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NEW CRITERIA FOR VISUAL STRENGTH GRADING OF SAWN TIMBER FROM BIRCH GROWN IN SWEDEN

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ABSTRACT: Today there is no standard for strength grading and CE-marking sawn timber of Birch grown in Sweden, which makes it impossible to use this material as structural timber. Internationally, there are standards for visual grading of hardwood in several European countries. However, these standards may not be used to classify Birch timber grown in Sweden without having been tested and verified to meet the standard's requirements. In a project (BizWOOD) run by RISE, 600 pieces of sawn birch wood from Sweden is visually graded and strength tested.

The project aims to result in grading rules for birch, either by using international standards or where international standards will be used as references for the identification of defects that will be included in the grading model. This paper summarizes parts of the BizWOOD project and includes 1) description of sampling and timber origin, 2) visual grading according to international standards, 3) strength testing of the material, 4) evaluation of mechanical characteristics, 5) evaluation of grading techniques.

KEYWORDS: Birch (*Betula spp.),* density, bending strength, modulus of elasticity, MOR, MOE, strength grading.

1 INTRODUCTION

The Swedish forests consists of about 18% hardwood and this proportion is increasing as a result of environmental goals [1] and certification criteria [2]. The largest proportion of the deciduous forests are located in Southern Sweden [3], where pure stands of deciduous trees are found. However, the market for sawn timber from deciduous trees is very limited today and for several tree species the market is largely non-existent. A large proportion of the Swedish hardwood that is felled is used as pulpwood or firewood, only a very limited proportion is used as sawn timber in Sweden and a small proportion is exported as logs. The problem is often explained by a Catch-22 within the value chain - no demand leads to no production and no production leads to no demand. The large players in the market find it difficult to rationally handle the relatively small quantities of hardwoods that come out of the market. This means that the hardwood market is dominated by a few larger companies specializing mainly in floor manufacturing. In addition, the market consists of many small sawmills, all of which are included in the small and medium sized enterprises category.

The Swedish deciduous forest is dominated by Birch, a combination of *Betula pendula* and *Betula pubescens*. The total timber stock of Birch in the Swedish forest is about 386 million m^{3}sk (forest cubic meters), where the growth is about 14 million m^{3}sk per year [3]. The felling in Sweden is about 8 million m^{3}sk, i.e. the growth is significantly higher than the felling but of which only 77 000 m^{3}sk is used in the four larger sawmills in Sweden [4] for furniture and joinery without strength grading, e.g. about 1% of the total volume. The remaining material is used in pulp mills or as firewood. One of the reasons for this is that, today, there is no strength grading standard that can be used for strength grading sawn birch timber grown in Sweden. This makes it very difficult to use birch wood as structural timber in Sweden.

The objective of this paper is to present the BizWOOD findings where timber characteristics were measured for birch timber grown in Sweden. Data for strength grading, both for visually- and machine-grading will be presented for about 600 pieces. All specimens were strength tested in four-point bending, in accordance with EN 408 [5], the results for bending strength, modulus of elasticity (MOE) and density will be presented. The possible yields in different grades based on the sampled material will be presented.

The long-term aim is to establish methods that can be used to strength grade sawn timber from birch grown in Sweden and thus make it possible to use birch as a structural material in Sweden. This will broaden the raw material base in the Swedish forestry sector. The work is done as part of a larger project BizWOOD, with the aim

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of finding more use of hardwood timber grown in Sweden.

2 MATERIAL AND METHODS

The sampling and measurements were done according to the principles used when setting initial values for machine strength grading in accordance with EN 14081 [6]. This meant sampling and testing more than 450 pieces of timber from the growth area. A growth area is defined, according to EN 14081-2 [7], as the source from which timber is intended to be strength graded.

2.1 Sampling of material

The sampling was carried out at 5 different sawmills in Sweden, see Figure 1, and a total number of 600 specimens of sawn timber were collected. The specimens were divided into four so-called verification samples (sub-sample): North Sweden, Mid Sweden, Southeast Sweden and Southwest Sweden. The material from the two sawmills in Mid Sweden was grouped as one sub-sample as their source areas are overlapping.

The thickness of the specimens varied between 22 mm to 66 mm, and the width from 60 mm to 200 mm. The length of the specimens was between 2,9 and 3,2 meters, which is the standard length of birch timber in Sweden. The number of specimens in each sub-sample, together with corresponding dimensions and origin, is summarized in Table 1.

Figure 1. *Locations of the five sawmills represented in the study. The material from the two sawmills in Mid Sweden was grouped into one sub-sample as the catchment area for the two sawmills were overlapping.*

The total sample of specimens were later broadened to include an additional sub-sample consisting of 120 specimens from Norway. However, these specimens are not included in the evaluation presented in this paper.

The birch grown in Swedish forest consists of a mix of *Betula pendula* and *Betula pubescens* which are not distinguishable visually when sawn to boards. Due to this reason the birch species *Betula pendula* and *Betula pubescens* are processed as one species, the number of specimens of each species in the sample is unknown. The sawmills processing birch timber are relatively small and not all of them uses kiln drying. The specimens included in sub-samples Mid Sweden and Southeast Sweden were kiln dried to approximately 12% moisture content. The specimens in the other subsamples were air-dried. All specimens were planed before testing.

Table 1. *Number of specimens from different sub-samples (geographical sources) and their dimensions and tested length (span length) in four-point bending. The dimensions marked with * could not be tested with a span length of 18h.*

Sub-sample	Nominal dimension [mm x mm]	Span length [m]	Number
North	22 x 75	1.35	40
North	48 x 75	1.35	42
North	48 x 100	1.80	41
Mid	48 x 200	3.00*	42
Mid	36 x 70	1.26	52
Mid	39 x 150	2.70	51
Mid	47 x 60	1.08	79
Mid	50 x 125	2.25	50
Southeast	45 x 95	1.71	43
Southeast	45 x 70	1.26	39
Southeast	45 x 150	2.70	24
Southwest	45 x150	2.70	27
Southwest	45 x 170	2.72*	33
Southwest	66 x 125	2.25	37
Total			600

2.2 Measurements – visual, physical, and mechanical characteristics

In the laboratory the visual characteristics were recorded, and the mechanical properties were tested for each specimen.

2.2.1 Visual characteristics

Visual characteristics of each specimen were recorded in the form of; knot sizes in the critical cross section, rot, cracks, slope of grain, and wane according to INSTA 142 [8]. If other defects were found these were noted in the protocol. The measurements were done by hand. The parameters distortion and annual ring width were not recorded.

Knots were recorded for a length of 150 mm at the critical cross section within the middle 6h of the length, i.e. the

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part of the specimen used as the middle span in the bending tests.

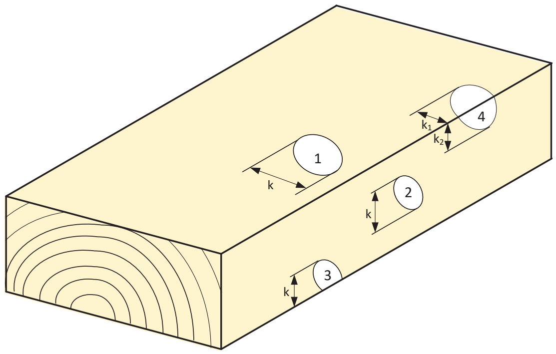

Figure 2. *Principal definition of knot measurement for five different types of knots.*

The main principle for the knot measurement was that a factor (k) was determined as length of the knot in the right angle to the length of the piece, see for example illustration of knot 1 in Figure 2. This is the principle described in INSTA 142 [8].

The knot measurement of knots fully on the edge side are measured perpendicular to the longitudinal axis (knot 2). Knots on the corner between heartwood face of the sample and the edge are measured on the edge side and counted as edge knots (knot 3). Knots on the corner between the sapwood face and the edge side (knot 4) are measured as:

$$k = k_1 + 0.5k_2 \qquad \text{(Eq. 2)}$$

and classified as an edge knot. Knots going through the specimen from one flat face to the other are measured on the sapwood face of the specimen. If the through going knot is closer to the edge than the measure (k), the knot is classified as an edge knot. If the knot is visible on the whole edge side, it is classified as an edge knot with the knot measure equal to the thickness of the specimen. Overlapping knots are not taken into account, each knot was measured as a single knot.

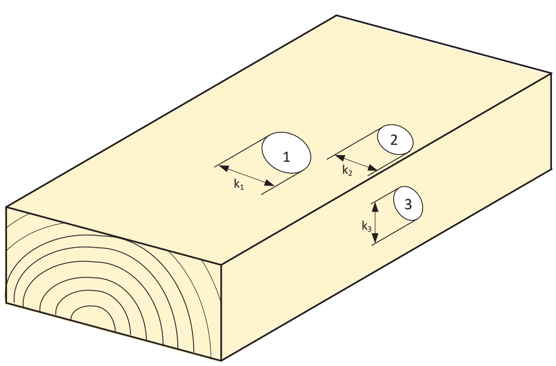

Figure 3. *Principal definition of knot group measurement.*

Knots are counted as knot group if they occur within the same 150 mm specimen length, see Figure 3. The knot measure for a knot group is defined as: the sum of the face knots (on the sapwood face) and the edge knots on both edges.

$$k_g = k_1 + k_2 + k_3 \qquad \text{(Eq. 3)}$$

Slope of grain was measured using a scribe on the sapwood face of the samples and expressed as a ratio between the "fiber deviation/ measurement length".

2.2.2 Density and moisture content

Clear wood density (ρ) was measured on a section of each sample after the bending test according to EN 408 [5]. This means measurement of the dimensions and the weight of the specimen. The test specimen was taken as close as possible to the fracture in clear wood. Clear wood density is defined as:

$$\rho = \frac{m}{V} \qquad \text{(Eq. 4)}$$

where (m) is the mass of the test sample and (V) the volume of the test sample. The volume was measured by Archimedes principle i.e., the mass of water displaced by the specimen.

Moisture content was determined using the oven drying method according to EN 13183 [9], and on the same samples as used for determining density. The moisture content (u) in percent was calculated as:

$$u = \frac{m_1 - m_0}{m_0} \cdot 100 \qquad \text{(Eq. 4)}$$

where (m_1) is the mass of the sample before drying and (m_0) the mass of the sample after oven drying.

2.2.3 Dynamic modulus of elasticity

The dynamic modulus of elasticity was evaluated for each specimen using the first resonance frequency in the axial direction. The measurement of the resonance frequency can be summarized as follows: the specimen was firstly placed on a rubber foam to simulate free-free conditions. An accelerometer was then placed at one of the ends of the specimen and a hammer was used to produce an axial shock wave through the specimen. The time signal from the accelerometer was registered and a Fast Fourier Transform (FFT) was performed. The first resonance frequency, (f_{A-1}) was picked as the first peak in the frequency spectra. The first axial resonance frequency together with the measured length and density of the specimen was then used to calculate the dynamical modulus of elasticity (E_{dyn}) according to [10] using Eq. 2.

$$E_{dyn} = 4 \cdot \rho \cdot L^2 \cdot f_{A-1}^2 \qquad \text{(Eq. 2)}$$

Where (ρ) is the density of the specimen at the measurement time based on volume and weight of the whole board, (L) is the length of the specimen and (f_{A-1}) is the first resonance frequency in the axial direction.

Measurement for E_{dyn} are missing for one series, why this series is omitted in figures presenting (E_{dyn}) below.

2.3 Strength testing according to EN 408

The static bending tests were performed at RISE test laboratory in Borås, accredited as testing laboratory according to EN 408 [5]. According to EN 408 [5] and EN 384 [11] each specimen was tested in edgewise four-point bending. A span length of 18 times the depth (h) of the specimen between the outer supports was used. The inner span length, i.e., the length between the loading points, was $6h$. Local and global modulus of elasticity were measured. The local modulus of elasticity was measured as curvature over a span of $5h$, see Figure 4. The global deflection was also measured giving an alternative value for modulus of elasticity.

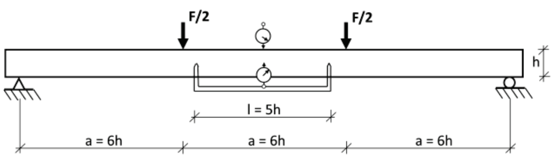

Figure 4. *Four-point bending test including span length and measurement of local and global deflection.*

The critical cross section was, if possible, centred between the loading points. The measured defects were placed randomly in either tension or compression.

The standard log length when harvesting birch in Swedish forest is about three meters. This meant that for the series with specimen depth of 170 and 200 mm it was not possible to use the length of 18 h between the supports. The span length between the outer supports were adjusted to $15h$ for the specimens with depth of 200 mm, and to $16h$ for the specimens with a depth of 170 mm.

2.4 Strength reducing characteristics and machine grading visual override

The regulations for machine strength grading includes a visual override where specimens including some strength reducing characteristics results in the specimens being assigned to a grade with a lower strength class. These characteristics include values for cracks, distortion, wane and rot. In the protocol 25 pieces were recorded as having rot to some extent. Wane was recorded in 46 pieces; where some extended over the limit of 1/3 of the face or edge. Slope of grain above 1/10 was recorded in 20% of the pieces. Other defects were noted in 10% of the protocol entries. No specimens were rejected due to the visual override. The distortion: bow, spring, twist and cup were not measured, and no specimens were rejected for testing because of distortion.

2.5 Evaluation of data

Based on the test results from the bending tests the characteristics local MOE ($E_{m,l}$), global MOE ($E_{m,g}$) and bending strength (f_m) was evaluated as:

$$E_{m,l} = \frac{a l_1^2 (F_2 - F_1)}{16 \frac{bh^3}{12} (w_2 - w_1)} \quad \text{(Eq. 6)}$$

$$E_{m,g} = \frac{3al^2 - 4a^3}{2bh^3 \left(2 \frac{w_2 - w_1}{F_2 - F_1}\right)} \quad \text{(Eq. 7)}$$

$$f_m = \frac{3Fa}{bh^2} \quad \text{(Eq. 8)}$$

where the measures (a) and (l) are defined in Figure 4, ($F_2 - F_1$) is the increment in load between 0.1 max load (F) and 0.4 of the max load (F), and ($w_2 - w_1$) the corresponding deformations either measured locally or globally. The dimensions of the specimen are depth (h) and width (b).

The evaluated data was adjusted for moisture content, depth, and length. Test values for density were adjusted to a moisture content u_{12} = 12%, according to the formula in clause 5.4.2.2 in EN 384 [11], Eq. 9. Test values for modulus of elasticity were adjusted to a moisture content u =12%, according to the formula in clause 5.4.2.3 in EN 384 [11], see Eq. 10.

$$\rho = \rho_u (1 - 0.005(u - u_{12\%})) \quad \text{(Eq. 9)}$$

$$E_0 = E_{0,u} (1 - 0.005(u - u_{12\%})) \quad \text{(Eq. 10)}$$

The measured bending strength for samples with a depth less than 150 mm was adjusted with a (k_h) factor given in EN 384 [11]. The measured bending strength for the two tested dimensions with a span shorter than the stated 18h, for these series the bending strength has been adjusted with factor (k_l) given in EN 384 [11].

$$k_h = min \begin{cases} \left(\frac{150}{h}\right)^{0.2} \\ 1.3 \end{cases} \quad \text{(Eq. 9)}$$

$$k_l = \left(\frac{48h}{l_{ef}}\right)^{0.2} \qquad l_{ef} = l + 5a \quad \text{(Eq. 10)}$$

Where (l) is the distance between the two outer support points and (a) is the distance between the two inner loading points.

3 RESULTS

3.1 Knot size distribution

Knot size is the most important parameter for visual grading. Figure 5 shows the knot size distribution on the face side of the specimens. The majority of the knots cover less than 20% of the face side of the specimens.

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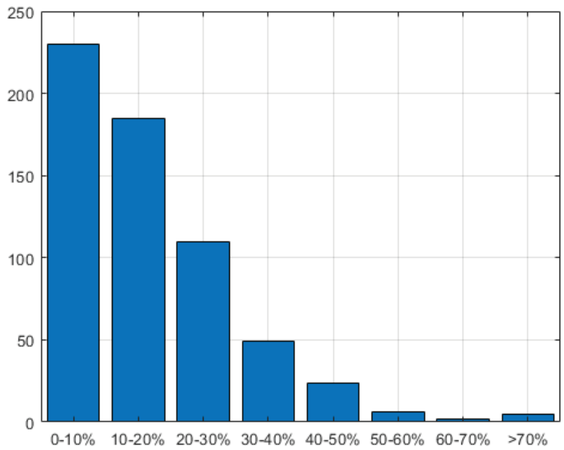

Figure 5. *Histogram of knot size (as percent of the total face) on flat face of the specimens.*

Figure 6 shows the knot size distribution on the edge sides of the specimens. The majority of the knots cover less than 10% of the edge sides of the specimens.

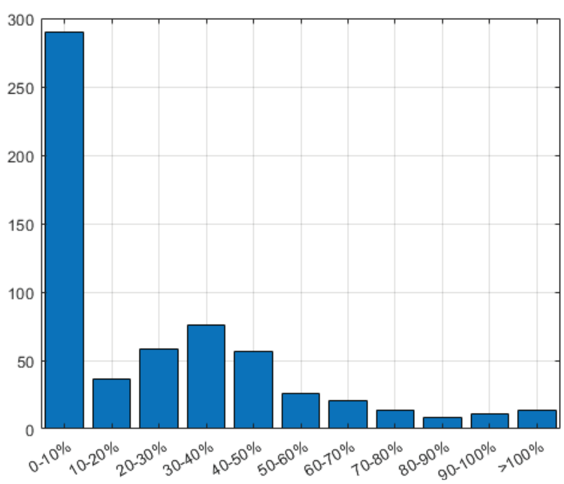

Figure 6. *Histogram of knot size on edge sides (as percent of the total sides) of the specimens.*

3.2 Variation in density, modulus of elasticity and bending strength

The parameters density, stiffness and bending strength are all defined as grade determining properties in strength grading. Figure 7 shows the distribution of density in the 600 specimens.

Figure 8 and Figure 9 show the distribution of local MOE ($E_{m,l}$) and bending strength (f_m), respectively, for all 600 specimens.

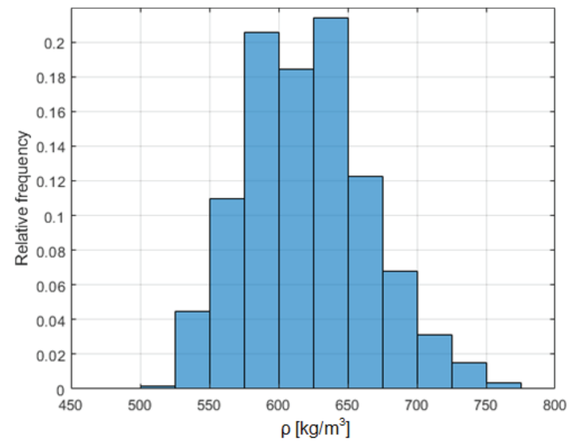

Figure 7. *Histogram for the distribution of density (**ρ**).*

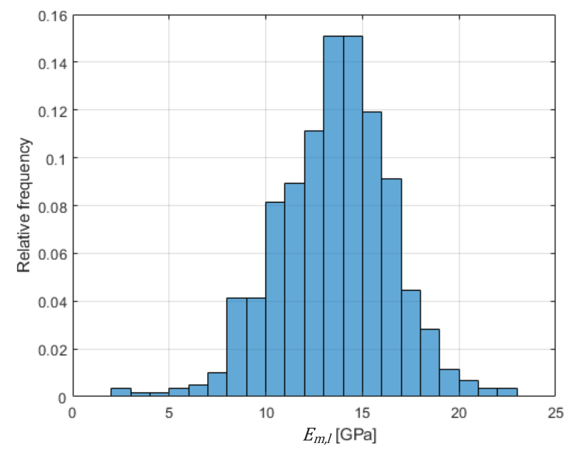

Figure 8. *Histogram for the distribution of local modulus of elasticity MOE ($\boldsymbol{E_{m,l}}$).*

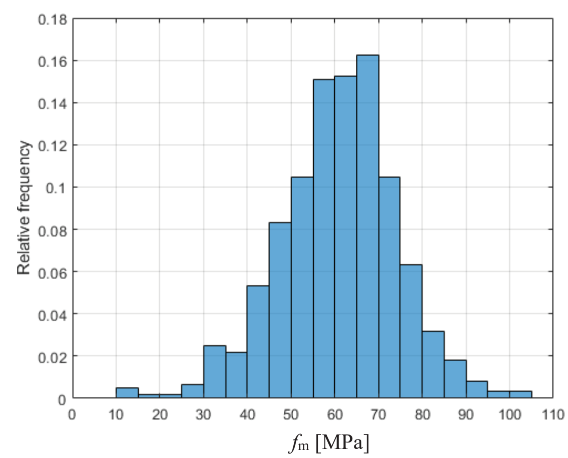

Figure 9. *Histogram for the distribution bending strength ($\boldsymbol{f_m}$).*

The data was evaluated to investigate the mean values for density, modulus of elasticity and bending strength as well as the coefficient of variation (CoV) and the 5% percentile value (characteristic value) according to EN 14358 [12].

The mean value for bending strength shows a value of 60.9 MPa with a value for the characteristic bending strength of 38.6 MPa (5% percentile), see Table 3. The results in Table 3 also shows that the different geographical sources have similar values for both strength and Coefficient of Variation (CoV). The latter indicates that the sampling worked well and that no discrepancy can be found between the subsamples. Splitting the bending strength values between different sizes of samples shows also similar results and the same depth adjustment factor used for softwood in EN 384 [11] works also for birch.

The mean modulus of elasticity for all the samples is 13.6 GPa, when splitting between different geographical sources there is a difference in mean value varying from 12.3 to 14.6 GPa. The mean density is just over 600 kg/m^3 for all samples and varying between 603-638 kg/m^3 when split between the different geographical sources.

3.3 Visual grading

All specimens were assigned to a single grade class (T0–T4) according to INSTA 142 [8], using the requirements for knots on the edge side (k), the flat face (k), knot groups (k_g) and slope of grain as described in Table 4. The number of specimens assigned to each grade class can be found in Table 2.

Table 2. *Number of samples in each assign grade according to requirements in Table 4.*

Grade	N
Reject	21
T0	45
T1	132
T2	188
T3	214
Sum	600

Table 3. *Compiled mean value, coefficient of variation and 5% percentile (characteristic value) for bending strength (f_m), local modulus of elasticity ($E_{m,l}$) and density (ρ) for all specimens and divided for geographical source and for specimen size.*

	Geographical source					Specimen depth		
	All	North	Mid	Southeast	Southwest	<90	90-150	>150
f_m **[MPa]**	60,9	59,8	62,2	65,0	54,1	61,8	62,3	58,5
CoV [%]	22%	19%	24%	23%	22%	26%	24%	19%
5% percentile	38,6	42,1	34,5	42,0	33,1	32,1	34,5	41,2
$E_{m,l}$ **[GPa]**	13.6	14.6	13.4	13.3	12.3	12.7	13.4	14.3
CoV [%]	21%	20%	24%	19%	20%	25%	24%	18%
ρ **[kg/m^3]**	620	603	619	638	613	620	620	604
CoV [%]	7%	13%	7%	11%	7%	7%	7%	6%
5% percentile	551	544	556	580	544	554	556	547

Table 4. *Used requirements from INSTA 142* [8] *for strength reducing characteristics used for assigning grades.*

	Grade class			
Characteristics	**T3**	**T2**	**T1**	**T0**
Single knot – edge side	k < 1/3 b	k < 1/2 b	k < 4/5 b	k = b
Single knot – flat face	k < 1/6 h	k < 1/4 h	k < 2/5 h	k < 1/2 h
Knot group	k_g < 1/3 b + 1/6 h	k_g < 1/2 b + 1/4 h	k_g < 4/5 b + 2/5 h	k_g < b + 1/2 h
Spiral grain angle	< 1:10	< 1:8	< 1:6	< 1:4

Table 5. *Comparison of mechanical properties, mean bending strength (f_m), mean modulus of elasticity ($E_{m,l}$) and mean density (ρ) from this study compared to other studies of birch timber and for two large studies for Norway spruce.*

Mean value	f_m [MPa]	$E_{m,l}$ [GPa]	ρ [kg/m^3]
Birch			
BizWOOD	61.0	13.6	620
Kilde 2006 [13]	43.5 (tension strength)	13.3	625
Obernoster & Jeitler 2021 [14]		15.1	603
Dunham et al. 1999 [15]	47.3-63.8	8.1-12.7	655-723
Norway spruce			
Olsson & Oscarsson 2017 [16]	42.1	11.6	441
Ranta-Maunas et al. 2011 [17]	40.2	11.2	428

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3.4 Correlation between strength and stiffness

The correlation between stiffness and strength is an important parameter for machine strength grading. Using all the data the correlation between local modulus of elasticity and bending strength is $r^2 = 0.41$, see Figure 10.

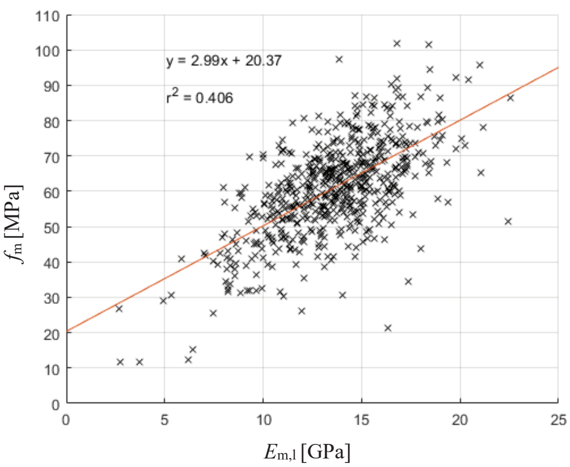

Figure 10. *Correlation between local MOE ($\boldsymbol{E_{m,l}}$) and bending strength ($\boldsymbol{f_m}$).*

4 ANALYSIS AND DISCUSSION

4.1 Mechanical properties

The mechanical properties for birch from this study can be compared to data from other studies, see
Table 6. The results show that the values are similar to values obtained in Norway [13] but higher than for studies performed in Austria [14] or the UK [15] for full size timber members with defects. Note that the Norwegian and Austrian values are obtained from tensile tests.

The values are also much higher than for the normally used Norway spruce, see Table 5. The bending strength for Norway spruce from the Nordic countries are normally just over 40 MPa, with a mean MOE of about 11.5 GPa and a mean density much lower than measured for the birch in this study.

4.1 Strength and stiffness of Birch timber from the Nordic countries compared to strength classes

Sawn timber is, in Europe, normally graded into different strength classes according to EN 338 [18]. The grading is done based on the characteristic value for bending strength, mean value for modulus of elasticity and characteristic value for density, see
Table 6. Values for the characteristic bending strength ($\boldsymbol{f_m}$), mean modulus of elasticity ($\boldsymbol{E_{m,l}}$) and characteristic density ($\boldsymbol{\rho}$) for some C-classes according to EN 338 [18].

Table 1Hardwood species can be graded into D-classes and softwood species into C-classes. The D-classes are designed for denser species like oak, ash and beech. The D-classes are rarely used in the Swedish building industry; therefore, we aim for grading birch into C-classes in this paper.

The results presented in Table 3. Compiled mean value, coefficient of variation and 5% percentile (characteristic value) for bending strength ($\boldsymbol{f_m}$), local modulus of elasticity ($\boldsymbol{E_{m,l}}$) and density ($\boldsymbol{\rho}$) for all specimens and divided for geographical source and for specimen size. show that the ungraded birch with the sampled distribution reaches the characteristic values for strength class C35. The grade determining factor that limits the strength grade is the mean modulus of elasticity of the material. The mean value of the modulus of elasticity is 13.6 GPa, which makes it possible to grade the material into C35 but not in a higher grade. The characteristic bending strength is 38.6 MPa which is also clearly in the C35 class. The mean density of 620 kg/m^3 and the characteristic density value of 551 kg/m^3 implies that the birch sample used in this study has a density much higher than required for grade C35.

Table 6. *Values for the characteristic bending strength ($\boldsymbol{f_m}$), mean modulus of elasticity ($\boldsymbol{E_{m,l}}$) and characteristic density ($\boldsymbol{\rho}$) for some C-classes according to EN 338* [18].

Grade	$\boldsymbol{f_m}$ [MPa]	$\boldsymbol{E_{m,l}}$ [GPa]	$\boldsymbol{\rho}$[kg/m^3]
C14	14	7.0	290
C24	24	11.0	350
C30	30	12.0	380
C35	35	13.0	390
C40	40	14.0	400
C45	45	15.0	410

4.2 Strength grading of birch

Two methods for strength grading of sawn timber from birch grown in Sweden were performed in this study:

- Visual grading,
- Machine strength grading.

4.2.1 Visual grading

For visual grading the regulations in INSTA 142 [8] were used. The grading of the material was based on comparing the characteristic bending strength, mean modulus of elasticity and the characteristic density for each T group with the values for the C classes, c.f. Table 6. This gave a result as in **Fel! Hittar inte referenskälla.**, for the different T-classes. No verification has been done for the subsamples, neither has the k_n factor been used.

Table 7. *Yield percentage and C-class for each visually graded T-class.*

Grade	Class	Percent yield
Reject	R	4%
T0	C24	8%
T1	C30	12%
T2	C35	31%
T3	C40	35%

As the material has these natural properties the possibility to use simpler combinations were investigated. The first version was to combine T0 and T1 to one class and T2 and

T3 to one class. This yielded in 66% of the total sample could be assigned into strength class C40, see Table 8.

Table 8. Yield percentage and C-class for each combination of visually graded T-class.

Grade	Class	Percent yield
Reject	R	4%
T0 + T1	C30	30%
T2 + T3	C40	66%

The simplest combination is to grade all sawn timber in only T0 and better and reject. That yielded that all material that was not rejected could be assigned to C35, see Table 9. The limiting factor is in most cases the mean modulus of elasticity.

Table 9. Yield percentage and C-class using only the combination T0 and better.

Grade	Class	Percent yield
Reject	R	4%
T0 and better	C35	96%

When these thresholds are used for softwood the visually graded material in class T0 are assigned to grade C14 and material in class T2 are assigned to class C24 according to EN 1912 [19].

4.2.1 Machine strength grading

The most common method of machine grading softwood in Sweden is by using the dynamic modulus of elasticity as an indicating property. In the following figures the scatterplots for E_{dyn} versus f_m and E_{dyn} versus $E_{m,l}$ are shown.

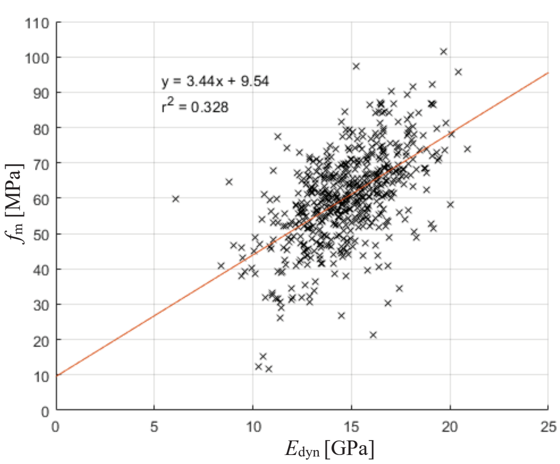

Figure 11. *Bending strength (f_m) versus dynamic modulus of elasticity (E_{dyn}).*

The relationship r^2 between the mechanical parameters are not as good for birch, as for softwood, see Table 10, [17], [18].

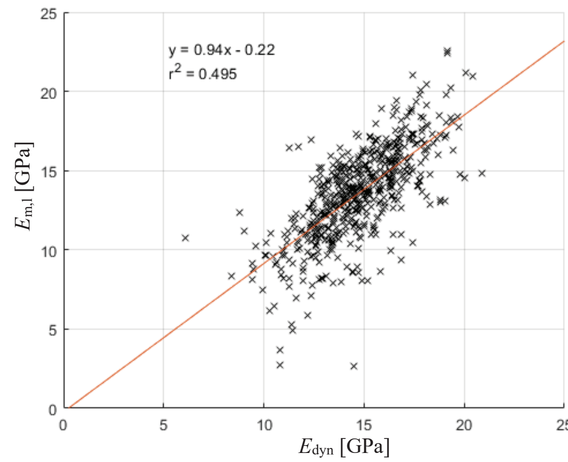

Figure 12. *Local modulus of elasticity ($E_{m,l}$) from the static tests versus dynamic modulus of elasticity (E_{dyn}).*

Table 10. *Coefficient of determination, r^2, between E_{dyn} and f_m and between E_{dyn} and $E_{m,g}$ in this study and two studies for spruce, and E_{dyn} and $E_{m,l}$ for birch.*

Species	E_{dyn} v. f_m	E_{dyn} v. $E_{m,g}$	E_{dyn} v. $E_{m,l}$
Birch	0.33	0.73	0.50
Spruce [17]	0.54	0.83	-
Spruce [16]	0.53	0.84	-

For simulating machine strength grading the measured dynamic modulus of elasticity was used as indicative property (IP). Using threshold values for the dynamic modulus of elasticity it was possible to assign 55% of the samples to class C45 and 35% of the samples to assign 35% to class C30. The values for characteristic bending strength and characteristic density were checked so that they fulfilled the requirements for the assigned strength class, c.f. Table 6. The threshold values presented in Table 11 were determined so that the pieces assigned to the grade fulfil the requirement of characteristic strength, characteristic density and mean MOE. No subsample control has been done, neither has the k_n factor been used.

Table 11. *Threshold values for IP (E_{dyn}), strength class and percent yield for each class.*

Threshold IP	Class	Percent yield
Reject	R	10%
> 12.0 GPa	C30	35%
> 14.5 GPa	C45	55%

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5 CONCLUSIONS

This study shows that the unsorted birch material has a higher mean bending strength, MOE and density than the softwood species used in the Swedish industry today. Studies show that mixed stands of Spruce and Birch give a higher volume growth than spruce monocultures, that is the most common silvicultural choice today.

The findings of this study show that it would be possible to strength grade birch from Sweden by using the existing set of rules from INSTA 142. This study also shows that by the means of using frequency and density measurements for indicating properties, machine strength grading would be possible. Both methods would possibly give good yields in high strength classes, for material of the same distribution as the sampled material. A combination of using both machine grading and visual grading could in some strength class combinations be favourable.

The possibility to strength grade sawn timber of birch is important for the possibility of utilizing also other hard woods grown in Sweden. This is a potential in the Swedish forest that at the moment is not possible to utilise as structural timber. This will increase both the utilisation of existing material in the Swedish forests in products with a long lifetime. This will also improve the possibility for increased biodiversity in the forest by increasing the value of the hardwoods and therefore give the forest owners incentive for also growing hardwood species.

The 600 pieces from this test will together with 120 pieces from Norway be a good foundation for publishing a new grading regulation for birch wood grown in Sweden and Norway.

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