Differences of Pine (*Pinus sylvestris* L.) Wood Physical and Mechanical Properties From Different Forest Site Types in Lithuania

MARIUS ALEINIKOVAS AND JONAS GRIGALIŪNAS
Lithuanian Forest Research Institute, Liepu 1, Girionys, LT-53101, Kaunas distr., Lithuania, Phone +370 37 547283, Fax +370 37 547446

Aleinikovas, M. and Grigaliūnas, J. 2006. Differences of Pine (*Pinus sylvestris* L.) Wood Physical and Mechanical Properties from Different Forest Site Types in Lithuania. *Baltic Forestry*, 12 (1): 9–13.

Abstract

The paper presents the evaluation and comparison of some physical and mechanical properties of Scots pine (*Pinus sylvestris* L.) wood from three Lithuanian forest sites - normal humidity very poor site (Na), normal humidity poor site (Nb) and normal humidity fertile site (Nc). The data have been collected on the basis of 9 sample plots.

Wood samples were taken at the stem butt-end. The average annual ring width, late wood percentage in annual ring, wood density, bending strength in tangential direction and compression strength along the grain were determined in the samples.

Wood density of pine trees from the analysed three forest sites have not differed significantly. The estimated bending strength (92.68 MPa) and compression strength parallel to grain (82.48 MPa) of wood from Nb site are highest and significantly differ, in comparison with Na and Nc forest sites.

Key words: Scots pine, forest site type, wood physical - mechanical properties

Introduction

Scots pine is the widespread tree species and productive in indigenous stands in Lithuania. Pine stands cover 36.2 % of the forest area and its average growing stock volume comprises 167 m^3/ha (*Lithuanian Statistical Yearbook of Forestry* 2005). The majority of pine stands in Lithuania (77.8 %) grow on normal humidity sites – on Na (normal humidity very poor site), Nb (normal humidity poor site) and Nc (normal humidity fertile site) sites, respectively 9.69 %, 55.79 % and 12.14 %. Various growth conditions could influence the composing of different strength wood. There were studies done by Stinskas A. (1957), Kobylinski F. (1969), Perelygin L. (1963) analysing the effects of various environmental factors on wood structure and properties, though, mainly on forest site type. However, the following research did not present the dependence of wood properties on growth conditions of pine stands in Lithuania.

The aim of this study was to evaluate and compare some physical and mechanical properties of Scots pine *(Pinus sylvestris* L.) wood from three forest sites in Lithuania.

Materials and methods

The object of the studies is the wood from three forest sites Na, Nb and Nc. The main inventory indices of the studied stands are presented in Table 1.

Table 1. Main inventory indices of the studied stands

Stand location, area	Forest site type	Age, years	Site index	Height, m	DBH, cm	Stocking level	Stand volume, m^3/ha
Druskininkai FE, Latežeris NPP, block 294, site 1, 0.9 ha	Na	110	III	21	24	0.7	230
Druskininkai FE, Latežeris NPP, block 294, site 15, 3.8 ha.	Na	85	IV	20	26	0.8	230
Druskininkai FE, Latežeris NPP, block 294, site 18, 0.5 ha.	Na	85	IV	20	26	0.8	250
Dubravos FE, Vaišvydava NPP, block 96, site 10, 1.1 ha.	Nb	90	II	27	28	0.8	380
Dubravos FE, Vaišvydava NPP, block 97, site 12, 0.9 ha.	Nb	90	I	28	30	0.7	350
Dubravos FE, Vaišvydava NPP, block 98, site 3, 4.0 ha.	Nb	95	I	28	30	0.7	350
Dubravos FE, Vaišvydava NPP, block 83, site 5, 0.9 ha.	Nc	85	I	28	32	0.8	400
Dubravos FE, Vaišvydava NPP, block 84, site 1, 3.0 ha.	Nc	95	I	31	36	0.9	520
Dubravos FE, Vaišvydava NPP, block 84, site 8, 4.7 ha.	Nc	95	I	30	36	0.9	480

The growth identity was estimated while evaluating the maximum of mean diameter increment of the analysed stands (Grigaliūnas 1998).

In each selected stand the wood bore samples were drilled in ten chosen tree stems at the 1.3 m height for measuring the width of annual rings and the percentage of latewood. For measuring of the wood mechanical properties two sample trees in the each stands were randomly selected. The north and south directions were marked on the standing sample trees. Wood density, bending strength in tangential direction as well as compression strength along the grain of pine wood were studied based on small clear specimens. The study was conducted on 2 - m long butt logs cut from the sample trees. From the central part of each log, a 75 mm thick board was cut, oriented towards the north - south direction, including the pith. The boards were kiln - dried to air dry condition (MC ca. 12 %).

Measurements of the width of annual rings and the proportion of latewood in annual rings were started from the pith. The width of annual rings and the amount of latewood were measured perpendicularly to the circle of annual ring using binocular microscope with the accuracy of ± 0.1 mm. The proportion of latewood was calculated according to Formula 1.

$$m = \frac{\sum \delta}{l} \times 100 \qquad (1),$$

here: $\Sigma\delta$ - total width of latewood, cm.

$\Sigma\delta = \delta_1+\delta_2+\delta_3+...+\delta_N$,

N - number of annual rings, l - total width of annual rings in the radial direction, cm.

The remaining part of the board was cut longitudinally into 30 x 30 mm size wood samples, starting from the pith. The samples were numbered in ascending direction, moving from the pith to the bark. From each sample clear 20 x 20 mm size samples were prepared for the measurement of density and mechanical properties. To measure wood density and compression strength parallel to grain, 30 mm long samples were used, while to measure static bending strength - 300 mm long samples were used. Totally, 2094 samples were studied.

Wood properties were determined according to test standards (ISO 3130:1975, ISO 3131:1975, ISO 3133:1975, ISO 3787:1976). The number of wood samples necessary for reliable determination of individual wood properties was ascertained applying statistical methods (Saladis and Aleinikovas 2004).

Having determined the moisture content of samples by weighing, wood density and strength properties were calculated for the standard moisture content of 12 % (ISO 3130:1975). Strength properties were determined by using 5 tons powered testing machine P-5. Prior to testing, the thickness and width of each sample in the centre were measured with the accuracy of 0.1 mm.

Results and discussion

The data on physical and mechanical pine wood properties of three forest sites is shown in Table 2.

Table 2. Average pine wood properties in the studied forest site types

Forest site type	Stand No.	Width of annual rings, mm	Latewood,	Density, kg/m^3	Bending strength, MPa	Compression strength ||, MPa
Na	1	1.73	33.57	574	84.85	69.38
	2	1.54	37.00	613	93.64	80.78
	3	1.66	33.53	570	81.87	74.41
	Average	1.64 0.06	34.70 1.15	586 13.46	86.73 3.53	74.86 3.30
Nb	4	1.77	37.69	566	83.17	76.03
	5	1.86	35.45	586	97.1	84.54
	6	1.76	37.76	564	97.76	86.87
	Average	1.80 0.03	36.97 0.76	572 6.82	92.68 4.76	82.48 3.29
Nc	7	1.85	38.34	558	84.31	75.23
	8	1.74	39.69	583	77.79	69.68
	9	2.07	37.76	584	80.23	72.99
	Average	1.89 0.10	38.60 0.57	575 8.55	80.78 1.90	72.63 1.61

As the results show, the smallest annual ring width (1.64 mm) and late wood percent (34.70 %) were estimated in wood of trees from the Na sites type. The presented Na site values differed essentially while comparing with the Nb and Nc site tree wood values. Nevertheless, the essential differences between Nb and Nc site tree wood annual rings properties were undetermined. As is it known, the physical and mechanical wood properties depend on the annual rings width. There are estimated optimal annual rings width then wood quality is best for certain tree species (Jakimavičius 1998).

The analyses of Dubrava forest pine wood rings were done in 2002 (Saladis 2002). The annual rings of pine wood from peatland sites were narrow. The average annual ring width was only 1.0 mm in mature pine stands from peatland sites and 1.3 – 1.9 mm in young stands. The widest annual rings were estimated in pine wood stands from normal and slopes humidity sites. Average rings wide were 2.1 – 2.2 mm in mature pine stands and 2.2 – 2.8 mm in young stands.

Stravinskienė (1983) has found that earlywood occupies 70 – 80 % of the annual rings width in young pine trees and about 60 – 70 % in mature trees. Though, the amount of latewood increases with age. However, there are and converse data. It was found that the latewood percent in oak wood decreases 18 percent during 50 - 200 years (Grigaliūnas 1999).

We have estimated that wood density of pine trees from the analysed three forest sites have not differed significantly. As the results show the higher wood

density (586 kg/m^3) was estimated on the Na site, whereas on Nb – the smallest wood density (572 kg/m^3). While comparing pine wood strength properties it was estimated, that bending strength (92.68 MPa) and compression strength (82.48 MPa) of wood from Nb site were highest and significantly differed in comparison with Na and Nc forest sites.

Essential differences in wood strength properties of trees from Na and Nc site were undetermined.

In our study the variation of wood density, bending strength and compression strength parallel to grain in stem radial direction were estimated. The data on the study results are presented in Figures 1 - 3.

The lowest wood density and strength properties have been found in pine trees from Nc site in the juvenile age (in the juvenile wood). Though, the described distribution of wood properties is related to tree growth rate. At the early growth stage, the pine trees on Nc site have the widest annual rings with lowest percent of late wood, while pine trees from Na site - narrow annual rings with highest percent of latewood.

At the later growth stage (in the mature wood) pine trees from Nc and Nb sites have narrow annual rings with highest percent of late wood, while the wood density and strength properties increase. The wood properties of pine trees aged 40 – 60 year old from Nc and Nb sites exceed the values of pine wood properties from Na site, and in the following external layers of stem the values are higher.

It was noticed, that wood density and strength properties of pine wood from Na site are equal in stem radial direction. For example, in the first layer the wood density is 575 kg/m^3, after, it increases up to 618 kg/m^3 and in the last outside layer decreases to 558 kg/m^3. Though, pine wood density of Nc forest site varies in a wide diapason. There the wood density is 455 kg/m^3 in the first layer, after that, it increases up 623 kg/m^3 and in the last outside layer decreases to 585 kg/m^3. The described variation of wood properties in the stem radial direction is reducing the average values of pine wood properties of Nb and Nc sites.

The general physical and mechanical properties of studied pine stands are presented in Table 3.

While analysing the obtained data, it was found that the coefficient of variation was higher for the width of annual rings (60.11 %) and lower for the wood density (13.2 %). According to the data found by Jakimavičius (1998), the relative coefficient of variation for the wood density is 10 %, late wood percent - 28 %, the width of annual rings - 37 %, bending strength - 15 % and for the compression strength - 13 %. This data correspond to the coefficient of variation in wood properties described in the research by Perelygin

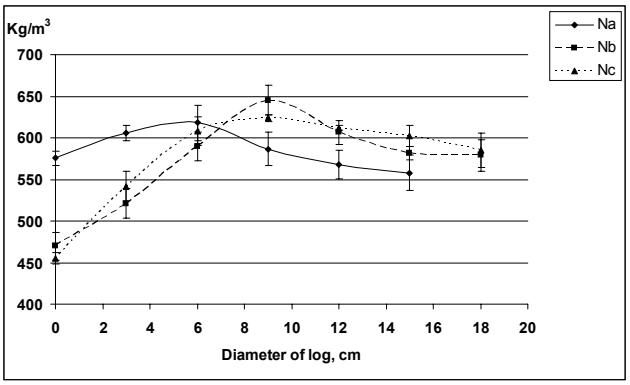

Figure 1. The variation of pine wood density in stem radial direction

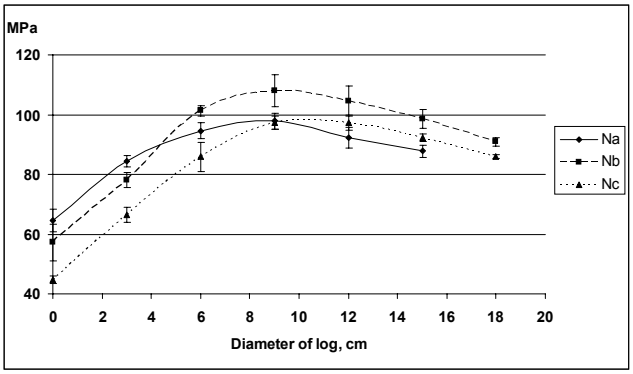

Figure 2. The variation of pine wood bending strength in stem radial direction

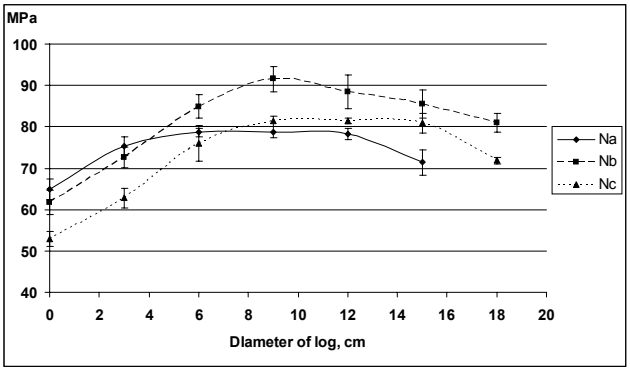

Figure 3. The variation of pine wood compression strength parallel to grain in stem radial direction

Table 3. Values of pine wood physical and mechanical properties according to studied stands

	Width of annual rings, mm	Latewood,	Density, kg/m^3	Bending strength, MPa	Compression strength ‖, MPa
Average value	1.77	39.88	574	85.97	76.11
Minimum value	0.2	10.12	356	33.75	37.41
Maximum value	8.2	63.0	803	157.53	113.40
Number of measurements	7214	7214	475	675	675
Coefficient of variation,	60.11	32.16	13.2	24.92	18.71
Precision indice of the average value,	0.71	0.38	0.61	0.96	0.72

(Перелыгин 1963). In our research, the coefficient of variation for the analysed wood properties is higher.

The data obtained were compared with these described in the literature, while the comparison of pine wood parameters is presented in Table 4.

Table 4. Comparison of pine wood parameters (*Šķēle *et al.* 2002, **Стинскас 1957)

	Wood density, kg/m^3	Bending strength, MPa	Compression strength ‖, MPa
Lithuania (butt-end)	574	85.97	76.11
Latvia* (butt-end)	492	-	-
Kola Peninsula** (all stem)	510	79.9	41.7
North part of Russia** (all stem)	540	87.7	46.6
Central part of Russia** (all stem)	530	78.5	44.3
Ukraine** (all stem)	540	73.2	38.4
The Far East** (all stem)	470	66.0	35.0
East Siberia** (all stem)	470	71.4	38.3
West Siberia** (all stem)	480	73.6	42.7

The values of wood density and strength of analysed pine stands are highest. This could be explained by the bottom logs of the stem used in the research.

The described results of our research have to be taken into account while exploiting wood for the production and scientific studies.

Conclusions

1. The smallest annual ring width (1.64 mm) and late wood percent (34.70 %) were estimated in wood of trees from the Na sites. The presented Na site values differed essentially while comparing with the Nb and Nc site tree wood values. Nevertheless, the essential differences between Nb and Nc site annual rings properties were undetermined.

2. Wood density of pine trees from the analysed three forest sites have not differed significantly.

3. The estimated bending strength (92.68 MPa) and compression strength parallel to grain (82.48 MPa) of wood from Nb site are highest and significantly differ in comparison with Na and Nc forest sites. Essential differences in wood strength properties of trees from Na and Nc sites were undetermined.

4. Wood density and strength properties of pine wood from Na site are equally in stem radial direction, though, pine wood properties of Nb and Nc forest site vary in a wide diapason. The described variation of wood properties in the stem radial direction is reducing the average values of pine wood properties of Nb and Nc sites.

References

Grigaliūnas, J. 1998. Lietuvos pušynų augimo dinamika ir jos vertinimas [The dynamics and assessment of Scots pine stands growth in Lithuania]. Habilitacinio darbo santrauka. Kaunas-Girionys, 103 p. (in Lithuanian).

Grigaliūnas, J. 1999. Ekologinių ir ūkinių sąlygų įtakos nustatymas medienos kokybei [The evaluation of ecological and forestry condition inflation to wood quality]. Ataskaita. Kaunas - Girionys, 16 p. (in Lithuanian).

ISO 3130:1975. Wood — Determination of moisture content for physical and mechanical tests.

ISO 3131:1975. Wood — Determination of density for physical and mechanical test.

ISO 3133:1975. Wood — Determination of ultimate strength in static bending.

ISO 3787:1976. Method of testing in compressive strength parallel to grain of wood.

Jakimavičius, Č. 1998. Medienotyra [Wood science]. Kaunas, „Technologija“, 248 p (in Lithuanian).

Kobylinski, F. 1969. Macrostructure, density and main mechanical properties of Scots Pine wood. *Technika Drewna* 16 (3), 63-68 p. (In Polish).

Lietuvos miškų statistika [Lithuanian Statistical Yearbook of Forestry]. 2005. Valstybinė miškotvarkos tarnyba, Kaunas. 112 p. (in Lithuanian and English).

Saladis, J. 2002. Medienos kokybės priklausomybės nuo medynų našumo tyrimai grynuose pušynuose [Dependence of wood quality on yield in pure Scots pine stands]. 2002 metų ataskaita. Lietuvos miškų instituto rankraštis. Girionys, 24 p. (in Lithuanian).

Saladis, J. and Aleinikovas, M. 2004. Pušų medienos fizinių ir mechaninių savybių kintamumas bei koreliaciniai ryšiai [Variability and correlation of physical and mechanical properties of pine wood]. *Miškininkyste,* 1, 55, 60-67 p (in Lithuanian).

Šķēle, K., Alksne, A., Cīrule, D. and Hrols, J. 2002. Parastās priedes (*Pinus Sylvestris* L.) koksnes anatomiskā uzbūve un fizikālās īpašības Latvijā [Anatomical structure and physical properties of pine (*Pinus Sylvestris* L.) wood in Latvia]. LLU Raksti 5. 68 -74 p. (in Latvian).

Лакин Г. Ф. 1974. Биометрия [Biometric]. Москва, „Высшая школа”, 293 с (in Russian).

Перелыгин Л. М. 1963. Древесиноведение [Wood science]. Москва, „Гослесбумиздат”, 283 с (in Russian).

Стинскас В. А. 1957. Физико-механические свойства древесины сосны (*Pinus sylvestris., L.*) произрастающей в условиях Литовской ССР [The physical and mechanical properties of pine wood in Lithuania]. Труды Академий Наук Литовской ССР, Вильнюс (Сер.Б.) 1(9), 119-132 с. (in Russian).

Стравинскене В. П. 1983. Динамика ранней и поздней древесины в годичных кольцах деревьев и ее изменение вследствие лесоосушения [Dynamics of earlywood and latewood in the annual rings of trees ant it variation as a result of forest drying]. *Экология* 6, 29 – 34 с. (in Russian).

Received 02 February 2006
Accepted 19 May 2006

СРАВНЕНИЕ ФИЗИКО – МЕХАНИЧЕСКИХ СВОЙСТВ ДРЕВЕСИНЫ СОСНЫ ПРОИЗРАСТАЮЩЕЙ В РАЗНЫХ УСЛОВИЯХ

М. Алейниковас, Й. Григалюнас

Резюме

В статье представлены физико-механическе свойства древесины сосны (*Pinus sylvestris* L.). Изучены свойства древесины девяти сосновых древостоев: - в нормально увлажненных неплодородных (Na), мало (Nb) и достаточно плодородных (Nc) почвенных условиях лесопроизрастания.

Образцы были взяты из комблевой части ствола. На основании собраного материала были: плотность, процент поздней древесины, ширина годичных слоев, прочность при статическом изгибе и прочность при сжатии вдоль волокон.

Ширина годичных слоев, процент поздней древесины и механические свойства древесины, имеют установлены существенные отличия в разных условиях лесопроизрастания.

Сравнивая плотность древесины сосняков, существенные отличия в разных условиях лесопроизрастания необнаружены. Наибольшая прочность при статическом изгибе (92,68 MPa) и прочность при сжатии вдоль волокон (82,48 MPa) были установлени в мало плодородных почвенных условиях лесопроизрастания и она существенно отличалась от прочности в неплодородных и достаточно плодородных почвенных условиях лесопроизрастания.

Ключевые слова: Сосна обыкновенная, физико-механические свойства, почвенные условия лесопроизрастания.