Saimaa University of Applied Sciences
Technology, Lappeenranta
Double Degree Programme
Civil and Construction Engineering

Anastasia Gruznova

COMPARISON OF TIMBER STRENGTH CLASSIFICATION SYSTEMS IN FINLAND AND IN RUSSIA

Bachelor’s Thesis 2012

ABSTRACT

Anastasia Gruznova
Comparison of timber strength classification systems in Finland and in Russia, 67 pages
Saimaa University of Applied Sciences, Lappeenranta
Technology, Degree Programme in Civil and Construction Engineering
Structural Engineering
Tutors: Timo Lehtoviita, Saimaa University of Applied Sciences, Pasi Kenola, FinScan

The purpose was to find out the way how to transfer Finnish strength classes into Russian ones, to study testing process of sawn timber elements and to investigate the current market of wooden products in both countries.

The theoretical part is a combination of background information about the features of timber as a construction material and a comparative analysis of grading of sawn timber in Russia and in Finland. The main issue was to find a correspondence between values given in the main normative documents about strength classification of sawn timber – Finnish EN 338 and Russian SNIP II-25-80. In addition the theoretical part includes a description of the existing strength determining tests in both countries. The empirical part consists of strength measurements carried out in Finnish and Russian laboratories. Samples made of Finnish timber C24 were used.

As a result of this project it could be stated that Finnish and Russian strength classifications are not the same, mainly because timber in Russia is commonly used as a finishing material. Therefore quality and appearance factors are important most of all. But there is a correspondence between Russian quality grades and Finnish strength ones. Russian and Finnish methods of laboratory strength determining differ in size and dimensions of samples, which means problems in using values from European standards in calculations according to Russian SNIPs. One way to facilitate and develop trade relations between Finland and Russia is to create a uniform base of normative documentation between Europe and Russia and synchronization methods of testing.

Keywords: sawn timber, strength classifications, grading of sawn timber, laboratory strength measurements.

.

CONTENTS

1 INTRODUCTION

During a long time trade relations were developing between Finland and Russia. One important export product is timber. It is used as a structural material for residential buildings in both countries.

According to the Report of the Ministry of Regional Development of Russian Federation Russia is going to finish the harmonization program of SNIPs and Eurocodes till the end of 2014. It means that in a few years Russia and Europe will have the same structure of normative documentation, the similar procedure of calculations and similar designations. Therefore it is very important to determine an interconnection between Finnish and Russian norms about wood, especially sawn timber.

The main problem is a difference between Finnish and Russian classifications of sawn timber. in Russia it is quality classification, in Finland other than quality classification there is a strength classification. They are not equivalent in estimation and values. The main purpose of this thesis work is to compare classifications and find a correlation between Finnish strength classes and Russian Quality grades of sawn timber.

The company FinScan Oy produces real-time image processing and optimizing systems for the sawmill industry. A comparative analysis of the thesis can be useful for FinScan Oy.

2 TIMBER AS A CONSTRUCTION MATERIAL

Timber is a natural resource that is widely available throughout the world. Timber has been an important construction material since humans began building houses.

Timber may be used in both residential and commercial buildings as a structural and aesthetic material. In buildings made of other materials, timber will still be found as a supporting material, especially in roof construction, in interior doors and their frames, and as exterior cladding.

Engineered timber products have highly predictable and reliable performance characteristics and provide high design flexibility: on the one hand, these products allow the use of smaller pieces, and on the other hand, they allow bigger spans. Due to the ease of workability, timber members can be produced in many sizes and shapes.

Engineered timber products prove to be more environmentally friendly and, if used appropriately, are often less expensive than building materials such as steel or concrete (Thelandersson 2003). These products are extremely resource-efficient because they use more of the available resource with minimal waste.

Pine and spruce are the main wood materials used in frame structures.

2.1 Macrostructure and microstructure of wood

Wood is obtained from two broad categories of plants known commercially as hardwoods (angiosperms, deciduous trees) and softwoods (gymnosperms, conifers) (Blass 1995, pp. A4/2).

The term "softwood" is actually not based on the hardness or density of the wood, but rather on how the tree reproduces (typically hardwood is denser and harder than softwood, but exceptions do exist). Softwoods are gymnosperms, plants whose seeds have no covering at all (such as pine cones). One more difference is that hardwoods are deciduous (trees who lose their leaves seasonally) and softwoods are evergreens.

Softwoods are inexpensive and readily available both in Finland and Russia, and are very well suited for construction engineering projects. Conifers are fast-growing, can be easily cultivated, and produce relatively straight trunks, which makes harvesting and processing much less expensive.

Before beginning a description of what wood is, it must be recognized that, unlike most other materials, wood exhibits macrostructure and microstructure. The figure below shows the structure of the wood at different levels. The first picture is a macro level,

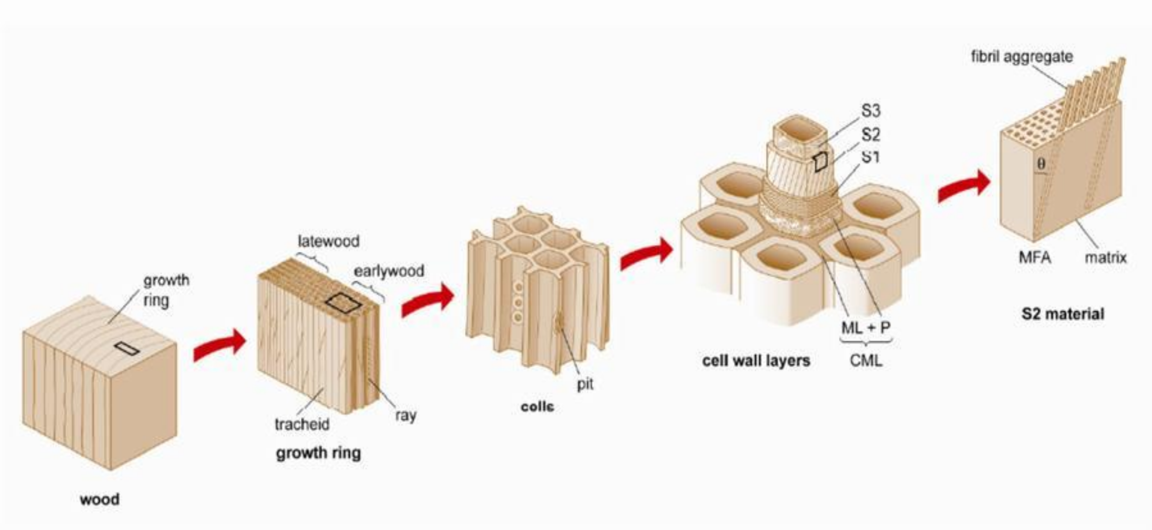


Figure 2.1.1 The softwood chain from macro level to micro level (Institute for building materials)

Both of them give rise to its properties. In contrast to all other materials, the macrostructure is the more important feature of wood.

The picture below illustrates the cross-section of a trunk with a designation of all main parts of wood macrostructure.

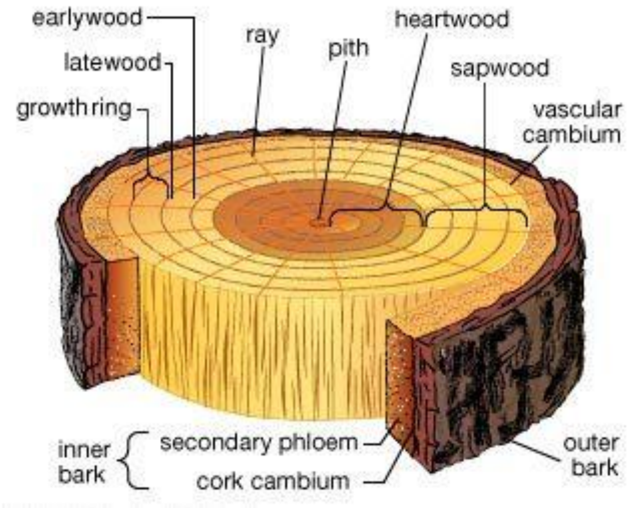


Figure 2.1.2 Main components of wood macrostructure (Encyclopedia Britannica Kids)

The wood technology science main page has a detailed description of the main parts of a tree trunk.

In the transversal direction the growth rings are an influential parameter for strength. Large annual *growth rings* mean a low density and thus a lower strength. A growth ring consists of a lighter and a darker part, i.e. the early wood evolved during spring and early summer and the latewood evolved during summer. During the first 10 - 20 years of the tree's life, the wood is characterized as *juvenile wood*, with a lower strength and stiffness. The growth rings near to the pith are called '*heartwood*' and the outer rings '*sapwood*'. The heartwood is characterized by the absence of living cells, while the sapwood is where liquid transport takes place. These two types of wood have no significant effect on strength.

Bark is the outer protective layer. *Cambium* is a layer of material inside a tree which consists of actively dividing cells which generate growth for the plant. The cambium is filled with undifferentiated cells which have the ability to differentiate into many different types of cells, depending on where in the tree they are growing.

A *knot* is a branch that is embedded in the main stem of a tree. It can been seen on the figure 2.1.3. Knots are undoubtedly the most common and influential defect. As long as the branch is growing the knot is known as 'tight'. When the branch dies the knot is called an 'encased knot'. For softwoods, the branches occur as whorls at more or less regular intervals producing knot clusters. The sawing pattern and location in the log influences how the knots will affect the strength of a wood member. The reduction in strength due to knots is due to the deviation in grain angle that occurs around knots. The main reason for the strength reducing effect of a knot is that it produces tension perpendicular to the grain, which is the weakest direction in wood (Thelandersson 2003, p. 47).

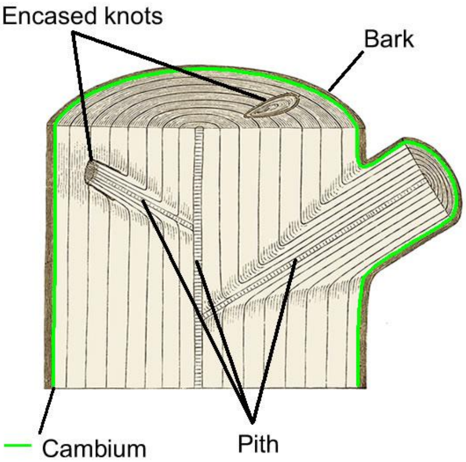


Figure 2.1.3 The fibre structure around knots (Willems 2012)

Grain deviation is defined as the angle between the grain and the longitudinal direction of the wooden element. Grain deviation can be due to spiral grain, pronounced tapering of the stem, crook and sawing of the log. Again, as with knots, grain deviation leads to tension perpendicular to the grain, and thus a reduction in strength (Thelandersson 2003, p. 48).

Wood is anisotropic, i.e. its physical properties depend upon direction. The reason for this is quite obvious in view of the microstructure and fibre structure of wood which are presented on the Figure 2.1.4. Softwood shows a relatively simple structure as it consists of 90 to 95% tracheids, which are long (2 to 5 mm) and slender (10 to 50 μm) cells with flattened or tapered, closed ends. The tracheids are arranged in radial files, and their longitudinal extension is oriented in the direction of the stem axis.

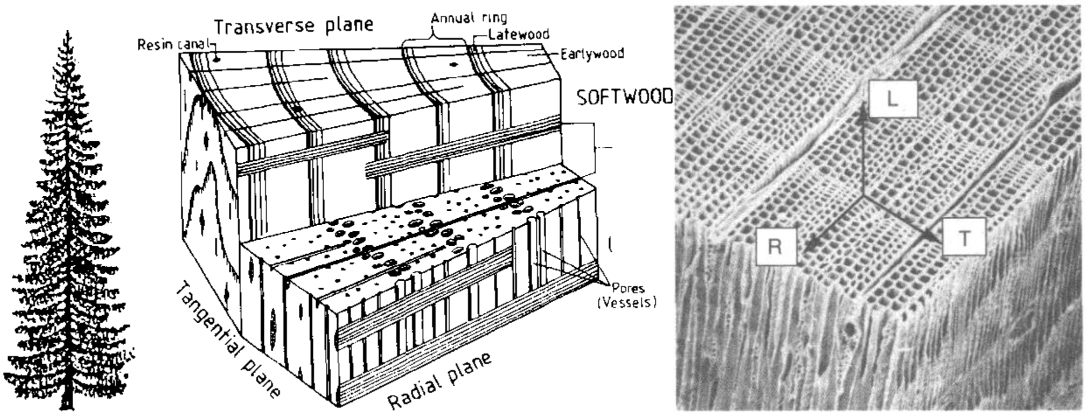


Figure 2.1.4 Macrostructure and microstructure of softwood (Blass 1995, p. A4/2-3)

The microstructure of clear wood is the key why wood is 20 to 40 times stiffer in the longitudinal direction than in the transverse direction (Blass 1995).

2.2 Properties of timber and wood-based materials

Timber is a living material. Due to the structure of trees (which was described earlier), the material properties are significantly different in the longitudinal (stem) direction and transversal (cross) direction. They change with changes in environmental conditions, load duration, moisture content, etc. The properties vary not only from species to species but even within a particular species.

2.2.1 Physical properties

The physical properties of wood include such features as:

- appearance (texture, gloss, color) and structure;
- moisture content and related properties (hygroscopicity, shrinkage and swelling);

- density;
- permeability by liquids and gases;
- thermal properties;
- electrical properties

Appearance is characterized by texture, gloss and color and it is considered when timber is used as a finishing material. That is why appearance is not so important as a structure for this thesis. Note only that the color of the timber should be preferably dark. A light color indicates low strength. Macroscopic and microscopic characteristics were discussed above.

Moisture content and related properties. Wood in green condition contains large amounts of water. The *moisture content* (weight of water in relation to weight of dry wood) can be of the order 100% or more in sapwood. The part of the water is free and stored in cavities of the wood cell, the rest is bound in cell walls. When wood is dried, the free water disappears first, and at around 30% moisture content almost all of the remaining water is bound in the cell wall. This moisture state is called the *'fibre saturation point'*. When wood is dried below fibre saturation, mechanical properties will depend upon moisture content, so that both strength and stiffness will increase when the wood becomes drier.

Timber is a *hygroscopic* material. Consequently the moisture content depends on the surrounding climate and changes accordingly. If timber dries below about 30% moisture content, it shrinks perpendicular to the grain whereas the shrinkage along the grain is small enough to be ignored. The shrinkage can amount up to about 7% of the cross-sectional dimensions. Therefore, timber should be installed at a moisture content close to the equilibrium moisture content likely to be achieved in service.

Shrinkage and *swelling* are also important when talking about wood as a construction material. Shrinkage means the decrease of linear dimensions and volume of timber when bounded water removes from it. Shrinkage of the wood is not the same in different directions: in the tangential direction it is 1.5 - 2 times greater than in the radial. For this reason, cross-sections of sawn timber change shape when they are initially dried and subsequently when moisture changes occur (buckling). Because of the different shrinkage in radial and tangential directions, splits can occur if large cross-section timber dries too fast. In general, splits do not reduce the strength of the timber members. They can be minimized by kiln drying. (Thelandersson 2003)

Swelling occurs during keeping wood in moist air or water. Swelling is the inverse value of shrinkage.

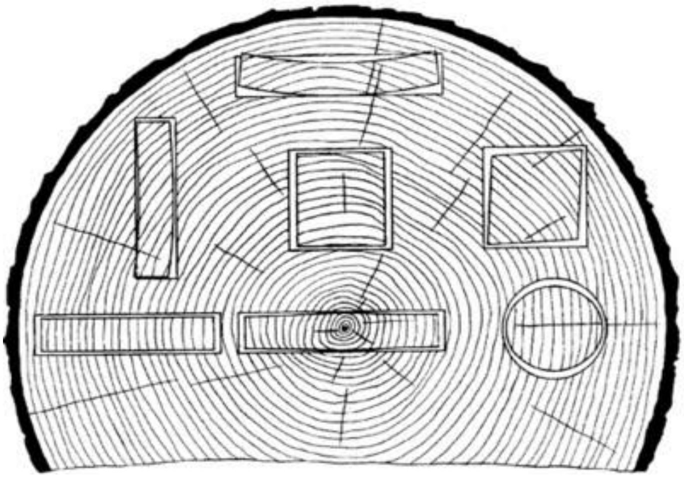


Figure 2.2.1.1 Distortion of cross-sections after drying of a sawn timber taken from different positions in the log (Thelandersson 2003, p. 20)

<u>Density</u> is the most important physical characteristic of timber. Most mechanical properties of timber are positively correlated to density. Density is defined as

$$\rho = \frac{m}{V} \qquad (2.2.1)$$

m – mass of timber, kg;
V – volume of timber, m^3.

Density depends on moisture, because moisture adds to the mass and may cause the increment of volume. In wood science and engineering, dry density ρ_0 and density ρ_{12} at 12% moisture content are most frequently used. Density values given in EC5 are defined with mass and volume corresponding to an equilibrium at a temperature of 20°C and a relative humidity of 65%. The density of the cell wall is about 1500 kg/m3. The density of wood, therefore, is dependent on its porosity, defined as the volume fraction of cell lumina. Structural timber typically shows dry density values in the range from 300 to 550 kg/m3 (Blass 1995).

Permeability is the ability of wood to pass liquids or gases under pressure. Water permeability of wood along the grain is much higher than across the grain

The thermal properties of timber are good; the low thermal conductivity means that cold bridges are not a big problem to the building designer and low expansion across and along the grain with temperature change is a particularly beneficial attribute in fire conditions.

Electrical conductivity is the ability of wood to conduct electrical current. Dry wood is the insulator. With increasing moisture content of wood, its conductivity increases. Particularly sharp increase (in the tens of millions of times) of electrical conductivity is observed with increasing of content of bound water.

2.2.2 Mechanical properties

The mechanical properties of wood include such features as:

- strength
- hardness
- stiffness
- deformability

Wood as a natural material has very different properties in different directions.

Strength is the ability of wood to resist destruction under mechanical stress. The strength of wood depends on the direction of the current load of wood, density, moisture content and presence of defects. Parallel to the grain, i.e. in the direction of the trunk of the tree, the strength of the material is particularly high, whereas perpendicular to the grain the strength properties are low. The *tension strength* of wood parallel to the grain is for example about 40 times greater than the tension strength perpendicular to the grain. It is quite easy to split wood along the fibres using an axe, but it is much more difficult to cleave a piece of wood perpendicular to the grain.

Hardness is the ability of wood to resist the penetration of more solid bodies in it. The hardness of wood is essential in the cutting processes: milling, sawing, peeling. Softwood products have low hardness.

Deformability is the ability of wood to change its size and shape under loads. If a deformation disappears after end of load – it is called an elastic deformation, if it remains – it is called a residual deformation. Wood behaves as an elastic body under short-term loads. An indicator of deformability is the modulus of elasticity. The ability of wood to deform characterizes its stiffness.

The strong anisotropy in wood is also valid for stiffness properties. The modulus of elasticity (MOE) perpendicular to grain is typically 50-80 times smaller than parallel to grain. When wood is subjected to compression perpendicular to grain, significant deformations will occur even at low load levels.

2.3 Relationship between strength/stiffness and timber characteristics.

It is important to consider how strength and stiffness properties of timber depend upon the clear wood properties and different kinds of defects.

The coefficient of determination, R^2, can be used as a measure of how strong the relationship is. First of all, microstructure and similar characteristics of wood cells mean that wood material properties such as MOE, strength along the grain and density are strongly linked to the cell wall thickness. This explains why the correlation between properties of clear wood (wood without defects) is very good (Thelandersson 2003).

For example:

Bending strength vs. modulus of elasticity R^2 = 0,76;
Bending strength vs. density R^2 = 0,66;
Modulus of elasticity vs. density R^2 = 0,64;

But timber normally contains defects, such as knots, compression wood, slope of grain, etc., which reduce strength properties differently. Knots have the greatest effect.

Table 2.3.1 presents the overview of relationships between strength on the one hand and a number of characteristics that can be measured non-destructively on the other. Correlation coefficients were defined after investigations of Norway spruce, which were made by different researchers: 1: Johansson et al. (1992), 2: Hoffmeyer (1984), 3: Hoffmeyer (1990), 4: Lackner et al. (1988), 5: Gloss et al. (1982), 6: Johansson et al. (1976).

Table 2.3.1 Correlation coefficients from various investigations of the relationship between strength and non-destructively obtained characteristics (Thelandersson 2003)

Characteristics that can be measured non-destructively	Coefficient of determination R^2						
	Bending strength				Tensile strength		
Source	1	2	3	4	1	5	6
Knots	0.27	0.20	0.16	0.25	0.36	0.42	0.30
Annual ring width	0.21	0.27	0.20	0.44	0.36	0.33	0.28
Density	0.16	0.30	0.16	0.40	0.38	0.29	0.38
MOE, bending or tension	0.72	0.53	0.55	0.56	0.70	0.69	0.58
MOE, flatwise, short span							0.74
Knots and annual ring width combined	0.37	0.42	0.39		0.49		
Knots and density combined	0.38		0.38		0.55	0.61	0.64
Knots and MOE	0.73	0.58	0.64		0.70	0.76	0.78

As can be seen, the R^2 values differ considerably between different investigations. This is most likely due to the fact that materials and test methods differ. In the process of analyzing the table the student came to the conclusion that the stiffness, which is normally expressed as a MOE, is the best predictor of strength. It gives a better prediction than density, annual ring width and knot data combined. Knots alone are on the second place of strength predictors. But if the location of knots is taken into account, then the correlation is higher. Both correlation between density and strength and between annual ring width and strength are poor.

Other factors also have effect on the strength and the stiffness. The strength depends on moisture, direction and duration of load. Significant influence on the strength of the wood has only associated moisture, which is contained in the cell membranes. Until it increases to the level 20-25%, the strength decreases. The Further increase of moisture content under the limit for water absorption (30%) does not affect the strength of timber. Timber under load shows an increase of deformation with time. In a constant climate, creep deformations only exceed the elastic deformations by about 50% in 20 years. If the moisture content of the wood varies, however, the creep deformations may exceed several hundred percent of the initial deformations. Apart from the moisture content, the duration of the load significantly influences the strength and deformations of timber and timber structures. With increasing load duration, the strength of timber decreases. The designer therefore has to assign each load to a load duration class and subsequently modify the characteristic strength properties based on the duration of the combination of loads. The influence of load duration on the deformations is taken into account by an increase in creep deformations.

3 TIMBER CLASSIFICATIONS

Sawn timber is classified differently in Finland and in Russia. Investigation of correlation between Finnish strength classes and Russian sorts of sawn timber is the good base for making export of sawn timber easier. More than that it helps to calculate constructions from foreign timber according to local norms.

3.1 Finnish classification of sawn timber

Strength classification

The strength class system for softwood species established in EN 338 "Structural timber - Strength classes" is shown in Table 1. This standard is applicable to all softwood timber for structural use. It consists of 11 classes from the weakest grade of softwood (C14) to the highest grade of softwood (C50), currently used in Europe. A strength class system groups together grades and species with similar strength properties thus making them interchangeable. This then permits an engineer to specify a chosen strength class and use the characteristic strength values of that class in design calculations.

EN 338 gives characteristic strength and stiffness properties and density values for each strength class and provides rules for the allocation of timber, i.e. combinations of species/source/strength grade, to the classes.

A timber population may be assigned to a strength class if its characteristic values of bending strength and density equal or exceed the values for that strength class given in Table 1, and its characteristic mean modulus of elasticity in bending equals or exceeds 95 % of the value for that strength class given in Table 3.1.1.

Table 3.1.1 Strength classes – characteristic values according to EN 338

		Softwood											
		C14	C16	C18	C20	C22	C24	C27	C30	C35	C40	C45	C50
Strength properties (in N/mm2)													
Bending	$f_{m,k}$	14	16	18	20	22	24	27	30	35	40	45	50
Tension parallel	$f_{t,0,k}$	8	10	11	12	13	14	16	18	21	24	27	30
Tension perpendicular	$f_{t,90,k}$	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
Compression parallel	$f_{c,0,k}$	16	17	18	19	20	21	22	23	25	26	27	29
Compression perpendicular	$f_{c,90,k}$	2,0	2,2	2,2	2,3	2,4	2,5	2,6	2,7	2,8	2,9	3,1	3,2
Shear	$f_{v,k}$	3,0	3,2	3,4	3,6	3,8	4,0	4,0	4,0	4,0	4,0	4,0	4,0
Stiffness properties (in N/mm2)													
Mean modulus of elasticity parallel	$E_{0,mean}$	7	8	9	9,5	10	11	11,5	12	13	14	15	16
5% modulus of elasticity parallel	$E_{0,05}$	4,7	5,4	6,0	6,4	6,7	7,4	7,7	8,0	8,7	9,4	10,0	10,7
Mean modulus of elasticity perpendicular	$E_{90,mean}$	0,23	0,27	0,30	0,32	0,33	0,37	0,38	0,40	0,43	0,47	0,50	0,53
Mean shear modulus	G_{mean}	0,44	0,5	0,56	0,59	0,63	0,69	0,72	0,75	0,81	0,88	0,94	1,00
Density (in kg/m3)													
Density	ρ_k	290	310	320	330	340	350	370	380	400	420	440	460
Mean density	ρ_{mean}	350	370	380	390	410	420	450	460	480	500	520	550

The establishment of strength classes and related strength and stiffness profiles is possible because, independently, nearly all softwoods commercially available exhibit a similar relationship between strength and stiffness properties.

3.2 Russian classification of sawn timber

The main normative document for sawn timber in Russia is GOST 8486-86 Coniferous sawn timber (Puzanova 2010) Specifications. After learning GOST the following result was obtained: there are no so-called “strength” classes of sawn timber in Russia. Probably, this situation is related to the lack of strong standards for building of small private houses, which are the more popular area for using sawn timber in Russia. Anyway GOST 8486-86 contains a classification of sawn timber by visual damages on 4 grades.

Table 3.2.1 Russian classification of sawn timber by visual damages by GOST 8486-86

Defects of wood by GOST 2140-81	Standards of defects limitation in sawn timber for sorts									
	Perfect		1st		2nd		3rd		4th	
1. Knots										
1.1. Fused healthy, and in uneven bars and partially fused and unfused healthy:	Allowed size in parts in parts of side width and in number on any 1-meter long each side no more than:									
	Dim	Numb	Dim	Numb	Dim	Numb	Dim.	Numb	Dim	Numb
Face and edge	1/5	2	1/4	3	1/3	4	1/2	4	Allowed	
Edge: at sawn timber up to 40 mm thick	1/3	1	1/2	2	2/3	2	On all edges	2	Allowed	
Thickness of 40 mm and more	1/4, but not exceeding 15 mm	2	1/3	2	1/2	3	On all edges	3	Allowed	
Note. In the bars the number of knots is not standardized.										

<table>
<tr><td rowspan="2">1.2 Partially fused and unfused</td><td colspan="10">Allowed in the total number intergrown sound knots the size of a fraction of the width and number in any 1-meter section of length on each side, no more than:</td></tr>
<tr><td>Dim.</td><td>Numb.</td><td>Dim.</td><td>Numb.</td><td>Dim.</td><td>Numb.</td><td>Dim.</td><td>Numb.</td><td>Dim.</td><td>Numb.</td></tr>
<tr><td>Face and rib</td><td>1/8</td><td>2</td><td>1/5</td><td>2</td><td>1/4</td><td>3</td><td>1/3</td><td>3</td><td>1/2</td><td>4</td></tr>
<tr><td>Edge: at sawn timber up to 40 mm thick</td><td>1/4</td><td>1</td><td>1/3</td><td>1</td><td>1/2</td><td>2</td><td>In all edge</td><td>2</td><td>In all edge</td><td>2</td></tr>
<tr><td>Thickness of 40 mm and more</td><td>10 mm</td><td>1</td><td>1/4</td><td>2</td><td>1/3</td><td>2</td><td>2/3</td><td>2</td><td>The same</td><td>3</td></tr>
<tr><td rowspan="2">1.3. Taint, rotten and snuff-colored</td><td colspan="2">Not allowed</td><td colspan="8">Allowed in the total number of partially intergrown and ununited healthy knots of the same size and no more than half their number</td></tr>
<tr><td colspan="10">Wood, environmental snuff-colored sticks, should not have signs of rot
In sawn timber for bearing structures all knots, placed on 200 mm piece, dimensions amount must not exceed allowed knots limit dimension</td></tr>
<tr><td colspan="11">2. Cracks</td></tr>
<tr><td rowspan="5">2.1. Face and edge including came on end</td><td colspan="8">Allowed with length in parts of sawn timber pattern length no more than</td><td colspan="2" rowspan="3">Allowed in condition of sawn timber pattern continuity retention</td></tr>
<tr><td colspan="4">Not deep</td><td colspan="4">Not deep and deep</td></tr>
<tr><td colspan="2">1/6</td><td colspan="2">1/4</td><td colspan="2">1/3</td><td colspan="2">1/2</td></tr>
<tr><td colspan="10">Deep</td></tr>
<tr><td colspan="8">1/10</td><td colspan="2">1/6</td></tr>
<tr><td rowspan="2">2.2. Face through including came on end</td><td colspan="6">Allowed with length in mm no more then</td><td colspan="4">Allowed with total length in parts of sawn timber pattern length no more than</td></tr>
<tr><td colspan="2">100</td><td colspan="2">150</td><td colspan="2">200</td><td colspan="2">1/6</td><td colspan="2">1/4</td></tr>
<tr><td rowspan="2">2.3. End (except shrinkage cracks)</td><td colspan="2" rowspan="2">Not allowed</td><td colspan="6">Allowed on one end with wide in parts of sawn timber pattern width no more than</td><td colspan="2" rowspan="2">Allowed in condition of sawn timber pattern continuity retention</td></tr>
<tr><td colspan="2">1/4</td><td colspan="2">1/3</td><td colspan="2">1/2</td></tr>
<tr><td colspan="11">Note. Allowed cracks dimensions are agreed for sawn timber with timber moisture content no more than 22%, in case of more moisture content value this cracks dimensions are decreased twice.</td></tr>
</table>

Also it has links to another normative document, SNIP II-25-80 “Timber structures”, which includes the table with fixed values of strength for the 1st, 2nd and the 3rd grades of sawn timber. These values are shown in the table 3.2.2. The perfect and the 4th grades are not included in the table because they are not used in the construction of building structures.

Table 3.2.2 Strength values for Russian quality grades of sawn timber by SNIP II-25-80

Tension type	Normative strength, N/mm2		
	1st sort	2nd sort	3rd sort
Bending during edge loading	26	24	16
Bending during face loading	30	27	20
Compression parallel to grain	25	23	15
Stretching parallel to grain	20	15	-
Shear parallel to grain	3,6	3,2	3,2

3.3 Investigation of correlation between Finnish strength classes and Russian sorts of sawn timber

According to European standards the bending strength, mean modulus of elasticity in bending and density are crucial in determining the strength class of timber. Other values of strength (for example, tensile strength parallel to the grain) can be determined using equations. That is why values of bending strength from EN 338 and bending strength during edge loading from SNIP II-25-80 were compared.

The result was that the 1st sort of Russian timber corresponds to C27, the 2nd to C24 and the 3rd to C16. It means that C24, which is mainly used in Europe for building private houses, can also be widely used in Russia as a structural material.

4 GRADING OF SAWN TIMBER

Because timber is a natural material the essential properties vary considerably. The strength properties of ungraded timber of any one species may vary to such an extent that the strongest piece is up to 10 times the strength of the weakest piece (Blass 1995, A6/3). In order to use timber efficiently as a reliable structural material, strength grading is necessary. Strength grading is not only a matter of strength. To use timber as a structural material, its stiffness properties need to be known and controlled. The density is also of importance as the strength of mechanical connections in timber is linked to it. In addition to grading rules for strength and stiffness, it is also necessary to define grade limits for geometric properties, for example wane and distortion such as bow, spring and twist which can also affect the structural use of wood.

4.1 Finnish methods of grading

Traditionally, strength grading was done by visually assessing timber, taking into account strength reducing factors that could be actually seen, mainly knots and annual ring width. Up to the beginning of the 20th century visual strength grading was essentially based on tradition and local experience. From the 1930s detailed grading rules were developed in various European countries. To improve the accuracy of strength grading with the aim of achieving a better utilization of the available timber qualities machine grading processes were developed from the 1960s. In machine strength grading it is possible to determine other characteristics such as bending modulus of elasticity, which are better correlated with strength properties.

Nowadays in Finland the minimum requirements for visual grading standards have been laid down in EN 518 "Structural timber - Grading - Requirements for visual strength grading standards". Requirements for machine grading can be found in EN 519 "Structural timber - Grading - Requirements for machine strength graded timber and grading machines" (Blass 1995, A6/3).

4.1.1 Visual grading

In visual strength grading the lumber is sorted by means of purely visual inspection, this can be done either manually or by a machine vision system. According to EN 518, the following characteristics have to be taken into account:

- limitations for strength reducing characteristics: knots, slope of grain, density or rate of growth, fissures;
- limitations for geometrical characteristics: wane, distortion (bow, spring, twist);
- limitations for biological characteristics: fungal and insect damage;
- other characteristics: reaction wood, mechanical damage.

Knots are regarded as very serious defects as they can greatly reduce strength and are almost always present in large numbers in a piece of timber. But strength is mainly reduced by grain deviations around knots rather than by the actual knots. Knots in sawn timber vary greatly in shape. They vary with sawing patterns and timber dimensions and are difficult to determine and classify. The knot ratio is usually calculated from the sum of knots within a defined section along the length of a piece of timber rather than merely from the biggest knot. Edge knots and knots in tensile zones have a greater effect on strength than centre knots or knots in compression zones. Therefore, the position of knots within cross-sections of timber is often also taken into account in grading rules.

There are four strength classes for visual graded timber: T18, T24, T30 and T40. These classes have the same characteristics as respective classes according to EN338: C18, C24, C30 and C40.

Graded timber should be marked. This marking shall as a minimum give the following information: grade, wood species or species combination, producer and the standard to which the timber is graded.

Advantages of visual strength grading:

- it is simple, easily understood and does not require great technical skill;
- it does not require expensive equipment;
- an effective method, if correctly applied.

Disadvantages of visual strength grading:

- it is labour intensive and rather inefficient in that wood structure and density in which influence strength is not sufficiently taken into consideration;
- it lacks objectivity.

4.1.2 Machine grading

To improve the accuracy of strength grading with the aim of achieving a better utilization of the available timber qualities machine grading processes were developed from the 1960s onwards in Australia, the USA, the UK and, later, in other countries.

Most of the grading machines in use today are the so-called bending machines which determine the average bending modulus of elasticity over short lengths. Timber is fed continuously through the grading machine. The machine bends each piece as a plank (i.e. about the weaker axis) between two supports which are some 0,5 to 1,2 m apart and either measures the applied load required to give a fixed deflection or measures the deflection under a particular load. From these values it calculates the local modulus of elasticity taking into account the cross-sectional dimensions and natural bow of the piece of timber which is either measured or eliminated by deflecting the piece in both directions.

Recent research has shown that predictive accuracy of machine grading can be further improved by technical modifications of the machine and by a combination of several grading parameters. The incorporation of density into the grading process can also contribute to the grading results, as this can be used to produce grades with higher characteristic density and also to reject timber with significant portions of reaction wood. The presence of knots may be determined by optical scanning across the four surfaces or by radiation, while density may be determined by weighing or radiation.

In optical scanning the four timber surfaces are monitored by line-scan cameras. Knots are detected via shades of grey and may be differentiated from other effects not related to strength such as dirt or stain by analyzing the surrounding texture. Values for knot ratio may be determined via image analysis.

Advantages of machine strength grading, specified in (Blass 1995):

- All disadvantages of visual strength grading can be overcome by machine strength grading.

Disadvantages of machine strength grading, specified in (Blass 1995):

- With visual grading, it is possible to check at any time the correctness of the grade assignment even with timber which is in use. In contrast, in machine grading this check is not possible by visual measures. For this reason there has to be frequent and regular control of the reliability of machine grading.
- Machine grading is more expensive

The FinScan Oy is a producer of real-time image processing and optimizing systems for the sawmill and veneer industry. Two main products of Finscan can be used for strength grading: BoardMaster and EndSpy (a brochure by FinScan). A brief description of these systems is presented below.

Board Master is an automatic grading system using line-scan cameras for green sorting, edging and dry sorting. The system is presented on the picture 4.1.2.1.

Figure 4.1.2.1 BoardMaster system

BoardMaster scans each board on four sides, quickly and efficiently processes the received images and qualitative indicators of the board. Based on these data, the system provides detailed information for optimizing the trimming, cutting, sawing and sorting. The system provides a detailed report in the pictures according to different user requirements. The process of report making is presented on the figure 4.1.2.2.

BoardMaster analyzes such parameters as board dimensions, knots, holes, wanes, cracks, fissures, warp, blue stain, rot, pitch pocket, knot displacements, relationship between areas with knots and without knots etc.

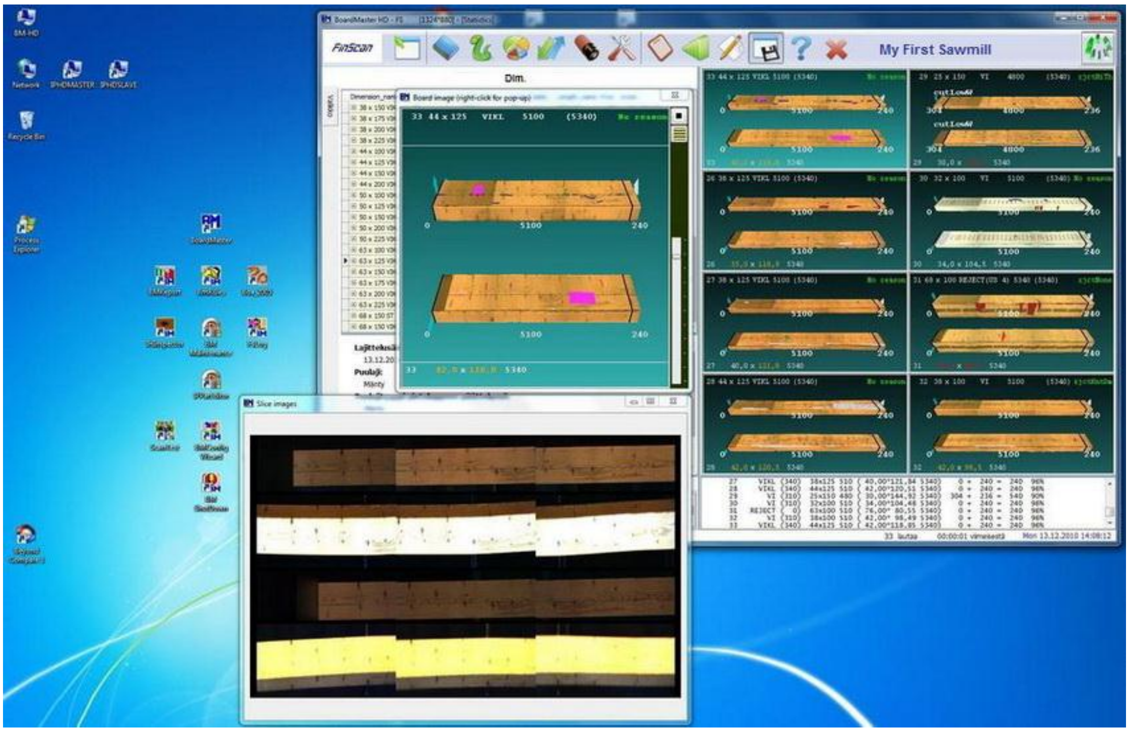


Figure 4.1.2.2 Processing of images on a computer

EndSpy is a system, which by using LED lights and an ultrafast matrix color camera scans the ends of the passing lumber pieces, and calculates e.g. the mean distance of the growth rings, and the location of the pith, even if it is not inside the piece. EndSpy analyzes also cracks, blue stain and rot from the end of the board. The mechanism of EndSpy system and the result of scanning of ends of boards are presented on the figure 4.1.2.3.

Figure 4.1.2.3 EndSpy system

BoardMaster and EndSpy can be used for strength grading of structural timber in the sawmill. The devices can be installed independently or together with strength grading machines, but the strength grading machine must always be complemented with a visual override inspection, done either by a human or a machine vision system like BoardMaster. The such strength grading system is presented on the figure 4.1.2.4.

Figure 4.1.2.4 Strength grading and CE marking with using BoardMaster and EndSpy systems

BoardMaster and EndSpy allow to obtain detailed information about the defects of the wood and to predict the strength characteristics. Real-time image processing and optimizing systems for the sawmill produced by FinScan allows certified sawn timber in accordance with the requirements of the European Union (CE). For strength grading FinScan has a software package “Visual strength grading” that permits grading according to Nordic grading rules INSTA 142 or British grading rules GS / SS.

4.1.3 Laboratory tests for determining the strength of sawn timber

The main document that regulates the carrying out laboratory tests in Finland is EN 408 “Timber Structures – Structural timber and glued laminated timber – Determination of some physical and mechanical properties”.

The chapter 4.1.3 is based on the EN 408 and all pictures and formulas are taken from that normative document.

Determination of tension strength parallel to the grain

Requirements for samples, testing rules and formulas for assessing the results of tests are given below.

Test piece

The test piece shall be of full structural cross section, and of sufficient length to provide a test length clear of the testing machine grips of at least nine times the larger cross-sectional dimension.

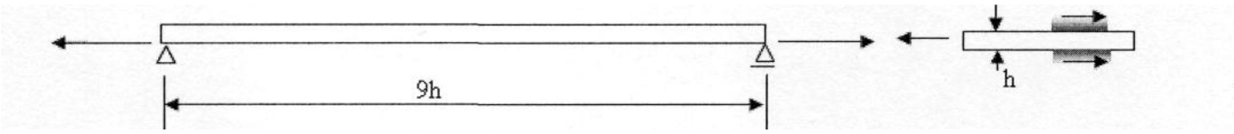


Figure 4.1.3.1 Test setup tensile strength parallel to grain

Procedure

The test piece shall be loaded using gripping devices which will permit as far as possible the application of a tensile load without inducing bending. The gripping devices and loading conditions actually used shall be reported.

The loading equipment used shall be capable of measuring the load to an accuracy of 1 % of the load applied to the test piece.

Load shall be applied at a constant loading-head movement so adjusted that the maximum load is reached within (300 + 120) s. This rate should be determined from the results of preliminary tests. The objective is that the time to reach Fmax for each piece is 300 s.

The time to failure for each test piece shall be recorded and its average reported. Any single piece diverging more than 120 s from the target of 300 s shall be reported.

Expression of results

The tensile strength $f_{t,0}$ is given by the equation:

$$f_{t,o} = \frac{F_{max}}{A} \qquad (4.1.3.1)$$

$f_{t,0}$ – tensile strength, MPa;
F_{max} – maximum load, N;
A – area of sample's cross-section, mm2;
The tensile strength, $f_{t,0}$ shall be calculated to an accuracy of 1 %.

Determination of compression strength parallel to the grain

Requirements for samples, testing rules and formulas for assessing the results of tests are given below.

Test piece

The test piece shall be of full cross section, and shall have a length of six times the smaller cross-sectional dimension. The end grain surfaces shall be accurately prepared to ensure that they are plane and parallel to one another and perpendicular to the axis of the piece.

Procedure

The test piece shall be loaded concentrically using spherically seated loading-heads or other devices, which permit the application of a compressive load without inducing bending. After load pick up the loading-heads shall be locked to prevent angular movement. The gripping devices and loading conditions actually used shall be reported.

Load shall be applied at a constant loading-head movement so adjusted that the maximum load is reached within (300±120)s. This rate should be determined from the results of preliminary tests. The objective is that the time to reach Fmax for each piece is 300 s.

The time to failure of each test piece shall be recorded and its average reported.

Expression of results

The compressive strength $f_{c,0}$ is given by the equation:

$$f_{c,0} = \frac{F_{max}}{A} \tag{4.1.3.1}$$

$f_{c,0}$ – compressive strength, MPa;

F_{max} – maximum load, N;

A - area of sample’s cross-section, mm2

Determination of tension and compression strengths perpendicular to the grain

Requirements for samples, testing rules and formulas for assessing the results of tests are given below.

Test piece

The fabrication of the test pieces shall be such as to allow the application of the loads to the test piece. For tension tests, the test piece shall be glued to steel plates or timber blocks. The gluing process shall be capable of ensuring the specified position of the test piece during testing. The loaded surfaces shall be accurately prepared to ensure that they are plane and parallel to each other and perpendicular to the test piece axis. The test pieces shall be as shown in Figure 4.1.3.2 and have the dimensions: b= 45 mm, h=180 mm, l=70 mm.

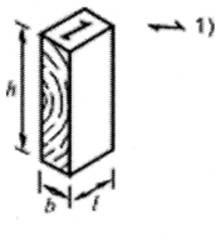


Figure 4.1.3.2 Structural timber test piece

Procedure

The test piece shall be loaded concentrically.

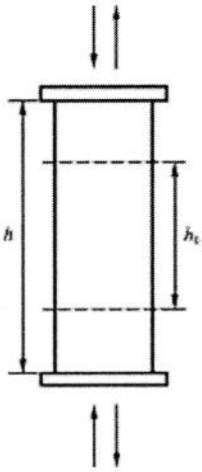


Figure 4.1.3.3 Test principle

This can be achieved using spherically seated loading-heads. In the case of the compression test, after an initial load has been applied, the loading-heads shall be locked to prevent rotation or angular movement during the test.

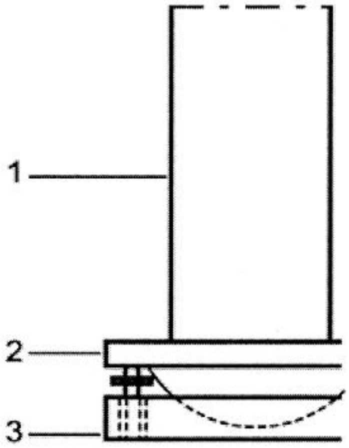


Figure 4.1.3.4 Compression test locking device: (1) - test piece; (2) - square `plate with hemispherical knee joint; (3) - adjustment and locking system

In the case of either a tension test or a compression test the longitudinal axis of the test piece shall be aligned with the axis of the machine and fixed in such a way that no initial stresses in the test piece are introduced, except those due to the weight of the test piece and the equipment.

In the case of tension tests on solid timber the test piece shall have pinned ends, with the axis of the pin parallel to the grain direction of the test piece.
The load F shall be applied at a constant rate of cross head movement throughout the test.

<u>Expression of results</u>
Compression perpendicular to the grain:
The compressive strength $f_{t,90}$ shall be determined from the equation:

$$f_{t,90} = \frac{F_{c,90,max}}{bl} \qquad (4.1.3.2)$$

$f_{t,90}$ – compressive strength perpendicular the grain, MPa;
$F_{c,90,max}$ – maximum load, N;
b – width of the sample, mm;
l – length of the sample, mm;

Tension perpendicular to the grain:
The tensile strength ftj90 shall be determined from the equation:

$$f_{t,90} = \frac{F_{t,90,max}}{bl} \qquad (4.1.3.3)$$

$f_{t,90}$ – tension strength perpendicular the grain, MPa;
$F_{t,90,max}$ – maximum load, N;
b – width of the sample, mm;
l – length of the sample, mm;

Determination of shear strength parallel to the grain

Requirements for samples, testing rules and formulas for assessing the results of tests are given below.

Test piece

The test piece shall be glued to steel plates. The steel plates shall be tapered as shown in Figure 4.1.3.5.

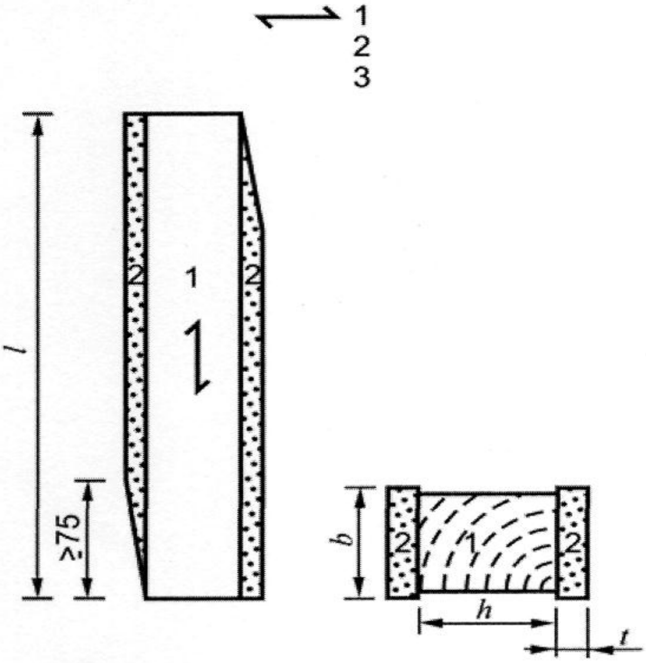


Figure 4.1.3.5 Timber test piece glued to steel plates: 1 - grain direction; 2 - steel plate; 3 - timber test piece

Procedure

The test piece shall be mounted in a test machine as shown in Figure 4.1.3.6. The test piece shall be aligned such that continuous contact is maintained where the line loads F are applied. The angle between the load direction and the longitudinal axis of the test piece shall be 14°.

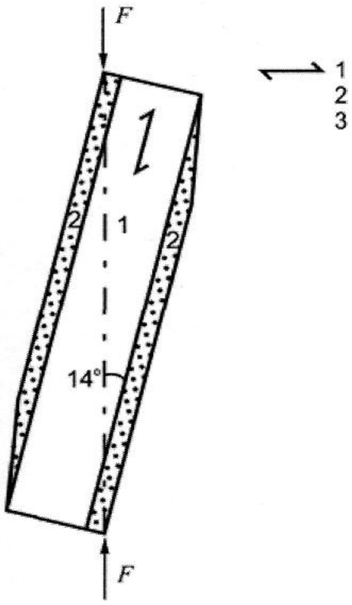


Figure 4.1.3.6 Loading arrangement: 1 - grain direction; 2 - steel plate; 3 - timber test piece

Load F shall be applied at a constant rate of loading-head movement so adjusted that the load F_{max} is reached within (300 ±120) s.

Expression of results

The shear strength f_v shall be determined from the equation 4.1.3.4 and shall be calculated to an accuracy of 1 %.

$$f_v = \frac{F_{max} cos 14°}{lb} \qquad (4.1.3.4)$$

f_v – shear strength, MPa;

F_{max} - maximum load, N;

l – length of the sample, mm;

b - width of the sample, mm;

Determination of bending strength parallel to the grain

Requirements for samples, testing rules and formulas for assessing the results of tests are given below.

Test piece

For the determination of the bending strength of the timber the test piece shall have a minimum length of 19 times the depth of the section. Where this is not possible, the span of the beam shall be reported.

Procedure

For the determination of the bending strength of the timber the test piece shall be symmetrically loaded in bending at two points over a span of 18 times the depth as shown in Figure 4.1.3.7 The test piece shall be simply supported.

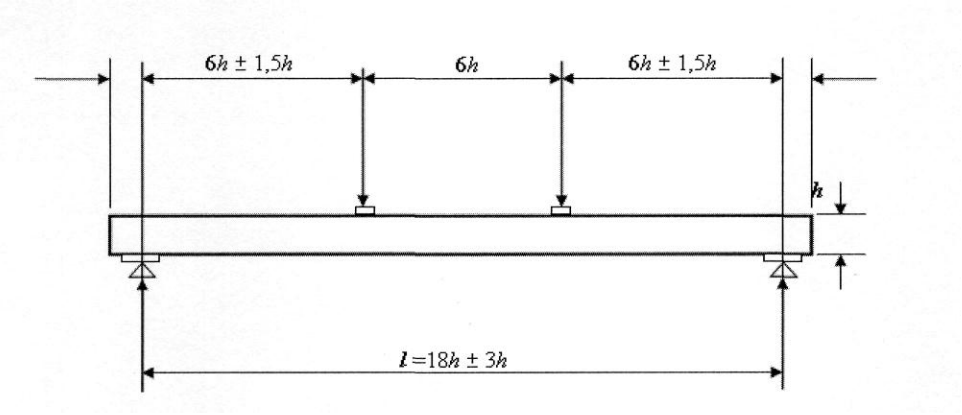


Figure 4.1.3.7 Test arrangement for measuring bending strength

Lateral restraint shall be provided as necessary to prevent buckling. This restraint shall permit the piece to deflect without significant frictional resistance.

Load shall be applied at a constant rate until failure occurs. The rate of movement of the loading head shall be not greater than (0,003 h) mm/s. The maximum load (Fmax) of the bending test shall be recorded.

Expression of results

The bending strength is determined by:

$$f_m = \frac{3Fa}{bh^2} \quad (4.1.3.5)$$

f_m – bending strength, MPa

F – maximum load, N;

a – distance between supports in bending, mm

b - width of the sample, mm;

h – height of the sample, mm;

For all tests the loading equipment used shall be capable of measuring the load to an accuracy of 1 % of the load applied to the test piece or, for loads less than 10 % of the applied maximum load, with an accuracy of 0,1 % of the maximum applied load.

All values of strength shall be calculated to an accuracy of 1 %.

4.2 Russian methods of grading

During many years in Russia grading of sawn timber was made by human visual sorting. It takes a lot of time and nowadays in such a rapidly developing area as building it is necessary to improve and accelerate the grading process. Therefore relationship between some non-visible timber parameters is investigated actively in many universities, for example between strength and density. At the moment, there are many prerequisites for the upgrade to the new sorting system timber.

4.2.1 Grading by visual damages

The Russian way is found in the system of grades (Perfect - best and from 1st to 4th - lowest). It is presented in GOST 2140-81. The Russian way is reduced to an analysis of all defects on any 1-meter-long piece of pattern. Appearance of timber board is investigated carefully and all visible damages are compared with a table in GOST (see Table 3.2.1 in Chapter 3). After comparing the conclusion about the grade of timber is made.

4.2.2 Machine prediction of strength of sawn timber by density

In Russia the influence of wood density on the speed of ultrasound is being studied. As a nondestructive method the ultrasonic diagnostic was used (Chubinsky, 2011, pp 109-115). A dependence between the speed of ultrasound passing through the timber and the density of wood has been established. A dependence between the durability of glue bonds and density of wood has been established also. The mathematical models are received, which help to predict the durability of glued bonds at the stage of sorting of sawn timber before gluing.

The ultrasonic diagnostic is based on the time of passage of the signal through the object. The similar system exists in Finland.

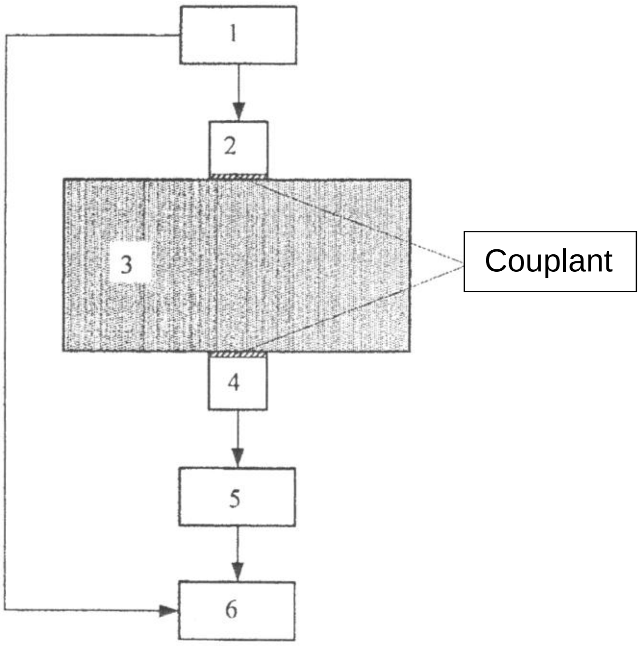


Figure 4.2.2.1 Schematic diagram of the ultrasonic diagnostic: 1 – generator; 2 – radiator; 3 – timber; 4 – receiver; 5 – amplifier; 6 - measuring of the pulse arrival time (Chubinsky, A., p.111)

The operating frequency of the ultrasound is 2,5 Hz. These values were determined in the research process:

- the delaying time of ultrasound in converter and in contact layers on the reference sample. This time characterizes the sensor and does not depend on the properties of wood.
- passing time of the first signal, which goes through the timber
- the propagation velocity of ultrasound in wood.

Dependence of ultrasonic propagation velocity from the wood density is close to the linear nature. With an increase of wood density the speed of ultrasound increases, too. The results of research can derive an equation (4.2.2.1):

$$v = 4{,}6854 \times \rho - 1024 \qquad (4.2.2.1)$$

v - the propagation velocity of ultrasound in timber;
ρ – the density of timber (350< ρ<650 kg/m3);

4.2.3 Laboratory tests for strength determining of sawn timber

Laboratory tests are the main method of strength determining in Russia. Each test has requirements established in individual GOST (Petrova 2011). The chapter 4.2.3 is based on GOSTs listed below. All pictures and formulas are taken from these GOSTs.

Determination of bending strength parallel to the grain (GOST 16483.3-84)

The essence of the method consists of determining the maximum failure load of the sample and calculating the stress at this load.

Test piece

The samples were manufactured in the form of a rectangular prism with a cross section 20 x20 mm and a length 300 mm along the grain. Samples should have right angles between adjacent faces of the samples. Length of specimens for static bending test should not exceed ± 1 mm.

Procedure

The sample is placed in the machine so that the bending force is directed along the tangent to the annual rings. Loading occurs according to figure 4.2.3.1

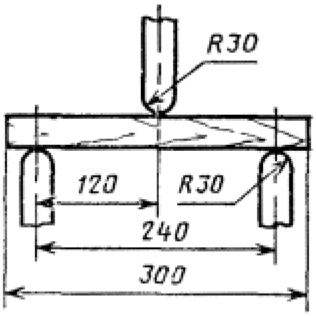


Figure 4.2.3.1 Setup of bending test

The sample is loaded uniformly with a constant rate of loading or with the constant moving speed of loading head of machine. The rate should be such that the sample is destroyed by (1,5 ± 0,5) min after the start of loading. If a machine with an electromechanical drive is used, it is allowed to carry out the loading of the sample uniformly at the rate (1350 ± 150) N/mm or to conduct test at the moving speed of the testing machine head 4 mm / min. The test is continued until the destruction of the sample, determining the maximum value of load before the failure (P_{max}). An error of determining P_{max} should not exceed 1%. A moisture content of samples is determined after the test according to the procedure described in paragraph 5.1.

Expression of results

The bending strength σ_w in MPa is calculated by formula (4.2.3.1):

$$\sigma_w = \frac{3Pmax*l}{2bh^2} \quad (4.2.3.1)$$

P_{max} – the maximum load, N;

l - distance between centers of supports, mm;

h - height of sample's cross-section, mm;

b - width of sample's cross-section, mm.

The result is calculated and approximated up to 1 MPa.

If it is necessary the result is recalculated on the moisture content 12% using the formula (4.2.3.2):

$$\sigma_{12} = \sigma_W[1 + \alpha(W - 12)], \qquad (4.2.3.2)$$

σ_W – the strength of the sample with W-moisture content at the moment of testing, MPa;

α - the humidity correction factor, equal to 0.04 for all species;

W - moisture content of the sample at the moment of testing,%.

Determination of shear strength parallel to the grain (GOST 16483.5-73*)

GOST 16483.5-73* corresponds ISO 3347-76 in parts about determining the shear strength parallel to the grain.

Test piece

The shape and dimensions of the samples should be the same as in Figure 4.2.3.2:

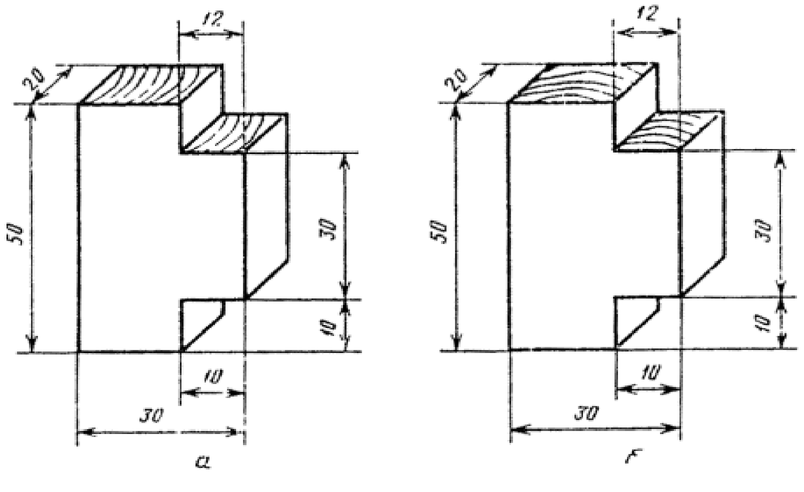


Figure 4.2.3.2 Samples for shearing tests: (a) – sample for shearing in tangential direction; (b) - sample for shearing in radial direction

Procedure

The sample is placed in a shearing test machine illustrated in Figure 4.2.3.3:

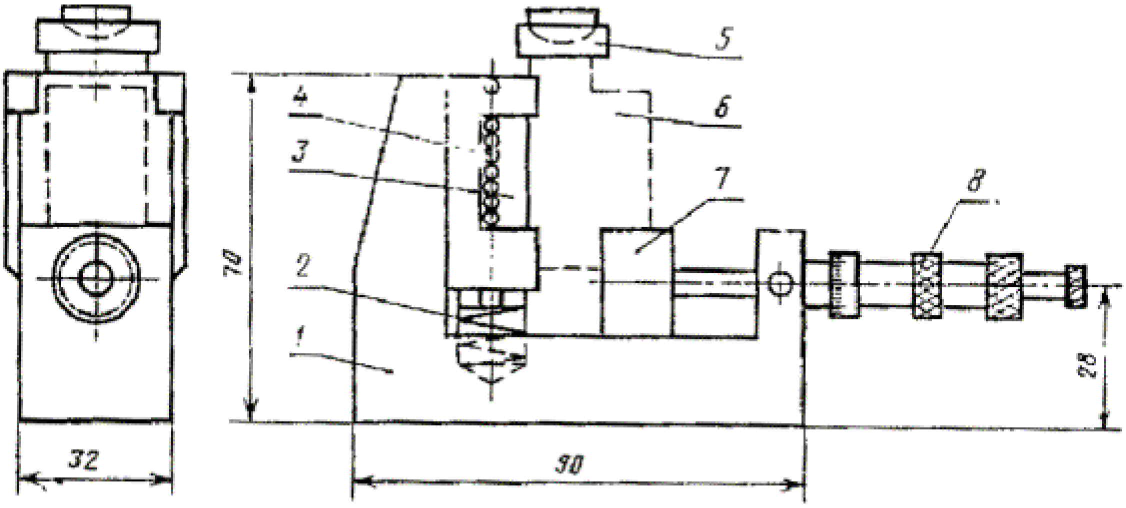


Figure 4.2.3.3 Shearing test machine: 1 – body frame; 2 – spring; 3 - movable plate; 4 – rollers; 5 - push prism with a pin-bearing support; 6 –sample; 7 - movable support; 8 - a device for a mobile support clamping.

A movable support 7 is brought to the contact with the sample. The load on the sample is passed by a push prism with a pin-bearing support 5. The sample is loaded uniformly with a constant rate of loading or with the constant moving speed of loading head of machine. The rate should be such that the sample was destroyed by (1,0 ± 0,5) min after the start of loading. If a machine with an electromechanical drive is used, it is allowed to carry out the loading of the sample uniformly at the rate (4000 ± 1000) N/mm or to conduct test at the moving speed of the testing machine head 4 mm / min. The test is continued until the destruction of the sample, determining the maximum value of load before the failure (P_{max}). An error of determining P_{max} should not exceed 10%. A moisture content of samples is determined after the test according to the procedure described in paragraph 5.1.

Expression of results

The share strength τ_w in MPa is calculated by formula (4.2.3.3):

$$\tau_W = \frac{P\max}{b \times l}, \qquad (4.2.3.3)$$

P_{max} - the maximum load, N;
b – thickness of the sample, mm;
l – length of shear, mm.
The result is calculated and approximated up to 0,1 MPa.

The result is recalculated on the moisture content 12% using the formula (4.2.3.4):

$$\tau_{12} = \tau_W[1 + \alpha(W - 12)], \qquad (4.2.3.4)$$

τ_w – the strength of the sample with W-moisture content at the moment of testing, MPa;
α - the humidity correction factor, equal to 0.03 for all species;
W - moisture content of the sample at the moment of testing,%.

Determination of compression strength parallel to the grain (GOST 16483.10-73*)

GOST 16483.5-73* corresponds ISO 3787-76 in parts about determining the compression strength parallel to the grain.

Test piece

The samples were manufactured in the form of a rectangular prism with a cross-section 20 x 20 mm and a length 30 mm along the grain.

Procedure

The sample is placed in a compression test machine illustrated in Figure 4.2.3.4:

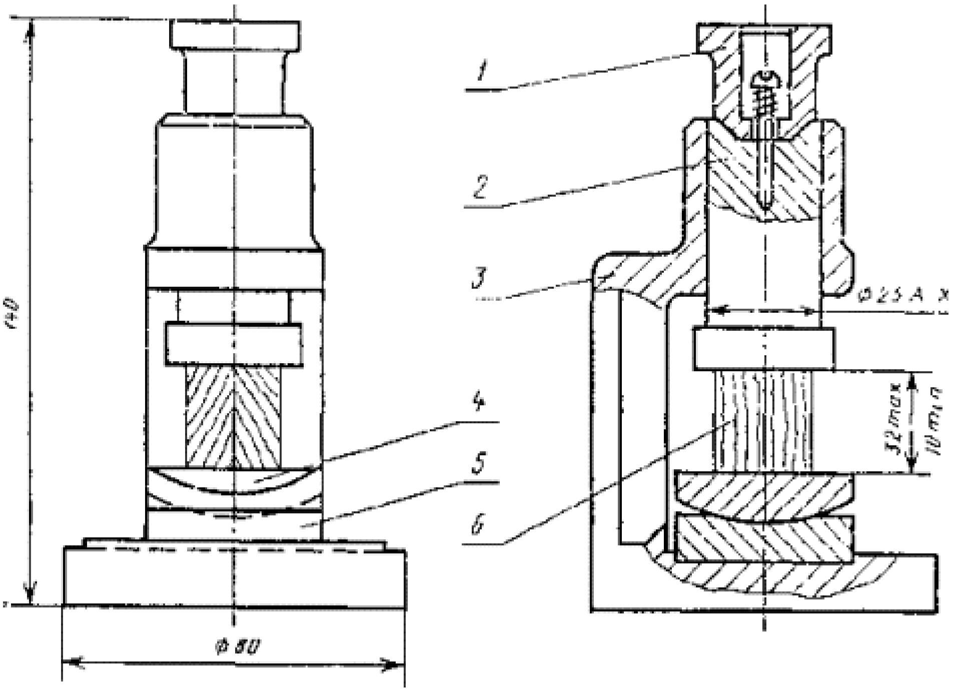


Figure 4.2.3.4 Compression test machine: 1 - cap 2 - punch 3 – body frame, 4 - pin-bearing support 5 - plate, 6 - sample

The load on the sample is passed by a punch 2. The sample is loaded uniformly with a constant rate of loading or with the constant moving speed of loading head of machine. The rate should be such that the sample is destroyed by (1,0 ± 0,5) min after the start of loading. If a machine with an electromechanical drive is used, it is allowed to carry out the loading of the sample uniformly at the rate (25000 ± 5000) N/mm or to conduct test at the moving speed of the testing machine head 4 mm / min. The test is continued until the destruction of the sample, determining the maximum value of load before the failure (P_{max}). An error of determining P_{max} should not exceed 1%. A moisture content of samples is determined after the test according to the procedure described in paragraph 5.1.

Expression of results

The compression strength parallel to the grain σ_w in MPa is calculated by formula (4.2.3.5):

$$\sigma_W = \frac{P_{max}}{a \times b}, \qquad (4.2.3.5)$$

P_{max} – the maximum load, N;
a, b – dimensions of the sample's cross-section, mm;
The result is calculated and approximated up to 0,5 MPa.

The result is recalculated on the moisture content 12% using formula (4.2.3.6):

$$\sigma_{12} = \sigma_W[1 + \alpha(W - 12)], \qquad (4.2.3.6)$$

σ_w – the strength of the sample with W-moisture content at the moment of testing, MPa;
α - the humidity correction factor, equal to 0.04 for all species;
W - moisture content of the sample at the moment of testing,%.

Determination of compression strength perpendicular to the grain (GOST 16483.11-72*)

Test piece

The samples were manufactured in the form of a rectangular prism with a cross-section 20 x 20 mm and a length 30 mm along the grain.

Procedure

The sample is placed in the testing machine tangential or radial surface upward. The testing machine is shown in Figure 4.2.3.5. It is a device for uniform loading of the sample, which has two self-aligning plates, which are contacted by spherical surfaces.

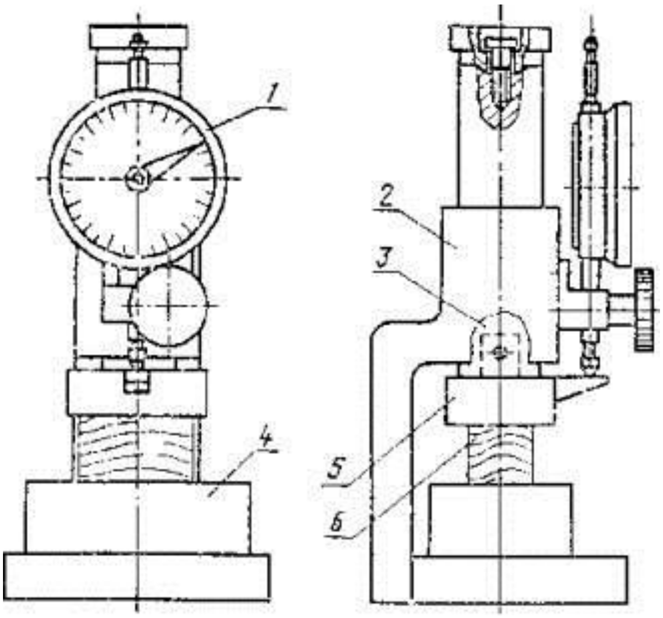


Figure 4.2.3.5 Compression testing machine: 1 – Indicator; 2 – body frame; 3 – Stem; 4 – support; 5 - removable punch; 6 – sample.

The load on the sample is passed by a removable punch 5. The sample is loaded uniformly with a constant rate of loading or with the constant moving speed of loading head of machine. The rate should be such that the sample is destroyed by (1,5 ± 0,5) min after the start of loading. If a machine with an electromechanical drive is used, it is allowed to carry out the loading of the sample uniformly at the rate (1000 ± 200) N/mm. The indicator measures the deformation of the sample with an error not exceeding 0.01 mm. The test is continued until the moment the deformation of the sample increases sharply. A moisture content of samples is determined after the test according to the procedure described in paragraph 5.1.

The load P, which corresponds with the strength, is determined by the diagram of compression perpendicular to the grain illustrated in Figure 4.2.3.6 P is determined as an ordinate of the point, where a tangent of the angle between P-axis and the tangent line to the graph (tangent of β-angle) increased by 50% versus its value on the straight portion of the graph (tangent of α-angle).

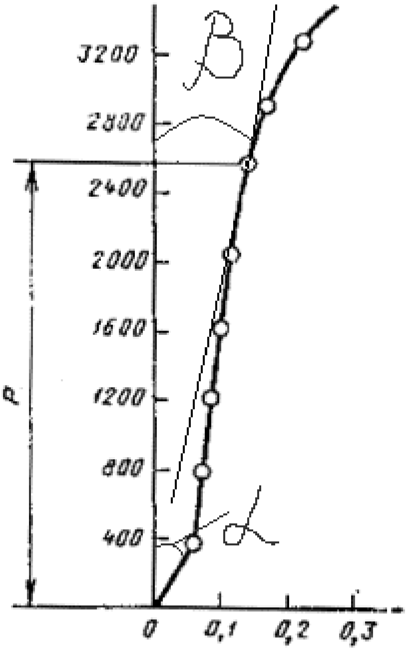


Figure 4.2.3.6 Diagram of compression perpendicular to the grain

Expression of results

The compression strength perpendicular to the grain σ_w in MPa is calculated by formula (4.2.3.7):

$$\sigma_W = \frac{P}{b \times l}, \qquad (4.2.3.7)$$

P – load, determined from the diagram, N;
b – width of the sample, mm;
l – length of the sample, mm;
The result is calculated and approximated up to 0,1 MPa.

The result is recalculated on the moisture content 12% using formula (4.2.3.8):

$$\sigma_{12} = \sigma_W[\,1 + \alpha(W - 12)], \qquad (4.2.3.8)$$

σ_w – the strength of the sample with W-moisture content at the moment of testing, MPa;
α - the humidity correction factor, equal to 0.035 for all species;
W - moisture content of the sample at the moment of testing,%.

Determination of tension strength parallel to the grain (GOST 16483.23-73*)

GOST 16483.23-73* fully complies with ISO 3345-75.

Test piece

The shape and dimensions of the samples should be the same as in Figure 4.2.3.7.

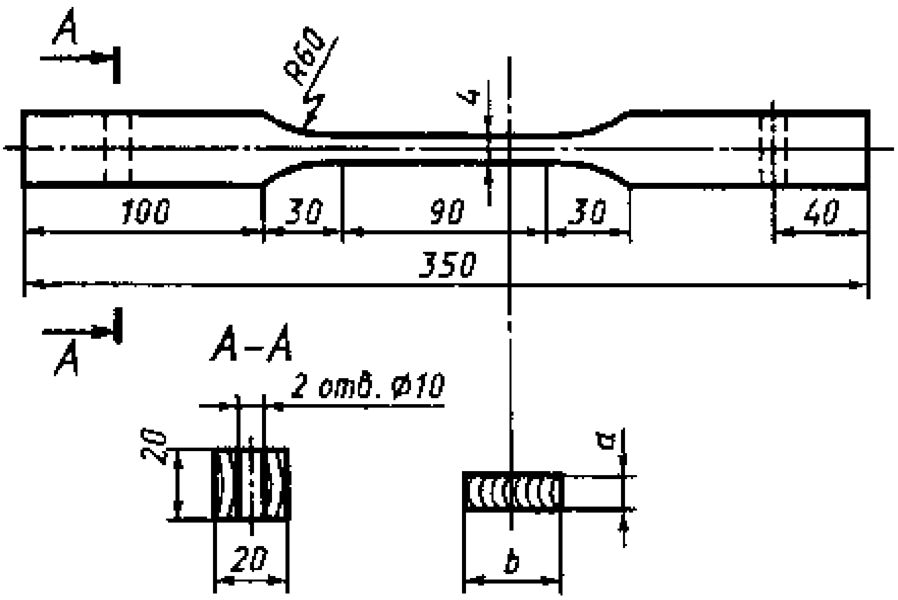


Figure 4.2.3.7 Sample for tension tests

Procedure

The sample is placed in the grips so that the portion of each head, bordering with rounding, remained free during 20 – 25 mm and a tensile load coincides with the longitudinal axis of the specimen.

The rate should be such that the sample is destroyed by (1,5 ± 0,5) min after the start of loading. If a machine with an electromechanical drive is used, it is allowed to carry out the loading of the sample uniformly at the rate (15000 ± 4000) N/mm or to conduct test at the moving speed of the testing machine head 10 mm / min. The test is continued until the destruction of the sample, determining the maximum value of load before the failure (Pmax). An error of determining P_{max} should not exceed the division value of measuring equipment. A moisture content of samples is determined after the test according to the procedure described in paragraph 5.1.

Expression of results

The compression strength parallel to the grain σw in MPa is calculated by formula (4.2.3.9)

$$\sigma_W = \frac{P_{max}}{a \times b}, \qquad (4.2.3.9)$$

P_{max} - the maximum load, N;
a, b – dimensions of the sample's cross-section, mm;
The result is calculated and approximated up to 1 MPa.

The result is recalculated on the moisture content 12% using formula (4.2.3.10):

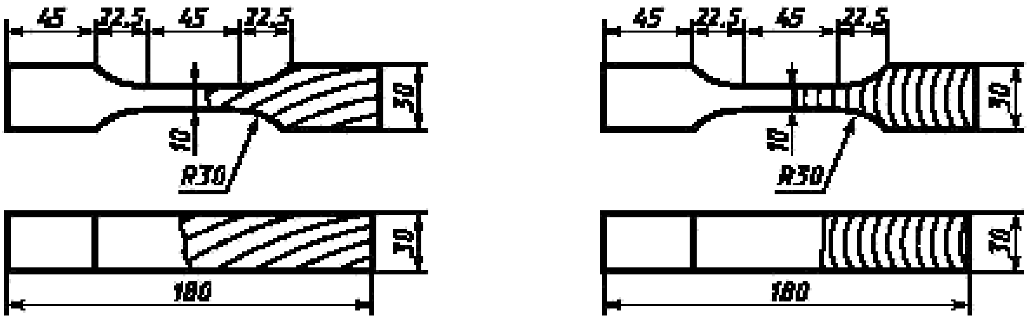
$$\sigma_{12} = \sigma_W[1 + \alpha(W - 12)], \qquad (4.2.3.10)$$

σ_w – the strength of the sample with W-moisture content at the moment of testing, MPa;
α - the humidity correction factor, equal to 0.01 for all species;
W - moisture content of the sample at the moment of testing,%.

Determination of tension strength perpendicular to the grain (GOST 16483.28-73)

Test piece

The shape and dimensions of the samples should be the same as on the Figure 4.2.3.8



(a) (b)

Figure 4.2.3.8 Test pieces for tension strength test (a) – in tangential direction; (b) – in radial direction.

Procedure

The sample is placed in the grips so that the portion of each head, bordering with rounding, remained free during 10 mm and a tensile load coincides with the longitudinal axis of the specimen.

The rate should be such that the sample is destroyed by (1,5 ± 0,5) min after the start of loading. If a machine with an electromechanical drive is used, it is allowed to carry out the loading of the sample uniformly at the rate (2500 ± 500) N/mm or to conduct test at the moving speed of one of the testing machine heads 4 mm / min. The test is continued until the destruction of the sample, determining the maximum value of load before the failure (P_{max}). An error of determining P_{max} should not exceed the division value of measuring equipment. A moisture content of samples is determined after the test according to the procedure described in paragraph 5.1.

Expression of results

The compression strength parallel to the grain σw in MPa is calculated by formula (4.2.3.10):

$$\sigma_W = \frac{P_{\max}}{a \times b}, \qquad (4.2.3.10)$$

P_{max} - the maximum load, N;
a, b – dimensions of the sample's cross-section (in the middle part), mm;
The result is calculated and approximated up to 0,01 MPa.

The result is recalculated on the moisture content 12% using formula (4.2.3.12):

$$\sigma_{12} = \sigma_W [1 + \alpha(W - 12)], \qquad (4.2.3.10)$$

σ_w – the strength of the sample with W-moisture content at the moment of testing, MPa;
α - the humidity correction factor, equal to 0.01 for all species in radial tension and 0.025 in tangential tension;
W - moisture content of the sample at the moment of testing,%.

5 LABORATORY STRENGTH MEASUREMENTS

As a practical part several tests in Finnish and Russian laboratories were made. The main aims were to compare the strength values of Finnish sawn timber fixed in EN 338 and the actual results obtained in laboratories.

5.1 Method of strength determining by the percentage of autumn timber (latewood)

This method allows to determine the approximate strength of timber if the latewood content in timber cross section is known.
For determining the percentage of autumn timber (latewood) in the sample GOST 16483.18-72 "Wood. Method for determination the number of annual rings in 1 cm and content of latewood in an annual ring" was used.

Preparation for testing
The dimensions of samples should be 20*20 mm for cross section and length along the fibres of 10 to 20 mm. But it is possible to use samples intended for other types of tests, provided that the cross section in the radial direction is not less than 20 mm.

The class of timber for the test was C24, the material was pine.

Figure 5.1.1 Preparation of samples

Testing process

Using the pencil the assistant draws the line perpendicular to annual rings and chooses the length of 20 mm.

Figure 5.1.2 designation of the interval for measurements

Because the formula for determining the approximate strength is suitable for timber with moisture content 12%, samples were dried in the oven. the duration of drying was 16 hours, the temperature in the oven was 105°C. The initial moisture content of each sample was also measured by its weighing before and after drying.

Figure 5.1.3 Weighing of samples before and after drying

The results are presented in the table below:

Table 5.1.1 Moisture content of samples

№ of the sample	Weight, g		Moisture content, %
	Before drying	After drying	
1	67,1	63,1	6,3
2	57,4	53,6	7,1
3	58,7	55,3	6,1
4	60,6	56,9	6,5

For determination of moisture content of timber information from GOST 16483.7-71* «Wood. Methods for determination of moisture content» was used.

$$W = \frac{m_1 - m_2}{m_2} \times 100\% \qquad (5.1.1)$$

m_1 – weight before drying, g
m_2 - weight after drying, g

The total width of latewood (dark areas) is measured on that interval by ruler or by other equipment. The student used an electronic caliper and a microscope.

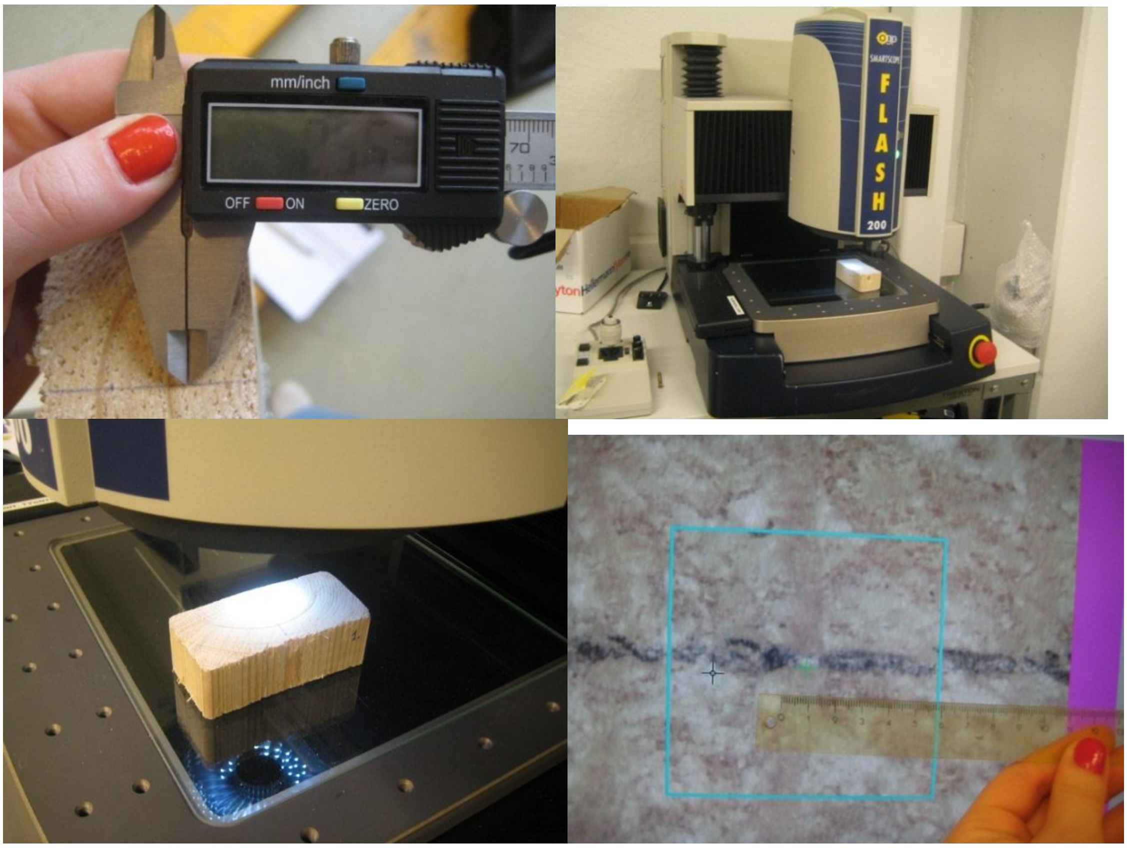


Figure 5.1.4 Various methods of determining the width of latewood

After that the percentage of latewood (m) is calculated by the formula with the accuracy of 1%:

$$m = \frac{\Sigma a_i}{l} \cdot 100\% , \qquad (5.1.2)$$

Figure 5.1.5 Designation of latewood at growth rings

a_i – the width of latewood in each annual ring;

l - the length of the interval with annual rings in the radial direction (20 mm);

The results of measurement are presented in the table:

Table 5.1.2 Percentage of latewood in samples

№ of the sample	Percentage of latewood
1	19,7
2	16,3
3	17,4
4	18,6

Correlation between the strength and the percentage of late wood for pine is expressed in the empirical formula (Khukhrianskii 1955, p.88):

$$R = A \times m + B \qquad (5.1.3)$$

R – strength in compression parallel to grain, N/mm^2;

A, B – empirical coefficient from the table;

Table 5.1.3 Coefficients for calculation (Khukhrianskii 1955, p.88)

Tension type	A	B
Compression parallel to grain	0,6	30

Table 5.1.4 Results of strength determination calculations

№ of the sample	strength in compression parallel to grain, N/mm^2
1	31,8
2	29,8
3	30,4
4	31,2

The results of the test show that strength from EN 338 for C 24 (see table 3.1.1) is much more lower than strength from the formula. It can be associated with different water content in the samples and with the inaccuracy of the measurements.

5.2 Comparison of the guaranteed strength of C24 with the result obtained in Russian laboratory

Standard samples were made of timber boards C24 in the mechanical laboratory of Saimaa University of Applied Sciences.

For bending test three samples were made. The dimensions were 20x20x300 mm. For compression test seven samples were made. The dimensions were 20x20x30 mm.

Figure 5.2.1 Material for samples

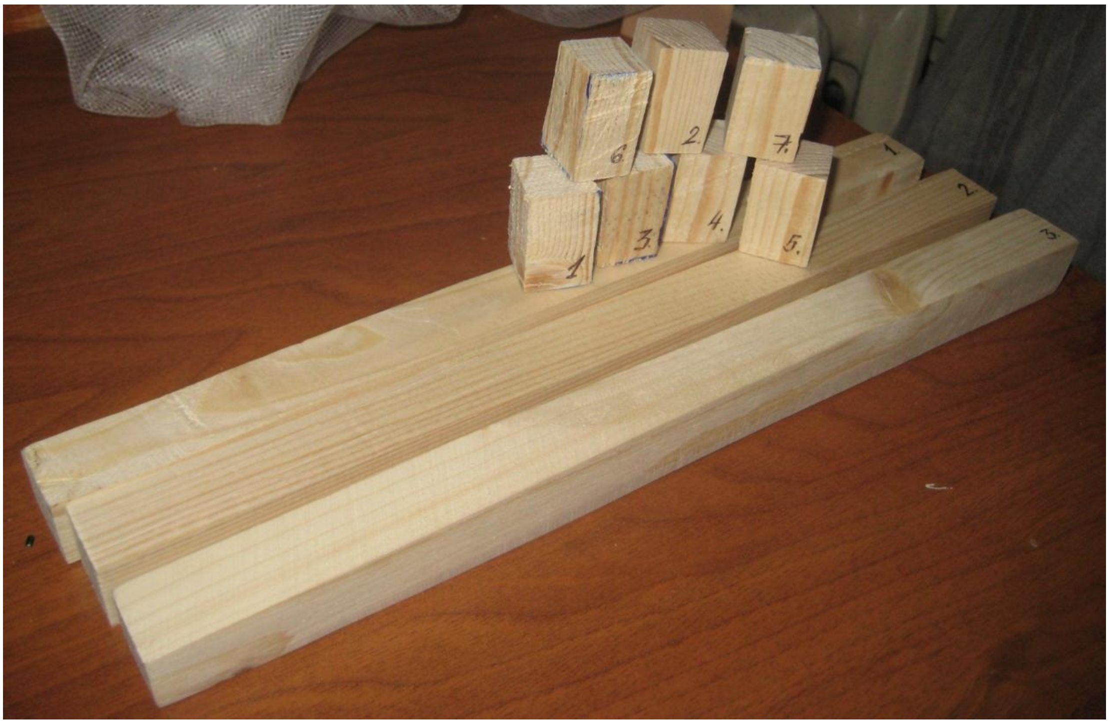


Figure 5.2.2 Samples for bending and compression tests

The guaranteed strength properties of C24 (according EN 338):

- Bending 24 N/mm^2;
- Compression parallel 21 N/mm^2;

The samples were tested in Russian mechanical laboratory of the Saint-Petersburg Transport University.

(a)

(b) (c)

Figure 5.2.3 Testing process: (a) testing machine, (b) bending test, (c) compression along the grain test

This equipment allows to find the failure load in bending and in compression parallel to the grain. The results of the destructive test are presented in the table below.

Table 5.2.1 Failure loads for samples in bending and compression tests

№ of the sample	Failure load, kN
Bending	
1	2,15
2	1,8
3	1,9
Compression parallel to the grain	
1	17,3
2	20,7
3	21,2
4	23,1
5	22,4
6	18,0
7	22,8

To determine the strength it is necessary to use formulas (Petrova 2011):

$$R\ bending = \frac{3\ P*l}{2*b*h*h} \qquad (5.2.1)$$

$$R\ compressive = \frac{P}{A} \qquad (5.2.2)$$

P – breaking load, kN;

l – distance between supports in bending (24 cm);

b – width of cross section of the sample (2 cm);

h – height of cross section of the sample (2 cm);

A – cross section area of the sample (4 cm^2)

Table 5.2.2 Strength of samples in bending and compression

№ of the sample	Strength, N/mm^2
Bending	
1	96,75
2	81,0
3	85,5
Compression parallel to the grain	
1	43,25
2	51,75
3	53,0
4	57,75
5	56,0
6	45,0
7	57,0

So high values of strength can be associated with small size of samples and “purity” of material. It was without knots, rot and other defects.

6 RESEARCH AND COMPARISON OF FINNISH AND RUSSIAN MARKETS OF CONSTRUCTION SAWN TIMBER

The hardware stores “K-Rauta” in Finland (Tullitie 2-4) and in Russia (Engels jne., 154) were investigated.

(a) (b)

Figure 6.1 K-Rauta markets: (a) Lappeenranta, (b) Saint-Petersburg

Types of structural timber were compared. The main points of comparison were cross sections and price. The main materials for structures in both markets are pine and spruce.

The range of sawn timber in Finnish and Russian markets is represented in the pictures below.

Figure 6.2 Assortment of sawn timber in the Finnish market

Figure 6.3 Assortment of sawn timber in the Russian market

Tables comparing the prices are presented below.

Table 6.1 Assortment of sawn timber in K-Rauta Lappeenranta

Material	Strength class	Thickness (mm)	Width (mm)	Price (€/m)
Pine	C24	48	98	1.69
		48	123	2.05
		48	148	2.64
		48	173	2.95
		48	198	3.40

Table 6.2 Assortment of sawn timber in K-Rauta Saint-Petersburg

Material	Grade	Thickness (mm)	Width (mm)	Price (€/m)
Pine	1	45	95	1.73
		45	120	2.19
		45	145	2.64

Comparing these two tables we can conclude that there are some differences between Finnish and Russian cross sections. In Finland the margin is 2 mm, in Russia it is 5 mm. The maximum of the width of sawn timber in Russian K-Rauta is 145 mm, wider boards should be specially ordered, but the price will be several times higher. In general, the prices of structural timber are quite similar in both shops.

7 CONCLUSIONS

Studies show that sawn timber is classified differently in Finland and in Russia. Finnish norms separate construction sawn timber into several classes with fixed values of strength. According to Russian norms the main parameter for classification of sawn timber is quality and appearance, which means classification by visual damages, rather than strength. Probably, this situation is related with the popularity of using sawn timber as a finishing material. But quality classes in Russia also have fixed values of strength, therefore comparison is still possible. Investigations of EN 338 and SNIP II-25-80 found that the 1st sort of Russian timber corresponds to C27, the 2nd to C24, the 3rd to C16. It means that C24, which is mainly used in Europe for building private houses, can also be widely used in Russia as a structural material.

The following result was obtained after consideration of normative documents about strength determining of sawn timber: there are a lot of differences between the Finnish and Russian process of grading of sawn timber. Finnish methods of grading are more various than Russian methods, but machine grading has first steps in Russian sawmill industry. Certainly in both countries laboratory tests have a great importance in questions of strength determining. Dimensions and methodology are rather different in general, which leads to difficulties in comparison of strength values, received during these tests.

Practical training consisting of of destructive tests of samples made of Finnish timber in Russian laboratories also show differences between values, noted in Finnish norms and values obtained from the formulas of GOST.

Research of Finnish and Russian markets of sawn timber led to the conclusion that they are similar in price aspect. But the assortment of cross-sections in Finnish marker is more diverse, which probably correlates with wider usage of sawn timber for construction in Finland.

After analyzing all the problems of this thesis work in the area of comparing two countries, the need of creating the connected base of normative documentation is becoming apparent. It will be a good base for making the export process of sawn timber easier. Moreover it helps to calculate structures made of foreign timber. So, the program of harmonization of SNIPs and Eurocodes in Russia is really actual nowadays.

FIGURES

TABLES

REFERENCES

Blass, H.J., Aune, P., Choo, B.S. 1995. Timber engineering – STEP 1. Basis of design, material properties, structural components and joints. Netherlands: Centrum Hout.

Chubinsky, A., Fedyaev, A., Pavros, K., Teplyakova, A. 2011. Forecasting of the durability of sawn timber for glued laminated beam by ultrasonic diagnostics. News of Saint-Petersburg State Electrotechnical University 7. 109-115.

EN 338. 2009. Structural timber. Strength classes.

EN 408. 2010. Timber structures. Structural timber and glued laminated timber. Determination of some physical and mechanical properties.

Encyclopedia Britannica Kids
http://kids.britannica.com/elementary/art-66141/Cross-section-of-a-tree-trunk
(Accessed on 04.06.2012)

GOST 16483.3-84. 1984. Wood. Method of determination of static bending strength.

GOST 16483.5-73*. 1973. Wood. Methods for determination of ultimate shearing strength parallel to grain.

GOST 16483.7-71* . 1971. Wood Methods for determination of moisture content.

GOST 16483.10-73*. 1973. Wood. Methods for determination of ultimate strength in compression parallel the grain.

GOST 16483.18-72. 1972. Wood. Method for determining the number of annual rings in 1 cm and content of latewood in an annual ring.

GOST 16483.23-73. 1973. Wood. Method for determination of ultimate strength in tension along the grain.

GOST 16483.28-73. 1973. Wood. Method for determination of ultimate tensile strength across the grain.

GOST 8486-86. 1986. Coniferous sawn timber. Specifications

Institute for building materials. SNF Sinergia Project: Multiscale analysis of coupled mechanical and moisture behavior of wood
http://www.ifb.ethz.ch/research/sinergia (Accessed on 04.06.2012)

Khukhrianskii, P.P. 1955. Wood strength. Leningrad: Goslesbumizdat.

Petrova T. & Poletaev A. 2011. Influence micro- and macrostructure of wood on properties of materials and products. Guidelines. Saint-Petersburg: Saint-Petersburg State Railway University.

Puzanova, D. 2010. Quality estimation and classification of sawn and planed wood according to SFS and GOST. Saimaa University of Applied Sciences. Degree Programme in Construction Engineering. Bachelor's Thesis.

Report of the Ministry of the Regional Development of Russian Federation. Harmonization of Russian and European systems of normative documents in construction.
http://www.minregion.ru/upload/documents/2010/12/doklad-mrr-kollegiya.doc
(Accessed on 04.06.2012)

SNIP II-85-80. 1980. Timber structures.

Thelandersson S., Larsen H.J. 2003. Timber Engineering. Chichester: John Wiley & Sons Ltd.

Strength Grading of Lumber: A brochure by FinScan.

Willems M. What is Wood Part 1
http://www.copperman.co.uk/didgeridoo/how_to_make_a_wooden_didgeridoo/what_is_wood.php (Accessed on 04.06.2012)

Wood technology science main page.
http://www.drevesinas.ru/ (Accessed on 04.06.2012)