Relationship between Anatomical Properties and Compression Strength Parallel to Grain of *Larix kaemferi C.*

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Journal of the Korea Furniture Society Vol.17 / No. 4(2006. 12)

Relationship between Anatomical Properties and Compression Strength Parallel to Grain of *Larix kaemferi C.*[*1]

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ABSTRACT

Larix kaemferi is now a major economic kind of trees and is produced in large quantity every year. Thus, the study of *Larix kaemferiis* conducted to acquire the basic date of measures for the reasonable use, clarifying the relation with the compression strength parallel to grain according to anatomical properties by heartwood and sapwood, and earlywood and latewood. As the length of an earlywood tracheid and the radial wall thickness of earlywood and latewood tracheids increased, the compression strength rose, and as the height of uniseriate ray in cell number increased, the compression strength parallel to grain fell. The major anatomical factors effecting on the compression strength parallel to grain of heart wood were the radial wall thickness of a latewood tracheid and the length of a latewood tracheid, while in sapwood, the length of an earlywood tracheid and the radial wall thickness of earlywood and latewood tracheids were the major factor on it.

Key words : Anatomical properties, Compression strength, Larix kaemferi

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*1 Received : 2006. 8. 7

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1. Introduction

Because wood is anisotropic material consisting of various cellular tissues, variation is very diverse not only between different kinds of trees but also within the same individual. To understand these properties of wood and use them effectively, the study on the basic material should be preceded first(Oh,1997). The factors effecting on the strength of wood can be classified into internal factors such as kind of cells, the structure of cell wall, the direction of grain, moisture content, specific gravity, or the width of annual ring and external factors such as the form and size of a specimen, temperature, or the way of loading(Bodig *et al.*, 1982; Kollmann *et al.*, 1968)

Particularly, it is known that anatomical factors have many effects on mechanical properties. Indeed, according to the report of Gerhards(1982), it showed that latewood and resin canal were the major effect factors to coniferous wood, while to hard wood, the arrangement and size of pores and the size of ray were the major effect factors. Also, it was reported that microfibril angle existing in the middle lamella of the secondary wall of cells had much effects on the mechanical and physical properties of wood(Bendtsen, 1978;Grossman *et al.*, 1971; Kucera *et al.*, 1982; Meylan *et al.*, 1968; Salmen *et al.*, 1985), and it was the important factor determining the compression strength parallel to grain and modulus of elasticity(Taylor *et al.*, 1992). In the mean time, used in the study as samples, the *Larix kaemferi* was introduced from Japan in 1904 and mainly planted in central south Korea and is now a major economic kind of trees. Besides, it is used for various purposes such as building interior materials, civil engineering materials, and flooring boards, and is produced in large quantity every year. In spite of the large amount of its production, previous studies of *Larix kaemferi* had been confined to physical, anatomical, or mechanical properties, and only a little attempts at studying the synthetic interrelation have been made, Thus, the study of *Larix kaemferi* is conducted to acquire the basic date of measures for the reasonable use, clarifying the relation with the compression strength parallel to grain according to anatomical properties by heartwood and sapwood, and earlywood and latewood.

2. Materials And Method

2-1 Samples

Ten larches, which were relatively excellent and straight, were exploited from *Jeollabuk-do, KOREA* and used in this study. The characteristics of these samples are shown in Table 1.

2-2 Making specimens for measurement of the compression strength parallel to grain

Specimens with the size of 20(R) x 20(T) x 60(L)mm each were made in accordance with KS F 2206(1980), the region of diameter breast height of exploited material timber. These specimens were treated by humidification in a constant temperature and humidity chamber (temperature 20±1℃, humidity 65±5%) and reached to equilibrium moisture content at 12%, and then they were used to measure the compression strength parallel to grain.

〈Table 1〉 Description of sample trees

Species	Sample tree No.	D. B. H (cm)	Height (m)	Age (year)
	1	29	17.5	37
	2	29	17.5	37
	3	28	17.0	37
	4	28	17.5	35
Larix kaemferi C.	5	27	17.0	35
	6	27	16.5	34
	7	27	16.0	34
	8	26	15.5	32
	9	26	15.5	32
	10	26	15.0	32

2-3 Making specimens for measurement of anatomical properties

After the strength test, specimens, differed in strength although physical properties such as the specific gravity and moisture content were the same, were sorted out, followed by taking the specimens of about 15 x 15 x 15mm, retting them in the water for 24 hours at the room temperature, and softening them in an autoclave for 30 minutes. The softened specimens were cut into three sections(radial, transverse, tangential) of 15-20μm in thickness with a sliding microtome, and then they were dyed with safranine. Next, they were retted in xylene after dehydrated with alcohol series and filled with Canada balsam, and permanent sliders were made. Also, specimens of about 2-3mm in thickness and 15mm in length were taken from the specimens used in making the three sections, followed by retting them into Schultze and dissociating them, dyed with safranine, and then temporary slides were made.

2-4 Measuring method

2-4-1 Measuring physical properties

The width of tree rings, the percentage of latewood, and specific gravity of specimens extracted from the neighboring part of rupture were measured.

2-4-2 Measuring the compression strength parallel to grain

After the specimens wee treated by humidification in a constant temperature and humidity chamber, they were measured in accordance with KS F 2206(1980). A universal testing machine was used for measuring, and the compression strength parallel to grain was calculated using the formula shown below.

Strength (kgf/cm^2) = maximum load (kgf)/cross section(cm^2) [1]

2-4-3 Measuring anatomical properties

2-4-3-1 Length of tracheids

From dissociated specimens, temporary slides were made by heartwood and sapwood, earlywood and latewood, and they were 100 times enlarged under an optical microscope and the length of 50 randomly tracheid were measured.

2-4-3-2 Width and wall thickness of tracheids

In the cross section of permanent slides which were made, the width and radial walls of the tangential direction and radial direction by heartwood and sapwood, earlywood and latewood were 400 times enlarged, and the width and thickness of 50 randomly tracheids each were measured.

2-4-3-3 Height of ray

In the tangential section of permanent slides, which were made, the height of 50 randomly ray were measured.

2-4-3-4 Microfibril angle

After drying the radial section cut with microtome, a gold which was 200Åthick was coated and its picture was taken under the accelerating voltage of 10-15kV using a SEM(Scanning Electron Microscope), and the tilt angle of microfibril was found by measuring the angle between the tracheid axis and the microfibril angle.

2–5 Statistical analysis

As a result of the experiment, to perform the statistical analysis to determine the impact factors of each anatomical property on compression strength parallel to grain, stepwise regression technique was used.

3. Results And Discussion

3–1 Compression strength parallel to grain by the size of tissue

Among the specimens which had been finished in measurement of compression strength parallel to grain, specimens differing in strength although the width of annual rings(3.0±0.2mm), the percentage of latewood(32.4±2.3%), specific gravity(0.52±0.02) and moisture content(12.0±1.0%), were the same, were sorted out at random, divided into heartwood and sapwood and their anatomical properties were measured. The results are shown in Table 2.

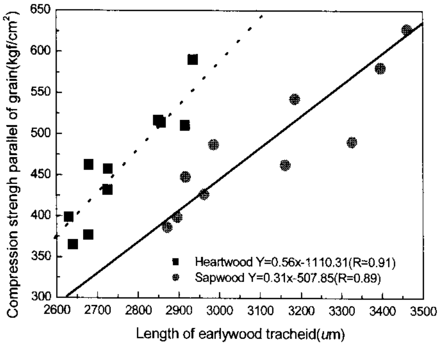
〈Table 2〉 Anatomical characters and compression strength parallel to grain of *Larix kaemferi C.*

	Heartwood				Sapwood			
	Max.	Min.	S.D.	Mean.	Max.	Min.	S.D.	Mean
X1	3105.5	2613.4	171.3	2872.5	3568.2	2863.3	238.7	3211.3
X2	3365.2	2816.5	183.2	2995.3	3760.4	2965.4	251.6	3360.5
X3	57.4	36.2	5.6	44.7	59.6	38.2	6.1	46.3
X4	24.6	15.7	3.8	18.2	27.3	16.0	3.9	20.5
X5	41.3	25.2	2.9	32.5	42.5	26.7	3.1	33.2
X6	42.5	27.3	3.0	33.7	43.3	27.7	3.2	33.9
X7	3.4	2.5	0.4	2.8	3.6	2.3	0.3	2.9
X8	6.3	4.0	0.5	5.6	6.9	4.2	0.5	6.0
X9	19.0	6.0	3.4	11.0	17.0	4.0	3.2	9.5
X10	21.2	14.6	2.6	17.5	15.6	11.2	1.9	13.0
Y	615.4	360.5	61.7	432.7	631.7	376.4	70.5	453.8

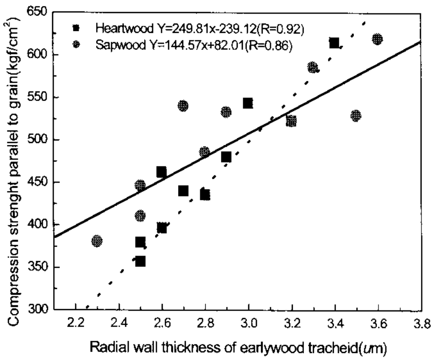
X1 : Length of earlywood tracheid(μm)
X2 : Length of latewood tracheid(μm)
X3 : Radial diameter of earlywood tracheid(μm)
X4 : Radial diameter of latewood tracheid(μm)
X5 : Tangential diameter of earlywood tracheid(μm)
X6 : Tangential diameter of latewood tracheid(μm)
X7 : Radial wall thickness of earlywood tracheid(μm)
X8 : Radial wall thickness of latewood tracheid(μm)
X9 : Height of uniseriate ray in cell number
X10: Microfibril angle (°)
Y : Compression strength parallel to grain(kgf/cm^2)

Of ten anatomical factors, it was shown that sapwood was large in diameter and length of earlywood and latewood tracheid; heartwood was large in the height of ray and microfibril angle. Also, the average compression strength parallel to grain of sapwood (453.8kgf/cm^2) was slightly higher than that of heartwood (432.7kgf/cm^2).

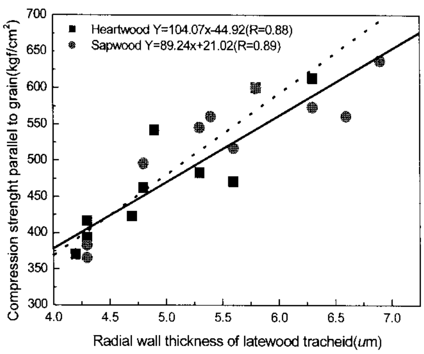
The compression strength parallel to grain according to the size of each constituent by heartwood and sapwood, as shown in Figs 1-4, became higher as the length of an earlywood tracheid and the radial wall thickness of earlywood and latewood went on the increase; it became lower as the height of uniseriate ray in cell number increased. There is a little difference in the strength between heartwood and sapwood in fact although it is known that there is no difference of special material, which are deposited within tissue, or various constituents. Furthermore, Wanggard(1950) reported that redwood, eastern red ceder, or black locust, which had more extracts in heartwood than in sapwood, were higher in that strength of heartwood, while other kinds of trees, which differed in the quantity of extract, were, if they had no defect, higher in the strength of sapwood. Moreover, Bendtsen(1978), who experimented with *pinus taeda*, presented that the longer a tracheid and the smaller the tilt angle of grain, the higher the strength. In the mean time, Bendsten and Senft(1986) reported on the investigation of anatomical properties and characteristics of strength of cottonwood and *pinus taeda* that as the greater the fibril angle and the smaller the length of fiber and the percentage of latewood, the lower the strength.



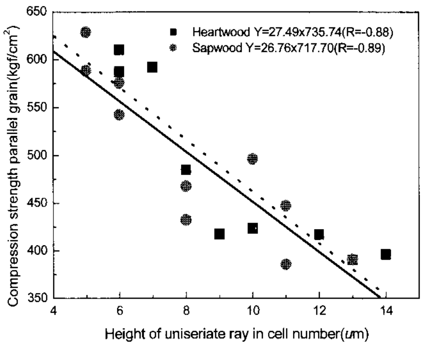
〈Fig. 1〉 Relationship between length of earlywood tracheid and compression strength parallel to grain.



〈Fig. 2〉 Relationship between radial wall thickness of earlywood tracheid and compression strength parallel to grain.



〈Fig. 3〉 Relationship between radial wall thickness of latewood tracheid and compression strength parallel to grain.



〈Fig. 4〉 Relationship between height of uniseriate ray in cell number and compression strength parallel to grain.

3–2 Relation between anatomical properties and compression strength parallel to grain

To investigate anatomical factors effecting on the strength after measuring the compression strength parallel to grain, multiple regression analysis of the relation between them in the way of stepwise was conducted, and the results are shown in Table 3.

It appeared that anatomical factors of heartwood, having an effect on the compression strength parallel to grain by heartwood and sapwood, were the radial wall thickness of a latewood tracheid, the length of a latewood tracheid, and the radial wall thickness of an earlywood tracheid, on the other hand, in sapwood, the length of an earlywood tracheid and the radial wall thickness of earlywood and latewood tracheids were the anatomical factors. Meanwhile, Bendtsten *et al.*(1981) studied mechanical properties according to anatomical properties of cottonwood and populus hybride NE-237, and they presented that fibril angle and specific gravity had much effects on the compression strength parallel to grain. In addition, Kaya and Smith(1993) made a report on analysis in stepwise way after measuring the compression strength parallel to grain with red pine that relative density and the length of a tracheid effected on the compression strength. However, because this study made an experiment using the specimen in the same specific gravity and moisture content, it was shown that the compression strength parallel to grain was more effected by the radial wall thickness of earlywood and latewood tracheids than specific gravity or moisture content. Besides, judging from the fact that microfibril angle did not effect on the compression strength parallel to grain, it calls for further studies.

〈Table 3〉 Coefficient of determination and regression equations of compression strength parallel to grain in *Larix kaemferi C.*

	No	Independent variables	Coefficient of determination	Regression equations
Heartwood	1	8	0.75***	Y = -482.35+17.27x8
	2	8 2	0.83**	+0.21x2+210.30x7
	3	8 2 7	0.90**	-21.81x4
	4	8 2 7 4	0.95**	
Sapwood	1	1	0.78***	Y = 313.15+0.17x1
	2	1 8	0.87***	+16.31x8+140.37x7
	3	1 8 7	0.91**	-0.27x2
	4	1 8 7 4	0.97**	

Notes: *** : $p < 0.01$, ** : $p < 0.05$
Legends: see table 2

4. Conclusions

Anatomical properties, by heartwood and sapwood having an effect on the compression strength parallel to grain of *Larix kaemferi* were examined here. As the lengthof an earlywood tracheid and theradial wall thickness of earlywood and latewood tracheids increased, the compression strength rose; as the height of uniseriate ray in cell number increased, the compression strength parallel to grain fell. The major anatomical factors effecting on the compression strength parallel to grain of heartwood were the radial wall thickness of a latewood tracheid and the length of a latewood tracheid, while in sapwood, the length of an earlywood tracheid and the radial wall thickness of earlywood and latewood tracheids were the major factors on it.

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