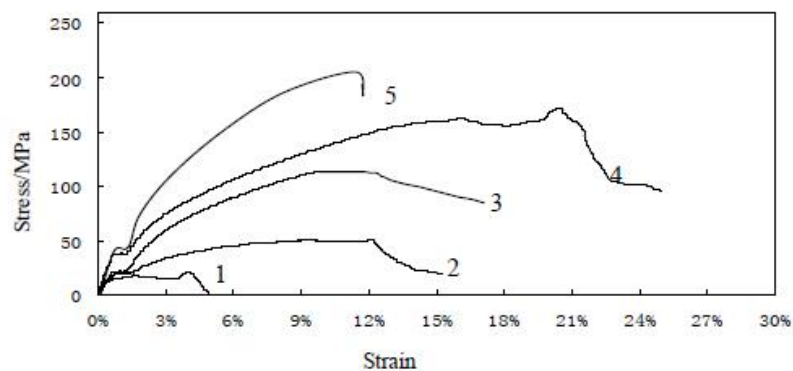
The specimen used in this experiment was harvested at 1 years of age that moso bamboo from Lin an city in Zhejiang province. The specimens for the contrast experiment of alkali treatment were made by upper bamboo and the specimens for moisture content experiment were made by mid-height of bamboo. The size of bamboo specimen according to GB/T 15780-1995 “bamboo physical and mechanical properties test method”, the specimen is softened with 2.5%NaOH solution for 24h. The test of bamboo specimens was performed on WDW-500 universal material testing machine with microcomputer-controlled, the load speed was selected 3mm/min. loading experiment curve was automatic painted by computer.

The tensile testing curve of virgin and alkali treated bamboo is shown in figure 1, tensile testing curve of moso bamboo after alkali treatment under different moisture content is shown in figure 2.



1-untreated bamboo; 2-alkali treated bamboo

**Figure 1.** Stress-strain curve of untreated bamboo and softening –treated bamboo with alkali under stretching parallel to the grain



Moisture content (%) 1—110%; 2—90%; 3—70%; 4—50%; 5—30%

**Figure 2.** Stress-strain curve of moso bamboo under stretching parallel to the grain with different moisture content

### 2.2. Results and discussions

The bamboo is a natural biomaterial and is composed of fibers and matrix. The bamboo fiber strength is in excess far of the matrix strength [5]. Based on the theory of composite material [6], bamboo strength under stretching parallel to the grain depends on bamboo fiber strength. A bamboo fiber contains many fibrils which are together by colloid. Therefore, we could think that tensile strength of bamboo depends on single fibril and their bonding strength and bamboo plastic elongation depends on slip deformation between single fibril mainly.

1) Mechanical property of untreated and alkali treated bamboo under stretching parallel to the grain

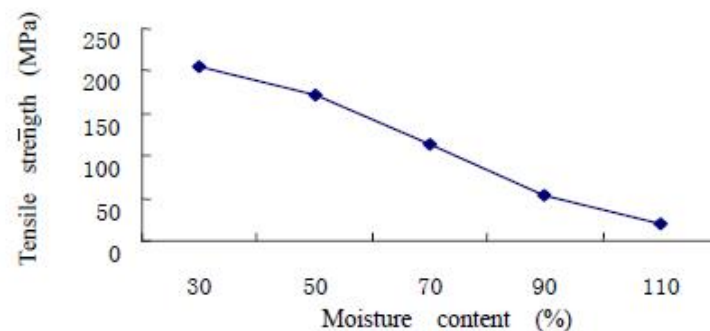
Figure 1 shows stress-strain curve of untreated and softening–treated moso bamboo under stretching parallel to the grain (moisture content is 18%), 1 is untreated bamboo and 2 is alkali treated

bamboo in figure 1. Tensile strength of bamboo not change and but plastic of bamboo increased significantly after alkali treatment. Bamboo without soft treatment in the tensile process, first elastic stage, then yield and small plastic deformation stage, last brittle fracture was occurred on cross-section in specimen where strain or elongation is 4%. Bamboo specimen after alkali treatment, through elastic, yield, plastic stage, last testing machine automatically unloaded where strain or elongation is 10% and fiber bundle were fractured. Elongation of bamboo without soft treatment is 4% and plastic elongation of bamboo increased to 10% after alkali treatment. Because the evaluation standard for plastic of bamboo is not been reported and according to the standard of metal material for plastic or brittle character, virgin bamboo is brittle material and bamboo after alkali treatment changes as plastic material, which provide a theoretical basis to build mechanical model in bamboo fiber making.

Change of bamboo characters owing to the colloid between single fibers and matrix were extracted partly with alkaline soaking. Colloid strength increased between single fibers with bamboo drying, decrease of moisture content and single fiber become was more closely. Therefore, Tensile strength of alkali treated bamboo has not change or increased slightly.

2) Relation between lengthways mechanical properties of alkali treated bamboo and moisture content.

According to the figure 2, the curve of a relation between the lengthways tensile strength and moisture content is shown in figure 3.



**Figure 3.** Change of the tensile strength parallel to the grain of alkali treated bamboo with moisture content

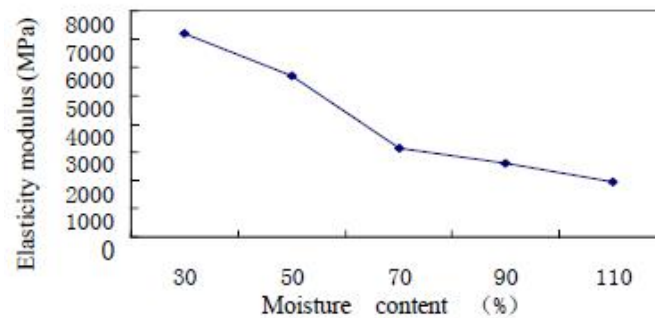
Figure 3 shows the lengthways tensile strength of bamboo increased with decrease of moisture content. The strength of bamboo increased is owing to strength of colloid increased with bamboo became drying or decrease of moisture content. Their relation was linear regressed, regression equation and correlation coefficient is entered Table 1.

**Table 1.** Lengthways tensile strength and moisture content regression of bamboo

bamboo	regression equation	correlation coefficient( $R^2$ )
moso bamboo	$y = -48.7x + 259.1$	0.9878

\*y- tensile strength; x- moisture content

Table 1 illustrates linear regression is good. Therefore, the longitudinal tensile strength of alkali treated bamboo can be estimated according to the regression equation. The relationship between tensile elasticity modulus and moisture content of alkali treated bamboo is shown in figure 4.



**Figure 4.** The relationship between tensile elasticity modulus and moisture content

Figure 4 shows that the elasticity modulus of bamboo was affected by moisture content. Above fiber saturation point, elasticity modulus of bamboo decreased with increase of moisture content. It dropped significantly where moisture content was 30% ~ 70% and dropped slow where moisture content was 70% ~ 110%. Figure 2 shows moso bamboo elongation reach maximum value where moisture content is 50%, more than 90% and elongation is only 4% in 110%. Elongation of bamboo more than 10% and plastic is better where moisture content is between 40% ~ 90%.

Sliding move between single fiber were occurred with load increase in the plastic deformation stage of alkali soaking bamboo, sliding length depends on the bonding strength between single fibers. Strength of the colloid between single fibers increased with decrease of the moisture content. The colloid between single fibers is low intensity where moisture content is 110% and degumming was occurred soon at stretching, Slippage between single the fiber is maximum with moisture content in 50-90%. Colloid strength increased and ductility decreased with the decrease of moisture content continual and in lead to decrease of elongation and reduce of plastic for bamboo.

According to change of tensile strength, elasticity modulus and elongation of alkali treated bamboo with moisture content, unfasten bamboo fiber by combing method, moisture content of alkali treated bamboo should be selected between 50%-70%.

### 3. Experiments of processing bamboo fiber

Processing bamboo fiber by combing machine for untreated moso bamboo and softening–treated moso bamboo respectively 10Kg, softening–treated bamboo with alkali 2.5% for 24h and moist content is 60%, as figure 5 and figure 6.



**Figure 5.** Bamboo fiber processed with untreated bamboo



**Figure 6.** Bamboo fiber processed by softened bamboo

The fiber yield, the fiber length and the fiber fineness respectively were calculated according to formula (1), (2) and (3), the computed results were given in Table 2.

$$f = \frac{m_1}{m_2} \times 100\% \quad (1)$$

$$L = \frac{n_1 l_1 + n_2 l_2 + \cdots + n_i l_i}{n_1 + n_2 + \cdots + n_i} (cm) \quad (2)$$

$$N_t = \frac{1000(1+13\%)G}{L} tex \quad (3)$$

Formula (1):  $m_1$ - bamboo fiber quality of absolute dry,  $m_2$ - bamboo quality of absolute dry

Formula (2):  $l_i$ - middle value of Fiber length in  $i$  group,  $n_i$ - Fiber number in  $i$  group

Formula (3):  $G$ - quality of absolute dry of 100 Fiber in calculated fiber Length

**Table 2.** The parameters of bamboo fiber untreated bamboo and alkali-treated bamboo

method	Yield ( % )	Length (mm)	Fineness (tex)
untreated	27	45	32
alkali-treated	52	82	18

Table 2 indicates: the fiber yield and fiber fineness of bamboo treated with alkali were about twice as high as those of untreated bamboo, and fiber length was longer than that of untreated bamboo.

#### 4. Conclusions

1) The virgin bamboo is brittle material, alkali treated bamboo with 2.5%NaOH soaking for 24h could be modified to plastic material (moisture content 18% ).

2) Lengthways tensile strength of bamboo after alkali treatment depends on bonding strength in single fibers and plastic elongation of bamboo depending on the slip deformation between single fibers.

3) After soaking bamboo by 2.5%NaOH for 24h, lengthways mechanical properties were closely related with moisture content. Tensile strength decreased with increase of the moisture content and fitting linear. Tensile elasticity modulus decreased with increase of the moisture content and elasticity modulus dropped slower where moisture content is above 70%. Elongation of bamboo is more than 10% where moisture content is 40%~90%. Therefore, moisture content of softening-treated bamboo should be controlled between 50%~ 70% in processing bamboo fiber with combing method.

#### 5. Acknowledgements

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