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SHRINKAGE PROPERTIES OF NORWAY SPRUCE WOOD

MATTI KÄRKKÄINEN and MICHEL MARCUS

Seloste

KUUSEN PUUAINEEN KUTISTUMINEN

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Spruce boards sawn from outer layers of logs were sampled from a sawmill in northern Finland and another in southern Finland. Test pieces 20 mm × 20 mm × 20 mm were selected according to maximum variation in growth ring width. Volumetric and longitudinal shrinkage from a soaked to a dry condition were measured. It was found that wood density correlated positively with the volumetric shrinkage but negatively with the longitudinal shrinkage. Dry density was a better predictor than basic density. With constant density and an increase in growth ring width, there was increased shrinkage; especially in samples from northern Finland. Besides this, when density was kept constant, the shrinkage was higher in the spruce wood from southern Finland than from northern Finland.

1. INTRODUCTION

The shrinkage of wood from a green or soaked to an absolutely dry condition is known to reflect dimensional changes of wood in use when the moisture varies due to weather. Therefore, shrinkage properties of wood are given in many handbooks. The radial, tangential and longitudinal directions are often separated. Their additive effect is the volumetric shrinkage.

A common model given in numerous textbooks is that the increase in wood density increases the shrinkage especially if only the variation inside tree species is studied. Between species the same holds true although great variation is caused by other factors.

The effect of growth ring width alone is also clear in many species. In spruce there is a negative correlation between the density and the growth ring width (see the literature in Kärkkäinen and Dumell 1983). Therefore, one can suppose that the shrinkage decreases as the growth ring width increases.

However, little is known of the effect of growth ring width when the density is kept constant. Similarly, the possible differences of spruce wood from northern and southern Finland are not known. Therefore, a detailed study was made of the relationships.

The laboratory measurements were made by Marcus who also computed the main results. On the basis of his preliminary manuscript Kärkkäinen wrote this report which was checked together. The language was corrected by Reino Pulkki, Lic. Sc. (For.). Comments were given by Juhani Salmi, M. Sc. (For.), and professor Olli Uusvaara. The authors thank for the support.

2. MATERIAL AND METHODS

A part of the material studied by Kärkkäinen and Dumell was used in this study. A part of the spruce boards sawn from outer layers of logs were from a sawmill situated in the Oulu area in northern Finland. The other part came from the Hämeenlinna area in southern Finland. The material was selected so that maximum variation in growth ring width was obtained between samples. However, all samples were from mature wood as all the boards were made from surface parts of sawlogs.

From the boards small cubes were made; the dimensions being 20 mm. Being first air dry, they were oven dried to absolute dryness, and the dimensions were measured to an accuracy of 0,1 mm. They were then soaked in water for a day and the dimensions were remeasured. Besides this, dry density and basic density were determined, as well as the average growth ring width. The number of samples was totally 183 pieces.

On the basis of the measurements the volumetric and longitudinal shrinkages from a soaked to an absolutely dry condition were computed. The relationships between variables were studied using regression analysis. Various transformations of variables, as well as interaction terms were included in the analysis. The effect of area (northern Finland – southern Finland) was studied using dummy variable. The interaction terms of the dummy variable and the other variables were computed, too.

The regression techniques were similar to those in Kärkkäinen (1984).

3. RESULTS

The means and standard deviations were as follows.

Variable	Northern Finland $\bar{x}$	Northern Finland s	Southern Finland $\bar{x}$	Southern Finland s
No. of observations	90		93	
Growth ring width mm	1,5	0,8	2,1	0,6
Basic density kg/m³	379	25	379	30
Dry density kg/m³	444	32	450	38
Volumetric shrinkage %	14,5	1,54	15,8	1,7
Longitudinal shrinkage %	0,61	0,20	0,57	0,1
Ratio volumetric shrinkage/ relative basic density	38,3	3,9	42,0	5,2

As can be seen, the average basic density was similar in both areas in this material. In spite of this, the volumetric shrinkage was 9 % higher in the material from southern Finland than from northern Finland. In longitudinal shrinkage, the difference favoured southern Finland and was 7 %.

The difference in the shrinkage behaviour resulted in dry density being higher in the southern Finnish material, although the basic density was similar.

In both areas there was a positive correlation between the volumetric shrinkage and the density. However, the correlation was much higher for northern Finland than for southern Finland. Besides this, the dry density was a much better predictor than the basic density. This can be seen from the linear correlation coefficients.

	Area Northern Finland	Area Southern Finland
Basic density × vol. shrinkage	0,36	0,14
Dry density × vol. shrinkage	0,56	0,38

The correlation between the longitudinal shrinkage and the density was negative, although not statistically significant in south-

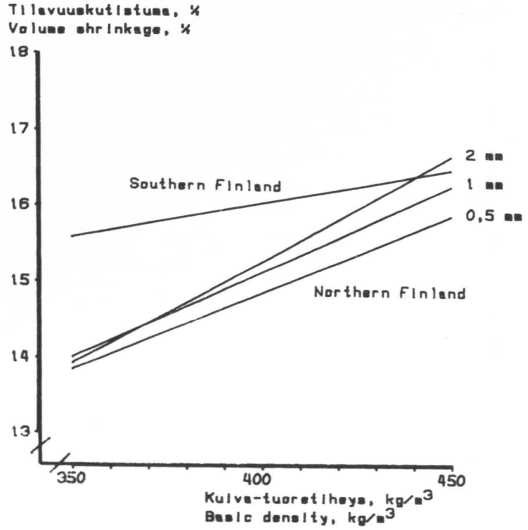

Fig. 1. Volumetric shrinkage of spruce samples from northern Finland (ring width levels 0,5, 1 and 2 mm) and southern Finland (all ring widths) according to basic density.

Kuva 1. Pohjois- ja eteläsuomalaisten kuusinäytteiden tilavuuskutistuma kuiva-tuoretiheyden mukaan, kun pohjoissuomalaisten näytteiden luston leveys on 0,5, 1 tai 2 mm ja eteläsuomalaisten taas kutistumaan vaikuttamaton.

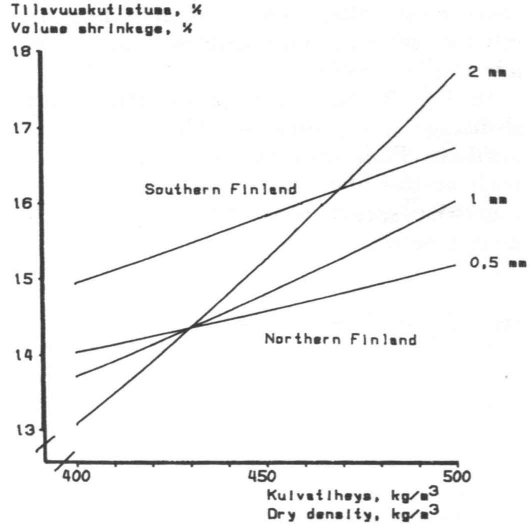

Fig. 2. Volumetric shrinkage of spruce samples from northern Finland (ring width levels 0,5, 1 and 2 mm) and southern Finland (all ring widths) according to dry density.

Kuva 2. Pohjois- ja eteläsuomalaisten kuusinäytteiden tilavuuskutistuma kuivatiheyden mukaan, kun pohjoissuomalaisten näytteiden luston leveys on 0,5, 1 tai 2 mm ja eteläsuomalaisten taas kutistumaan vaikuttamaton.

ern Finland. Even in this case the dry density was a better predictor than the basic density.

	Area Northern Finland	Area Southern Finland
Basic density × long. shrinkage	−0,47	−0,08
Dry density × long. shrinkage	−0,50	−0,13

Because there was a negative correlation between the growth ring width and the density (for both density variables −0,57 in northern Finland and −0,16 in southern Finland), it is logical that the growth ring width had a negative correlation with the volumetric shrinkage and a positive correlation with the longitudinal shrinkage.

	Area Northern Finland	Area Southern Finland
Ring width × vol. shrinkage	−0,26	−0,04
Ring width × long. shrinkage	0,49	0,23

When the density and the growth ring width were taken into account simultaneously, it was found that in northern Finland both variables were important in predicting shrinkage properties. On the contrary, in southern Finland only the density was statistically significant in the prediction.

The results concerning the volumetric shrinkage can be seen in Fig. 1 (basic density) and Fig. 2 (dry density). It can be seen that in the northern Finnish material, where the growth ring width had an effect, the shrinkage increased with increasing density and growing ring width. However, in mostly all cases the shrinkage is lower than in the southern Finnish material where only the density affects the shrinkage.

In Fig. 3 the results of the longitudinal shrinkage are presented. The spruce from northern Finland is better if the density is high and/or the growth rings are narrow, otherwise spruce wood from southern Finland is better.

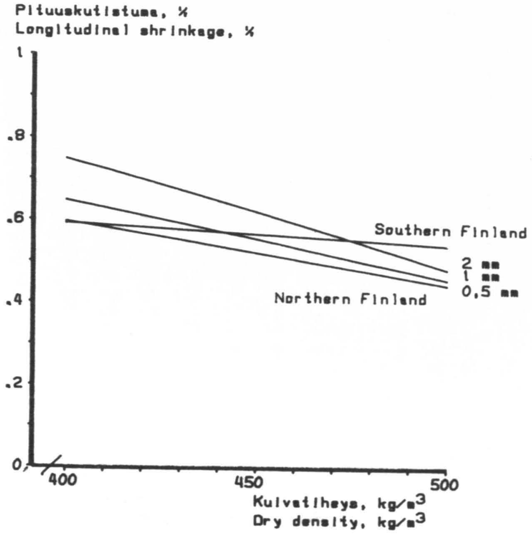

Fig. 3. Longitudinal shrinkage of spruce samples from northern Finland (ring width levels 0,5, 1 and 2 mm) and southern Finland (all ring widths) according to dry density.

Kuva 3. Pohjois- ja eteläsuomalaisten kuusinäytteiden pituuskutistuma kuivatiheyden mukaan, kun pohjoissuomalaisten näytteiden luston leveys on 0,5, 1 tai 2 mm ja eteläsuomalaisten taas kutistumaan vaikuttamaton.

4. DISCUSSION

The volumetric shrinkage of spruce wood measured in this study, 14,5 % in northern Finland and 15,8 % in southern Finland, are very high compared with shrinkage values given in handbooks from Central Europe. As an example, Kollmann (1951) gives the value 11,9 %, Knigge and Schulz (1966) 11,8 %, and Lohmann (1982) 11,7 %. However, a look at some original studies shows that the volumetric shrinkages of this study are not unexceptional for spruce, although high.

Volumetric shrinkage %	Corresponding basic density kg/m³	Author
14,5	379	This study, northern Finland
15,8	379	This study, southern Finland
12,8	385	Knudsen 1956
14,7	365	Ericson 1960
13,6	412	Tamminen 1964 [1]
14,3	365	Bernhart 1965
14,8	334	Regináč 1977

[1] 10 % height, outer layers of stems

The average longitudinal shrinkage measured in this study was high, too: 0,61 % in northern Finland and 0,57 % in southern Finland. In the textbooks mentioned earlier the average for spruce is 0,2 . . . 0,3 %.

One possible explanation for the high shrinkage values is the use of small samples. The dimensions used are according to ISO standard actually intended for the measurement of radial and tangential shrinkage (International . . . 1981). It is clear that in small samples various shrinkage restrictions have less effect than in larger samples, as pointed out by Ericson (1960). Therefore, the shrinkages found in sawngoods are smaller.

The results of this study support the model that the volumetric shrinkage increases with the density. If only ring width is studied, the volumetric shrinkage decreases with the widening of growth rings. However, if both density and growth ring width are regarded simultaneously, and density is kept constant, there is increased shrinkage with an increase in growth ring width. This finding is supported by Tamminen (1964), and these results are in accordance with results concerning pine (Tamminen 1962). In the material of the present study the relationship was statistically significant only in the samples from northern Finland, but could also be noticed in southern Finnish material.

The relationships between the volumetric shrinkage, density and growth ring width, result in northern Finnish spruce being better than southern Finnish spruce in regard to volumetric shrinkage. Especially if one selects slow-grown spruce, the volumetric shrinkage is low with respect to high density and good strength caused by it.

This conclusion is supported by the fact that the longitudinal shrinkage decreases with an increase in density and it is at its lowest when the growth rings are narrow. It is commonly supposed that high longitudinal shrinkage causes warping of timber. Therefore, the results support a common belief that spruce from slow-grown northern Finnish forests is excellent for joinery and other similar purposes.

The reason why density and volumetric shrinkage are positively correlated can be deduced from the anatomy of the cell wall. If density is high, the volume occupied by cell walls is high, and as the volume of hygroscopic material increases, the shrinkage also increases. This deduction is correct if the volume of lumen is relatively unaffected by the shrinkage.

The effect of growth ring width (keeping the density constant) is not easily explained. One theory is that the proportion of various cell wall constituents is affected by growth rate, and shrinkage properties due to this. Because no chemical analysis was made, this question remains open.

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Total of 12 references

SELOSTE

KUUSEN PUUAINEEN KUTISTUMINEN

Etelä- ja pohjoissuomalaiselta sahalaitokselta kerätystä kuusen pintalauta-aineistosta mitattiin tilavuuden ja syiden suuntainen kutistuminen märästä tilasta absoluuttisen kuivaksi. Mittaukset tehtiin virheettömistä kuutioista, joiden särmä oli 20 mm. Aineistoa valittaessa pyrittiin mahdollisimman suureen vuosiluston leveyden vaihteluun siten kuin se on selostettu samaa aineistoa käyttäneessä Kärkkäisen ja Dumellin (1983) tutkimuksessa.

Dimensiot mitattiin 0,01 mm lukematarkkuuden omaavalla mikrometrillä, jonka paine mittauspintaa vasten oli jousikuormitteisuuden ansiosta vakio. Tilavuus laskettiin stereometrisesti kuutioina. Tiheystunnuksina käytettiin kuiva-tuoretiheyttä (kuiva massa jaettuna kuution tuoretilavuudella) ja kuivatiheyttä (kuiva massa jaettuna kuution kuivatilavuudella). Lisäksi mitattiin poikkileikkauksesta keskimääräinen vuosiluston leveys.

Keskimääräiset tutkimusaineiston tunnukset olivat seuraavat.

Muuttuja	Pohjois-Suomi		Etelä-Suomi	
	$\bar{x}$	s	$\bar{x}$	s
Havaintoja	90		93	
Vuosiluston leveys mm	1,5	0,8	2,1	0,6
Kuiva-tuoretiheys kg/m^3	379	25	379	30
Kuivatiheys kg/m^3	444	32	450	38
Tilavuuskutistuma %	14,5	1,54	15,8	1,75
Pituuskutistuma %	0,61	0,20	0,57	0,15
Tilavuuskutistuman suhde suhteelliseen kuiva-tuoretiheyteen	38,3	3,9	42,0	5,2

Yksittäisistä riippuvuuksista merkittävin oli tilavuuskutistuman kasvu tiheyden kohotessa. Riippuvuus oli likeisempi kuvattaessa tiheyttä kuivatiheydellä kuin kuiva-tuoretiheydellä. Vuosiluston leveyden suuretessa kutistuminen pieneni, mikä johtui tiheyden ja vuosiluston leveyden negatiivisesta korrelaatiosta. Sitä vastoin, jos samanaikaisesti otettiin huomioon tiheys ja vuosiluston leveys, tiheyden ollessa vakio vuosiluston leventyminen lisäsi tilavuuskutistumaa.

Pituussuuntainen kutistuma aleni tiheyden kasvaessa, mutta kohosi vuosiluston leventyessä.

Riippuvuuksien perusteella voitiin päätellä, että ohutlustoinen pohjoissuomalainen kuusi on kutistumisominaisuuksiltaan eteläsuomalaista kuusta parempi. Kun voidaan olettaa, että tässä tutkimuksessa mitattu maksimaalinen kutistuma kuvaa myös puun vähäisempää elämistä ilman kosteuden vaihdellessa, tulosta voidaan soveltaa valikoitaessa puuta eri tarkoituksiin.