LABORATÓRIO NACIONAL
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PROPOSAL FOR A VISUAL STRENGTH GRADING STANDARD FOR SUGI

Characterization of Azorean sugi timber

REPORT 124/**2015 – DE/NCE**
English translation

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AZORINA – Sociedade de Gestão Ambiental e Conservação da Natureza, S.A.

Lisbon • April 2015

R&D STRUCTURES

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Characterization of Azorean sugi timber

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PROPOSAL FOR A VISUAL STRENGTH GRADING STANDARD FOR SUGI

Characterisation of azorian sugi timber

Abstract

A proposal for a visual strength grading standard for *Cryptomeria japonica* (Thunb. ex L.f.) D. Don timber is presented. The grading is based on the relation between different timber features (analysed in LNEC 66/2015 report) and the physical and mechanical characteristics showed by this timber. The proposal is established following the reference European standards (EN 338, EN 384; EN 408 and EN 14801-1).

This document was produced within a project settled with AZORINA, Sociedade de Gestão Ambiental e Conservação da Natureza, S.A (Ajuste Direto nº 36/AZORINA/2013).

Keywords: Azores / Sugi / Mechanical characteristics / Grading

PROPOSTA DE NORMA DE CLASSIFICAÇÃO VISUAL DE MADEIRA DE CRIPTOMÉRIA PARA FINS ESTRUTURAIS

Caracterização da madeira de criptoméria açoriana

Resumo

O presente relatório apresenta uma proposta de norma de classificação visual de madeira de *Cryptomeria japonica* (Thunb. ex L.f.) D. Don para fins estruturais baseada na relação das suas singularidades (analisadas no relatório LNEC 66/2015) com as suas propriedades físicas e mecânicas. A proposta é feita obedecendo ao disposto nas normas europeias de referência (EN 338, EN 384, EN 408 e EN 14801-1).

Este documento foi elaborado no âmbito do projeto estabelecido com a AZORINA, Sociedade de Gestão Ambiental e Conservação da Natureza, SA (Ajuste Direto nº 36/AZORINA/2013).

Palavras-chave: Açores / Criptoméria / Características mecânicas / Classificação

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1 | Introduction

1.1 Objectives

The herein report presents the results of tests for the mechanical and physical characterization of sugi timber from the Autonomous Region of the Azores and proposes a Portuguese standard for a visual strength grading standard of sugi. If this standard is approved by the Portuguese Quality Institute it will be used to obtain the CE marking on the basis of the harmonized standard EN 14081-1 :2005+A1:2011 (CEN; 2011).

The work is part of the study "Mechanical characterization of sugi timber in accordance with the applied European standardization (EN 338 (CEN; 2009), EN 408 (CEN; 2012), EN 14801-1 (CEN; 2011) and durability characteristics after being subjected to different treatments of protection against subterranean termites (*Reticulitermes* spp.) and drywood termites (*Cryptermes brevis*)". This study was carried out under the contract signed by direct award No 36 / Azorina / 2013 by Azorina, Sociedade de Gestão Ambiental e Conservação da Natureza, S.A.

This report concludes LNEC's report 66/2015-DE / NCE (Machado; *et al.*; 2015) and finalizes the task regarding the structural qualification of this type of wood.

1.2 European standarization in support of visual strength grading

Fitness of a timber for structural use, namely in accordance with the European standard regarding the design of timber structures (Eurocode 5) (CEN; 2014), assumes the existence of conditions for this timber to be subject to a CE marking process according to the harmonized standard EN 14801-1 (CEN; 2011). The CE marking ensures conformity of the construction product with the performance declared by the manufacturer and its free movement throughout the European Economic Area and Turkey. The general principles of marking are established in the Regulation Construction Products (Regulamento (UE) nº 305/2011) and its effective implementation in the internal judicial order is made by the Decree No 130/2013 (Decreto-Lei nº 130/2013).

The route for the CE marking by visual grading, route analysed in the present study, assumes the development of a strength grading standard that establishes visual quality grades by limitation of the presence of features or by the extent of their presence. Once these grades are defined resistance values should be allocated to each of them. Physical and mechanical characterization of structural timber with rectangular cross section for structural purposes should meet the criteria of the European standard EN 384 (CEN; 2010). This standard establishes which properties to determine experimentally, designated as "reference properties", for the characterization of timber for structural purposes.

Table 1.1 – Reference and other material properties

Reference properties (experimentally determined)		*Other material properties* (determined from the reference properties)	
Bending strength	f_m	Tension parallel to grain	$f_{t,0}$
Bending modulus of elasticity	E_0	Tension perpendicular to grain	$f_{t,90}$
Density	ρ	Compression parallel to grain	$f_{c,0}$
		Shear	f_v
		Modulus of elasticity perpendicular to grain	E_{90}

Testing for determination of reference properties should be conducted according to the procedures described in European standard EN 408 (CEN; 2012). The consequent data treatment should be done according to EN 384 (CEN; 2010). Once the characteristic values of the reference properties are calculated, the mechanical characteristics of visual grades can be associated to a strength class according to EN 338 (CEN; 2009) or declared based on the experimental values (section 5.2.2 of EN 14801-1 + A1 (CEN; 2011).

Figure 1 presents a flowchart of the possible routes for obtaining the CE marking of sawn timber for structural purposes.

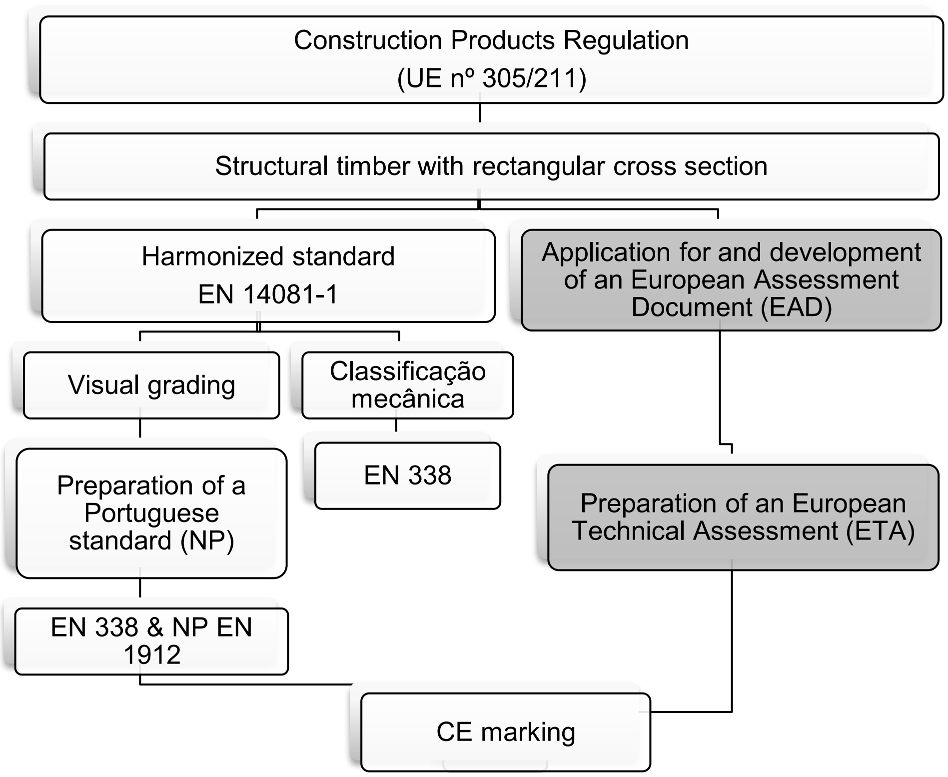

Figure 1.1 – Flowchart showing routes to obtain the CE marking

2 | Sampling

Sampling was conducted by Azorina according to the principles set by LNEC in the Technical Report 1/2014 - DE / NCE (MACHADO; *et al.*; 2014). Sampling considered two origins each one corresponding to an island. From each origin samples were taken from at least two populations to ensure the representativeness of the materials tested. Table 2.1 presents information on the material sent for testing. More detailed information is presented in Annex I of the Report 66/2015 – DE/NCE (MACHADO; *et al.*; 2015).

Table 2.1 – Data on the test pieces sent for testing

	Origin				
	S. Miguel		Terceira		
	Stand		Stand		
	P1	**P2**	**P1**	**P2**	**P3**
Age of stands (years)	59	59	> 40	> 40	> 40
Average DBH (cm)	27.36	27.36	22.48	22.48	38.65
Number of small test pieces	40	40	40	-	-
Number of large test pieces	40	40	-	33	7

DBH – Diameter at breast height
Small test pieces – 2000 x 100 x 40 mm^3
Large test pieces – 3000 x 150 x 50 mm^3

2.1 Conditioning and preparation of specimens for testing

Moisture content of the test pieces was measured at delivered in LNEC using a moisture meter based on electrical resistance (GANN Hydromette HT 85 T-percussion electrode with a 2% precision). All test pieces showing a moisture content above 18% were put aside and kept in a conditioning environment (20 °C ± 2 °C temperature and 65% ± 5% relative humidity) until they reached a moisture content below 18%.

The test pieces were then visually analysed for the characterization according to their features (MACHADO; *et al.*; 2015) and then tested in static bending.

2.2 Testing program

In the Annex the values of density, bending strength and global modulus of elasticity obtained for each test piece are presented (test values adjusted according to the EN 384 (CEN; 2010) requirements).

2.2.1 Static bending test

Prior to testing the samples were weighed and measured (width, thickness and length). The static bending test was conducted according to EN 408 (CEN; 2012). Figure 2.1 shows the test setup. The tests were performed at Wood Products and Systems Unit (UAPM) using a SHIMADZU universal mechanical testing machine with a 250 kN load cell (accuracy class 1).

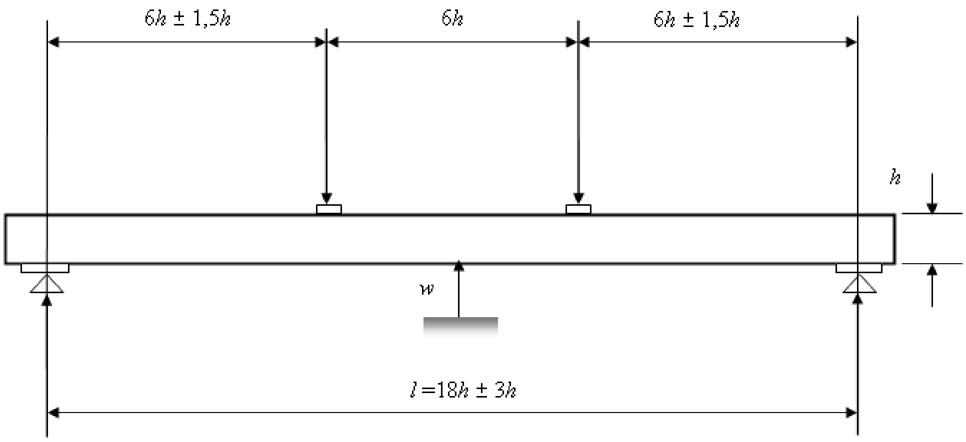

Figure 2.1 – Test setup (*h* – depth; *w* – deformation measured at mid-span)

The test was conducted with control of the movement of the loading head. Thus, a speed of 0.12mm/s and 0.17mm/s was set for the small and large test pieces from São Miguel, respectively. A speed of 0.12mm/s and 0.15mm/s was set for small and large test pieces from Terceira, respectively. The imposed speed is below the maximum speed defined in EN 408 (CEN; 2012) of 0.003 h mm/s. During the test it was recorded the displacement at mid-span (two LVDTs type DCT 1000A, range ± 25 mm) and the load.

The determination of bending strength and global modulus of elasticity obeyed to what is described in sections 19 and 10, respectively, of the standard EN 408 (CEN; 2012). The bending strength was determined using equation 1.

$$f_m = \frac{3 \times F \times a}{b \times h^2} \tag{1}$$

Where: f_m – Bending strength (N/mm^2)
F – Maximum load (N)
a – Distance between a loading position and the nearest support (mm)
b – Test piece thickness (mm)
h – Test piece depth (mm)

According to EN 384 (CEN; 2010) if the moisture content of the test pieces is between 8% and 18% when mechanical testing was performed, it is not necessary to adjust the bending strength for a reference moisture content of 12%.

The global modulus of elasticity was determined in accordance with equation 2.

$$E_{m,g} = \frac{3 \times a \times l^2 - 4 \times a^3}{2 \times b \times h^3 \times \left(2 \times \frac{d_2 - d_1}{F_2 - F_1} \right)} \quad (2)$$

Where: $E_{m,g}$ – Global modulus of elasticity in bending (N/mm²)

F_2-F_1 – Increment of load in Newtons on the regression line with a correlation coefficient of 0.99 or better (N)

d_2-d_1 – Increment of deformation corresponding to F_2-F_1 (mm)

a – Distance between a loading position and the nearest support (mm)

b – Test piece thickness (mm)

h – Test piece depth (mm)

According to EN 384 (CEN; 2010) it becomes necessary to adjust the value of the global modulus of elasticity in bending to a reference moisture content of 12%, equation 3.

$$E_{m,g,12} = E_{m,g} \times \left(1 + 0{,}01 \times \left(H - 12\right)\right) \quad (3)$$

Where: $E_{m,g,12}$ – Global modulus of elasticity in bending at 12%moisture content (N/mm²)

2.2.2 Determination of density

Immediately after the bending test a test piece of about 50 mm in length and comprising the entire cross section was cut. The test piece was cut as close as possible to the fracture and being careful so that it was free of any type of defect (ex. knots), thus obeying to the criteria included in the section 7 of the EN 408 (CEN; 2012) on the selection of samples for the determination of density.

The test pieces were weighed on a scale with 0.01 g resolution and its dimensions measured using a caliper with 0.01 mm resolution. Then density was calculated with equation 4. In accordance with EN 384 (CEN; 2010) it is necessary to adjust density of the test pieces to a reference moisture content of 12% with equation 5.

$$\rho_H = \frac{m_H}{V_H} \quad (4)$$

Where: ρ_H – Density at a moisture content *H* (kg/m³)

m_H – Mass of the test piece at a moisture content *H* (kg)

V_H – Volume of the test piece at a moisture content *H* (m³)

$$\rho_{12} = \rho_H \times \left(1 + 0{,}005 \times \left(12 - H\right)\right) \quad (5)$$

Where: ρ_{12} – Density at 12% moisture content (kg/m³)

2.2.3 Determination of moisture content

Wood is a hygroscopic material varying its physical and mechanical properties with its moisture content. Thus, as mentioned before, according to EN 384 (CEN; 2010) it becomes necessary to correct the density and global modulus of elasticity in bending values to a reference moisture content reference of 12%.

Thus, after being used for the determination of density the test pieces were placed in an oven at a temperature of 103°C±2°C. The samples were kept under this condition until the difference in mass between two successive weighings separated by an interval of 2 hours was less than 0.1 %; procedure recommended by NP EN 13183-1:2013. The moisture content of the test pieces was calculated according to equation 6.

$$w = \frac{m_H - m_0}{m_0} \times 100 \qquad (6)$$

Where: w – Moisture content (%)

m_H – Mass of the test piece before drying (g)

m_0 – Mass of the oven dry test piece (g)

Table 2.2 – Moisture content of the test pieces (determined immediately after bending test)

		S. Miguel	Terceira
Moisture content (%)	Average	14.3	14.0
	Standard deviation	0.67	0.60
	Maximum value	17.6	15.7
	Minimum value	13.1	13.1

3 | Analysis of the results

The analysis of the results with the purpose of drawing up a proposal for sugi visual strength grading standard was based on the following grading standards:

- the Portuguese standard for the visual strength grading of maritime pine timber NP 4305:1995 since it is the single standard applicable to home-grown timber;
- the French standard NF B52-001-1:2011+A1:2013, namely its amendment of 2013 which includes the sugi timber from the Island of Reunion.

The fitting of probability density functions (pdf) followed the recommendations made by JCSS Probabilistic Model Code (JCSS 2006):

- Bending strength and modulus of elasticity – *pdf* Lognormal.
- Density – *pdf* Normal.

3.1 Global analysis

In this section the distribution of reference properties (density, bending strength and bending modulus of elasticity) is analysed for the two islands where the sugi timber was collected. Regarding density, the Normal probability distribution fitted to the test data did not showed a significant difference between islands, figure 3.1.

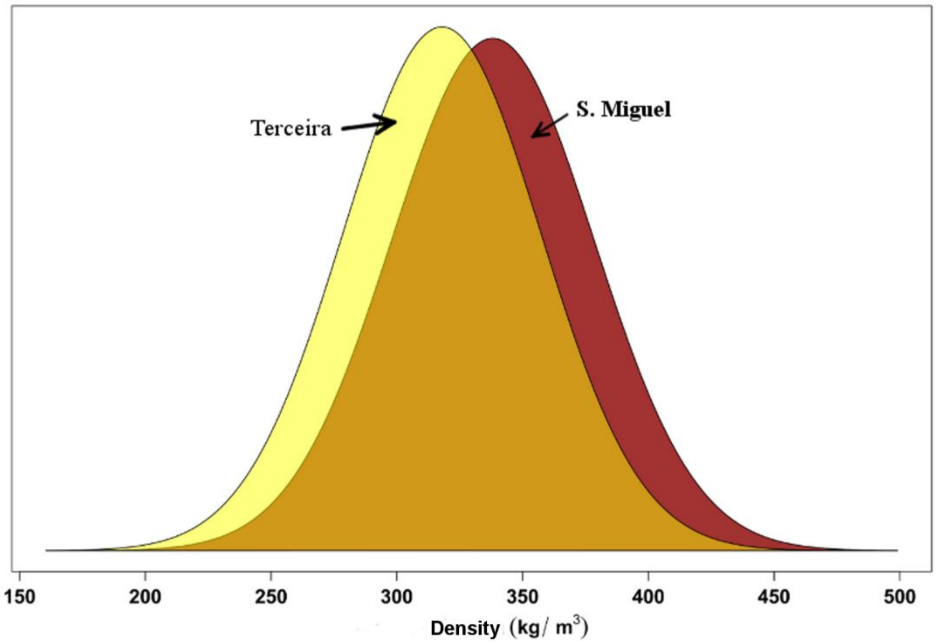

Figure 3.1 – Density distribution for the two origins

Analysing the distribution by stands, figure 3.2, a significant difference is observed (lower density) on the test pieces from stand P3 on Terceira Island.

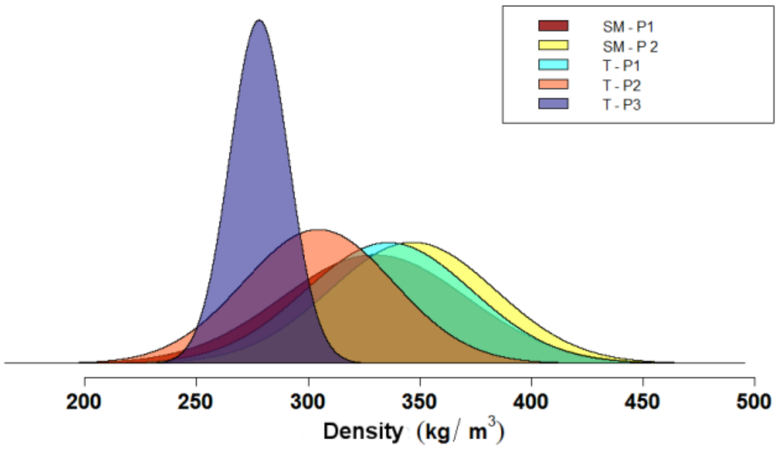

Figure 3.2 – Density distribution for the different stands (P) from both origins (SM – S. Miguel; T – Terceira)

This difference is related to the larger diameter at breast height of trees from this stand (DBH = 38.65 cm) in relation to the same characteristic of the remaining stands (22.48 cm and 27.36 cm). In general for softwoods[1] a higher DBH corresponds to a faster growth rate with the corresponding decrease of density.

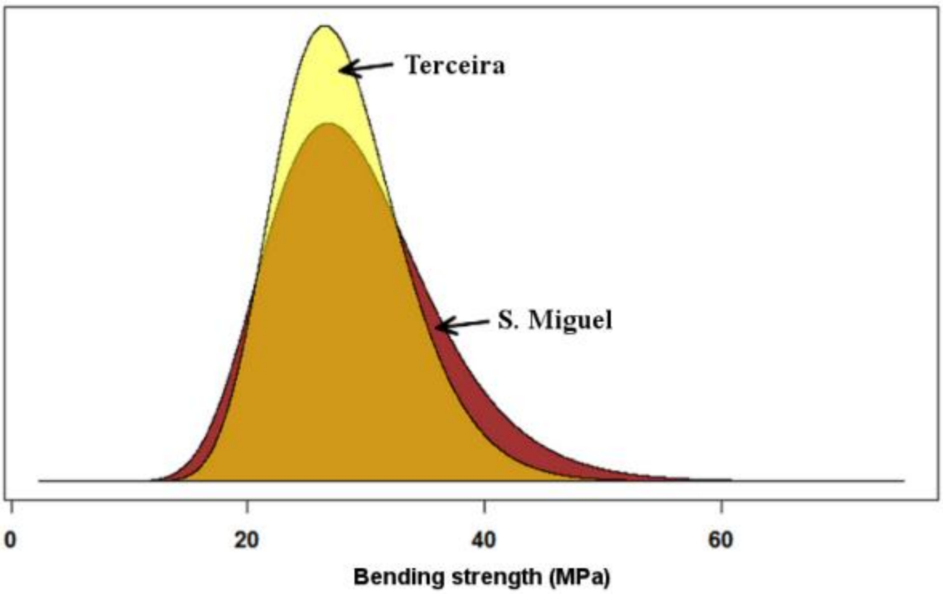

Figure 3.3 – Bending strength distribution for the two origins

[1] Softwoods – Group of species belonging to the class of Conifers

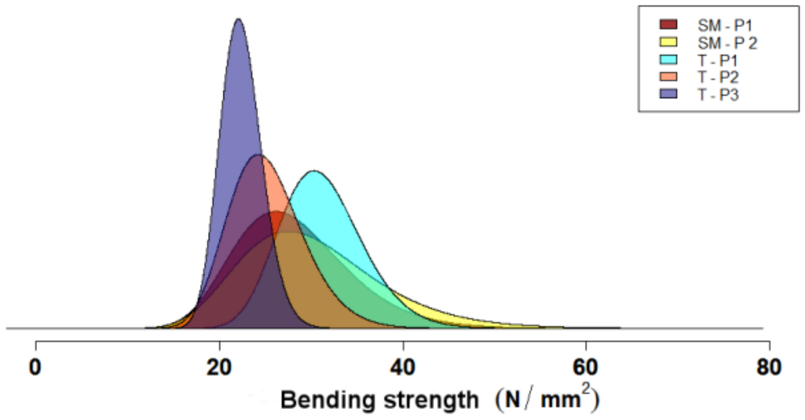

Figura 3.4 – Bending strength distribution for the different stands (P) from both origins (SM – S. Miguel; T – Terceira)

The observations made for density can also be applied to bending strength, figures 3.3 and 3.4. In respect to the modulus of elasticity in bending although a non-significant difference between origins (islands), is in general confirmed, figure 3.5, Terceira Island stands showed a noticeable difference amongst themselves, figure 3.6.

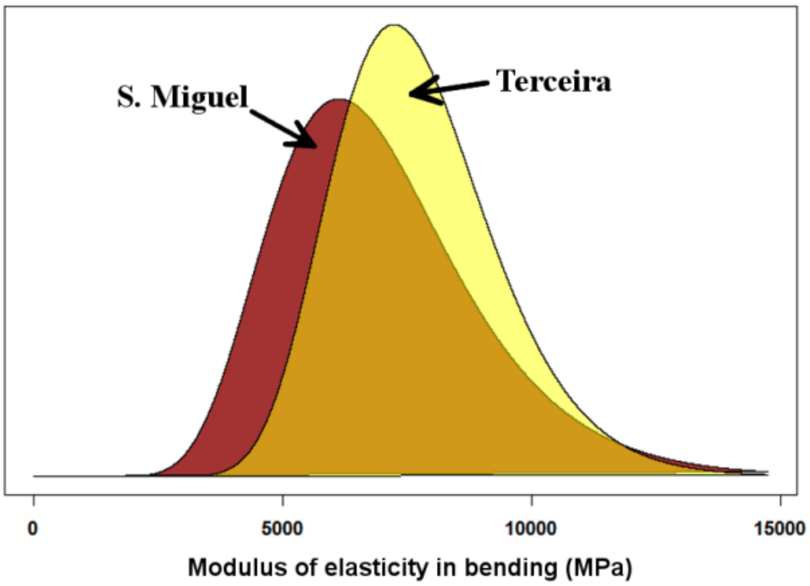

Figure 3.5 – Modulus of elasticity in bending for the two origins

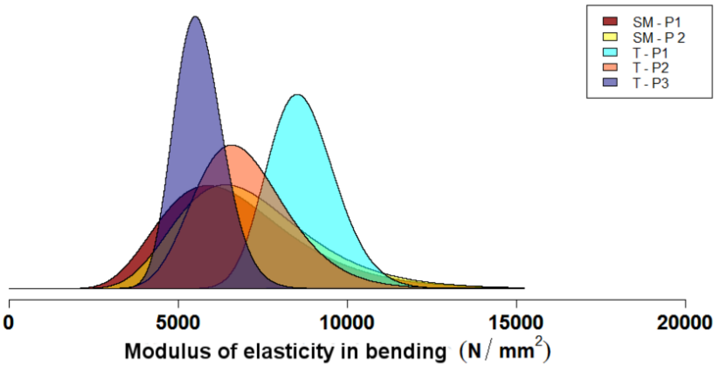

Figure 3.6 –Modulus of elasticity in bending distribution for the different stands (P) from both origins (SM – S. Miguel; T – Terceira

As mentioned above, P3 stand behaviour is explained by the lower density showed by the test pieces from this stand. Regarding stand P1, the data available cannot explain the higher values of modulus of elasticity. Therefore, neither density differences, figure 3.2, nor timber quality, figure 3.7, provided information that could sustain an explanation.

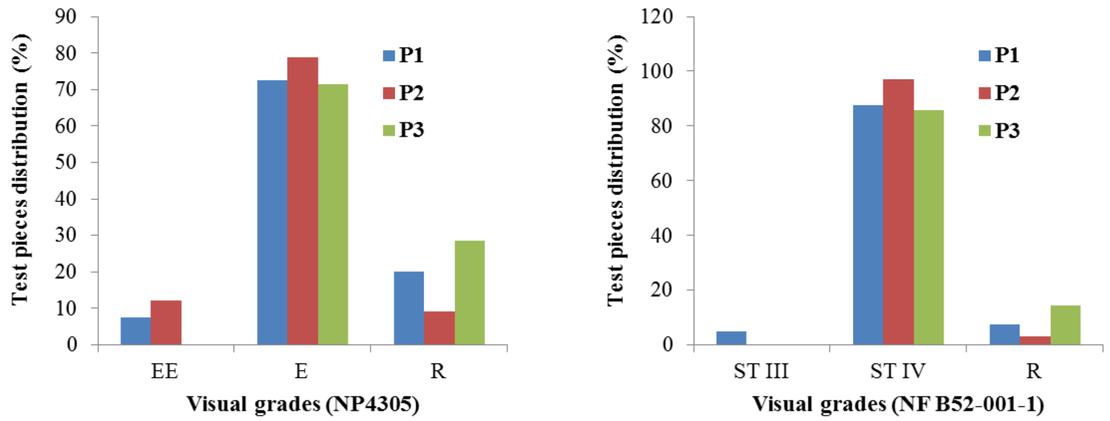

Figure 3.7 – Relative distribution of visual grades for Island Terceira according to the different stands

Notwithstanding the strength classes concept is based on a group approach, i.e. accepts that a percentage of the test pieces be below the requirements imposed for the reference properties (based on the 5 percentile for bending strength and density and the mean value modulus of elasticity in bending), a division of test pieces by strength classes was performed in order to analyse, in a simple way, the mechanical quality of the whole of the sampled material.

Thus the distribution of the test pieces by the various strength classes shows that a high percentage (40%) does not meet the requirements of the class C14 (lowest class), Figure 3.8. Note that the ST-III and ST-IV classes of the French standard (NF B 52-001-1:2011+A1:2013) correspond respectively to the C18 and C14 strength classes for sugi from Reunion Island.

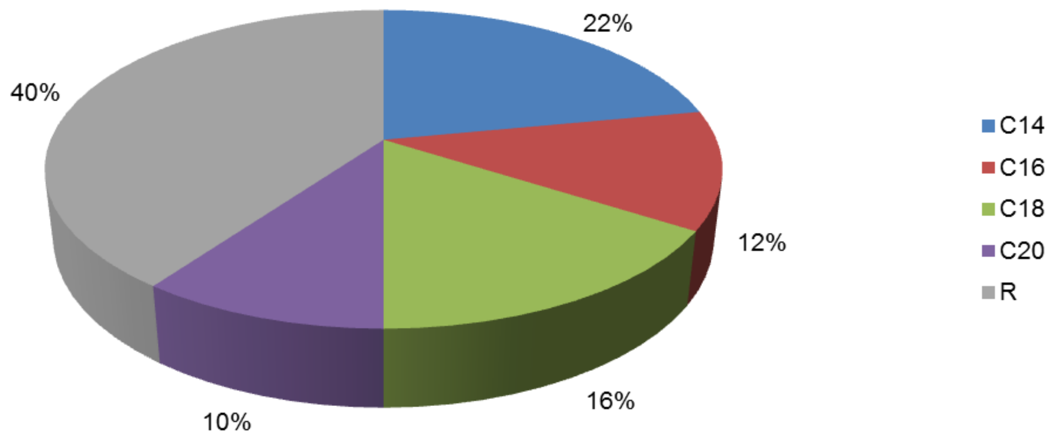

Figure 3.8 – Distribution of the test pieces by the different strength classes

The causes for mechanical downgrade of the tested timber relatively to C14 class are due mainly to a low value of the modulus of elasticity (68%) and density (31%), Figure 3.9. One should highlight that only in 1% of cases the bending strength is a critical factor.

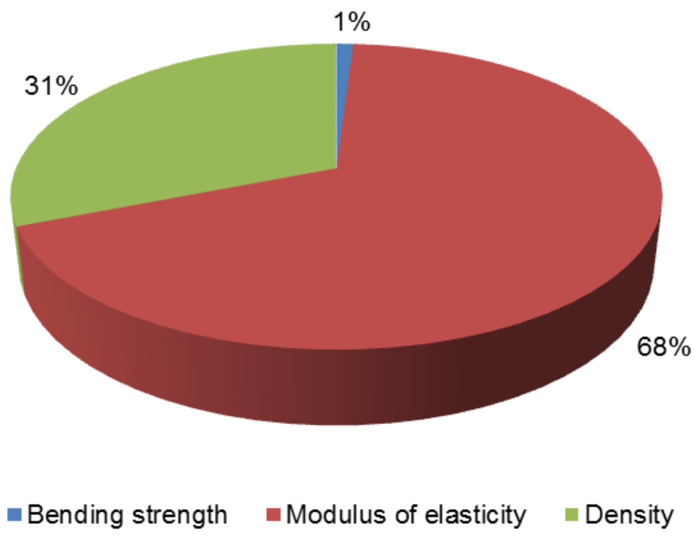

Figure 3.9 – Reasons for not inclusion of the test pieces in strength class C14

The values of modulus of elasticity determined in the present study are in accordance with those determined for small clear specimens of timber [(Carvalho 2009), Table 3.1, and with the mean value of 3700 N/mm^2 determined in LNEC previous studies (LNEC, 2014). The weak stiffness of the test pieces to bending was already noticeable during the tests, with these presenting a high deformability (strong plastic component) before the occurrence of failure, figure 3.10. This behaviour cannot be considered typical of timber when subjected to bending.

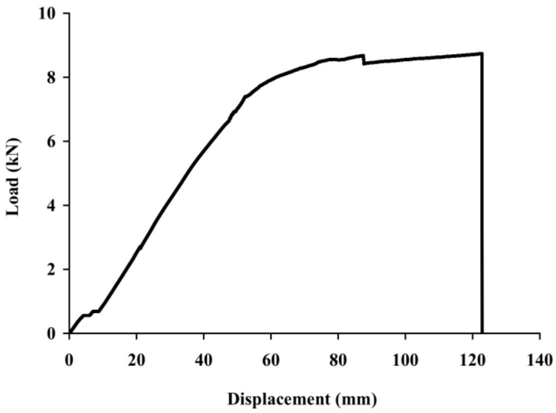

Figure 3.10 – Test piece from S. Miguel subject to static bending test

Table 3.1 – Modulus of elasticity for clear of defects sugi test pieces (Carvalho 2009)

General origin – S. Miguel	
Origin/age of stand/rate of growth	**Modulus of elasticity in bending (N/mm²)**
Furnas Age 43 years Rate of growth 4,1 mm	5922
Furnas Age 41 years Rate of growth 2,5 mm	8186
Povoação Age 40 years Rate of growth 6,3 mm	4310
Povoação Age 47 years Rate of growth 6,0 mm	6103
Povoação Age 46 anos Rate of growth 5,2 mm	6410
Povoação Age 28 years Rate of growth 7,0 mm	5374
Povoação Age 33 years Rate of growth 10,1mm	2999
Povoação Age 38 years Rate of growth 6,5 mm	3821

3.2 Influence of features on the reference properties

The visual strength grading standards are based on variables (in this case wood features) having a weak (correlation coefficient between 0.2 and 0.4) to average correlation (correlation coefficient between 0.4 and 0.6) with reference properties. Also they include variables that though not having direct correlation to these properties affect the application on-site of timber members, table 3.2. The correlation classification (high, medium, low and very low) is based on criteria established in (JCSS 2006).

Table 3.2 – Features influence on reference properties

Features used for visual strength grading of timber	
Showing correlation with reference properties	**Not showing correlation with reference properties**
Knots; Slope of grain; Rate of Growth; Fissures; Pith; Biological deterioration	Wane; Warp; Resin pockets; Inbark

In this section the variables with correlation to reference properties will be analysed in order to give the background for the establishing limits for their presence, and thus define the visual strength grades to be specified in section 4.1 of the present report.

3.2.1 Bending strength

Table 3.3 shows the correlation found between the features and bending strength. The table also includes results obtained from other softwood species for comparison.

Table 3.3 – Correlation between bending strength and sugi timber features. Comparison with values obtained for other softwoods (bibliography)

Features	Coefficient of determination r^2	Rage of coefficient of determination found in bibliography
Knots	*	0.27 – 0.16 (Hanhijärvi; *et al.*; 2005) 0.67 (Machado; 2001)
Rate of growth	0.18 (mean)	0,33 – 0,46 (Cruz; *et al.*; 1991)
Slope of the grain	*	0.18 (Hanhijärvi; *et al.*; 2005) 0.15 (Machado; 2001)

* No correlation

Figures 3.11 to 3.15 allow observing that with exception of rate of growth none of features present a correlation with bending strength.

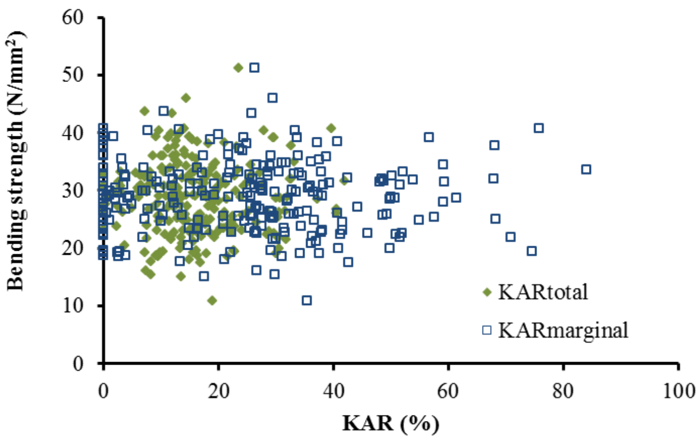

Figure 3.11 – Relation between KAR and bending strength

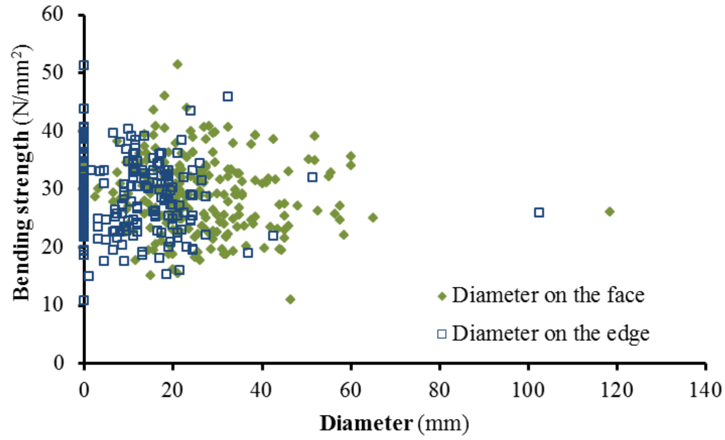

Figure 3.12 – Relation between knot's diameter and bending strength

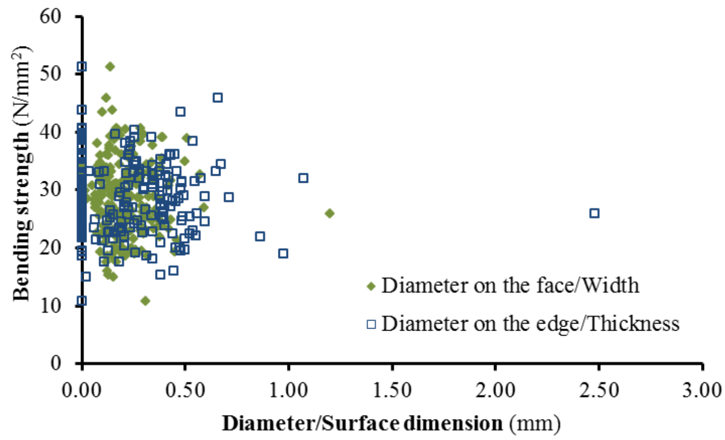

Figure 3.13 – Relation between bending strength and the ratio knot's diameter to the width of the face or to the thickness of the edge

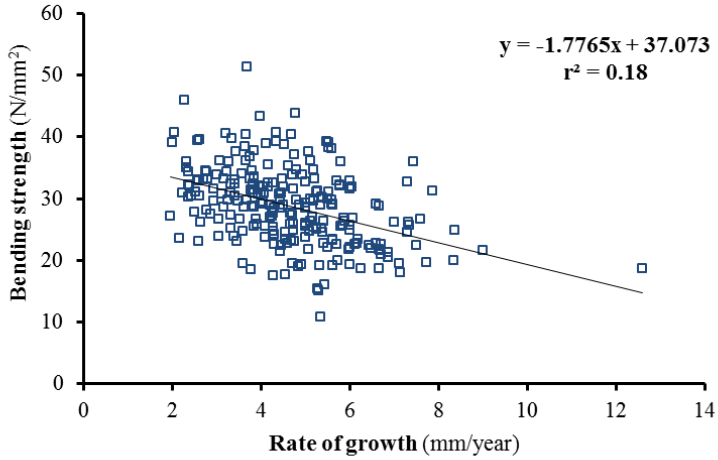

Figure 3.14 – Relation between rate of growth and bending strength

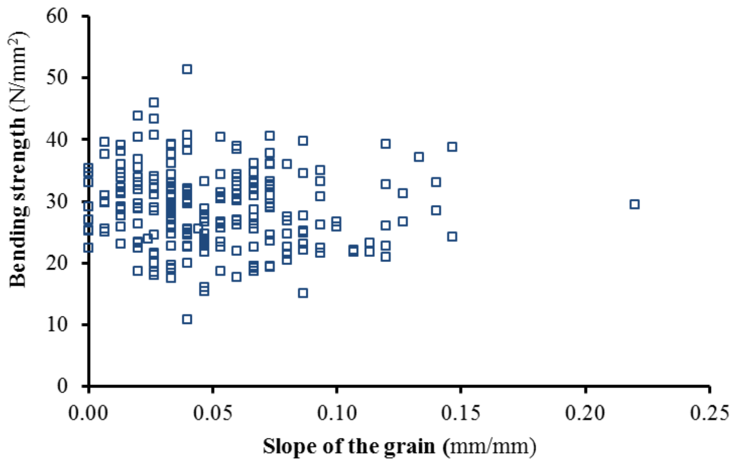

Figure 3.15 – Relation between slope of grain and bending strength

The presence of the pith[2] is not permitted in the upper grade (grade EE) of NP 4305:1995 due to the juvenile wood to which is associated. The structure of tracheids cell wall of juvenile wood causes that this type of wood present lower mechanical resistance than adult wood.

Figure 3.16 allows concluding for the lack of a significant difference between the group of test pieces of sugi with pith and that without pith.

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[2] Zone within the first growth ring that consist chiefly of soft tissue

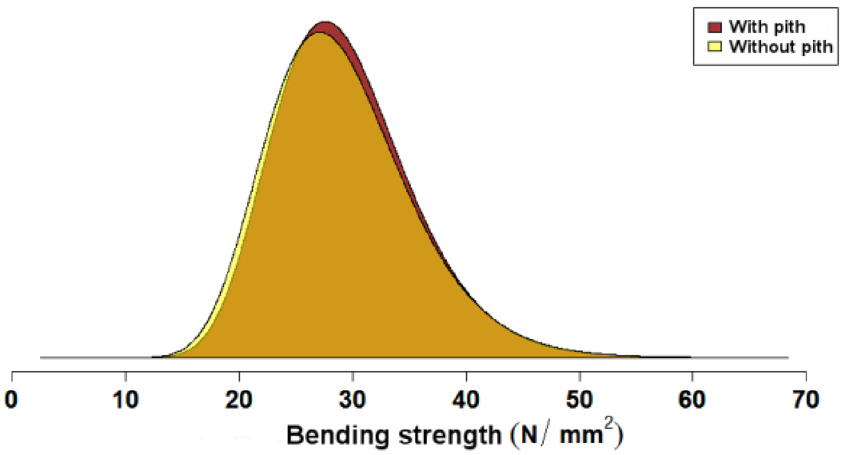

Figure 3.16 – Bending strength distribution for the groups of pieces with that without pith

3.2.2 Modulus of elasticity in bending

Table 3.4 shows the correlation between the features and the modulus of elasticity in bending comparing the results now obtained for sugi with results obtained from other softwoods species.

The results given in Table 3.4 and Figures 3.17 to 3.21 allow concluding that only the rate of growth presents a significant correlation with the modulus of elasticity. Nevertheless, figure 3.21 allows observing that there is a decrease trend of the modulus with the increase of slope of grain.

Table 3.4 – Correlation between modulus of elasticity in bending and sugi timber features. Comparison with values obtained for other softwoods (bibliography)

Features	Coefficient of determination r^2	Rage of coefficient of determination found in bibliography
Knots	*	0.11 – 0.45 (Hanhijärvi; *et al.*; 2005) 0.38 (Machado; 2001)
Rate of growth	0.12 (weak)	0.23 – 0.53 (Hanhijärvi; *et al.*; 2005) 0.45 – 0.49 (Cruz; *et al.*; 1991)
Slope of the grain	*	0.17 (Hanhijärvi; *et al.*; 2005) 0.18 – 0.12 (Machado; 2001)

* No correlation

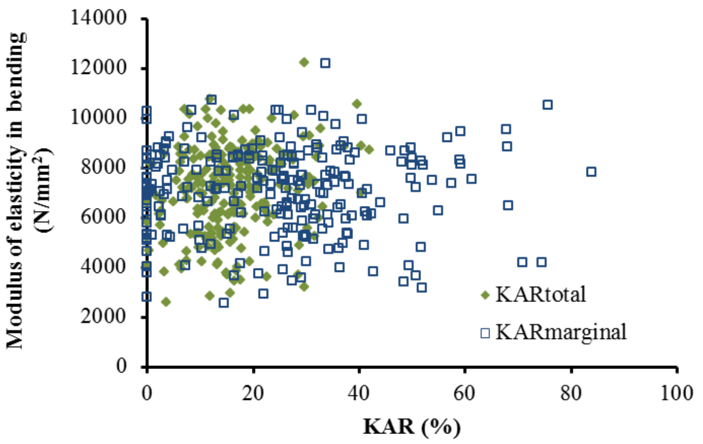

Figure 3.17 – Relation between KAR and modulus of elasticity in bending

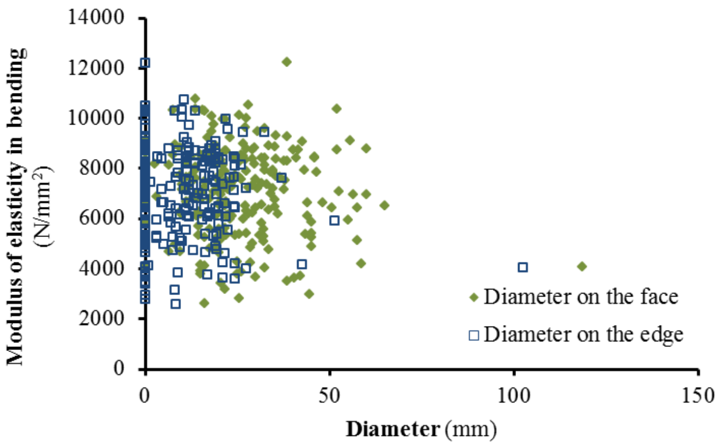

Figure 3.18 – Relation between knot's diameter and modulus of elasticity in bending

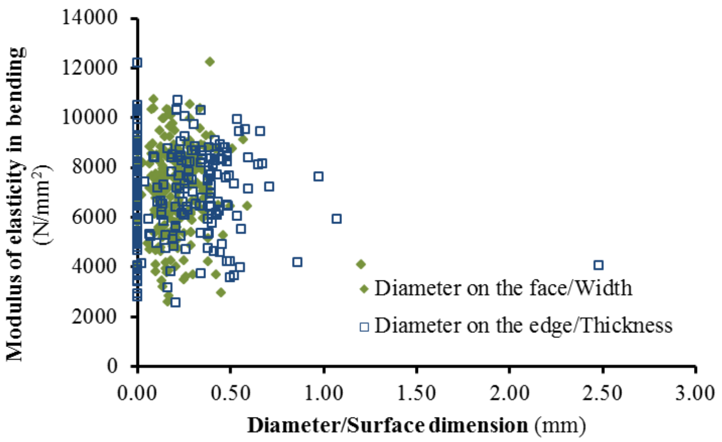

Figure 3.19 – Relation between modulus of elasticity in bending and the ratio knot's diameter to the width of the face or to the thickness of the edge

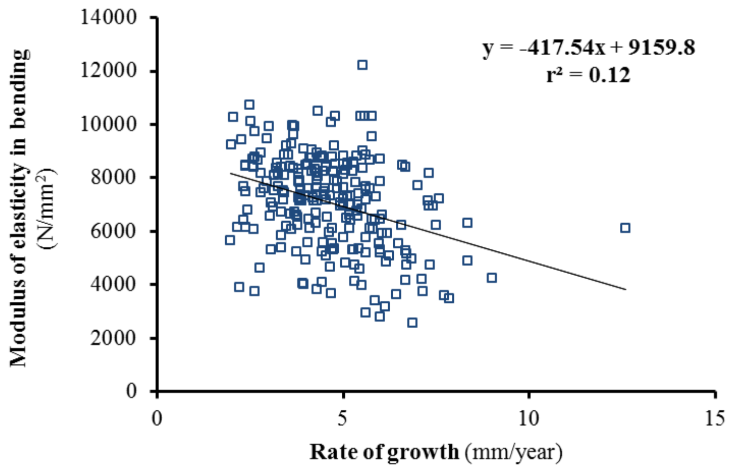

Figure 3.20 – Relation between rate of growth and modulus of elasticity in bending

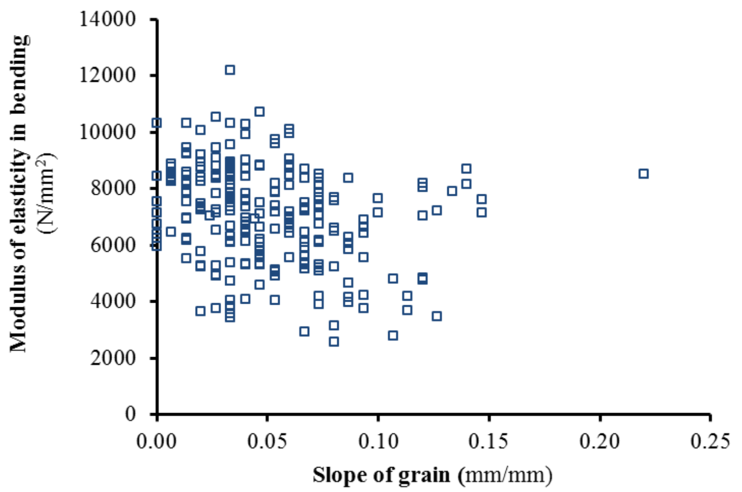

Figure 3.21 – Relation between slope of grain and modulus of elasticity in bending

Figure 3.22 allows concluding for the lack of a significant difference between the group of test pieces of sugi with pith and that without pith.

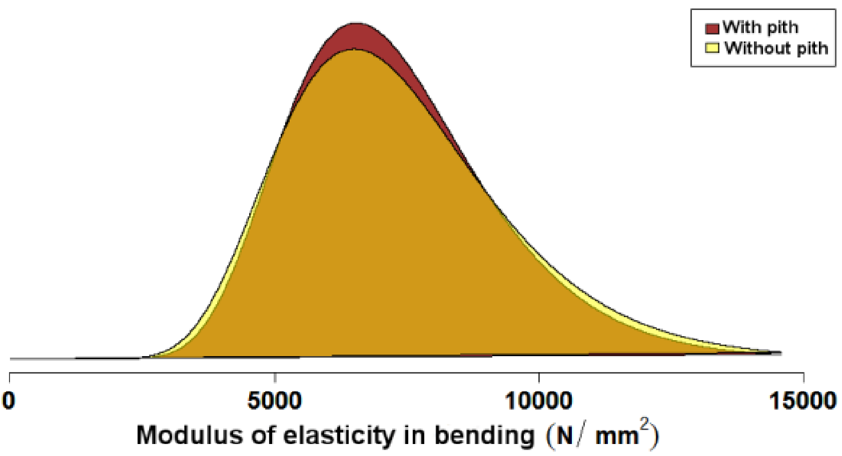

Figure 3.22 – Modulus of elasticity in bending distribution for the groups of pieces with and without pith

3.2.3 Density

The rate of growth is normally used by visual strength standards for softwoods as an estimator of the density. In this study a r^2 = 0.22 (medium correlation) was determined, this value is in the range of values observed in other studies (0.12 (Cruz; *et al.*; 1991), 0.38 – 0.09 (Hanhijärvi; *et al.*; 2005)) Figure 3.23.

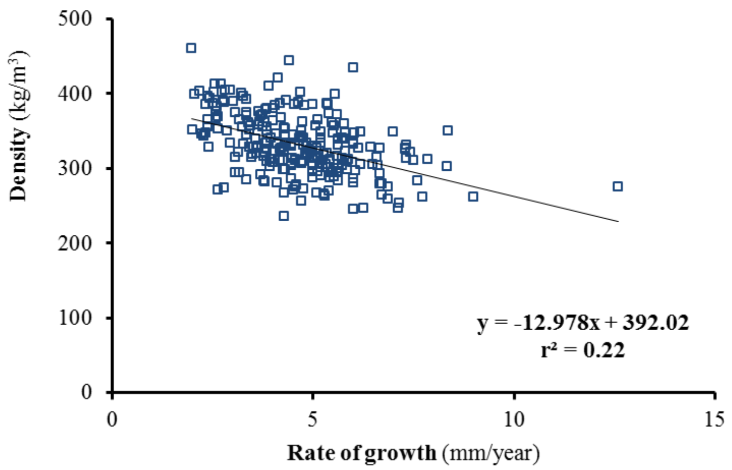

Figure 3.23 – Relation between rate of growth and density

Figure 3.24 allows concluding for the lack of a significant difference between the group of test pieces of sugi with pith and that without pith.

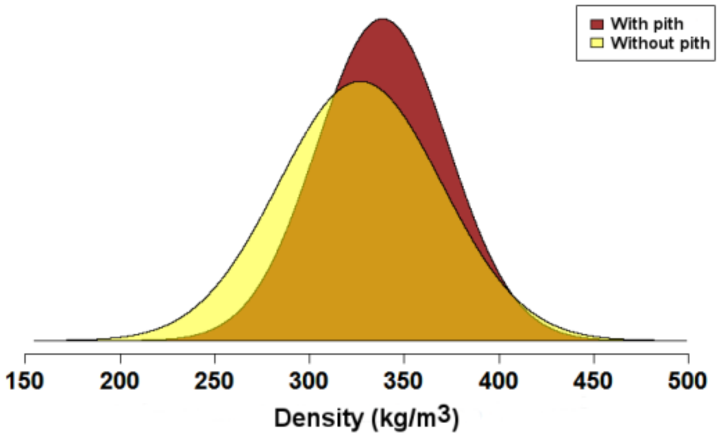

Figure 3.24 – Density distribution for the groups of pieces with and without pith

3.3 Application of NP 4305 and NF B52-001-1+A1 standards

Table 3.5 presents the characteristic values allocated to the different visual grades defined by the reference standards. The results indicate that none of the grades fulfil the requirements defined in European Standard EN 338 (CEN; 2009) for the lowest strength class.

Table 3.5 – Characteristic values for the reference properties of the visual grades indicated in NP 4305:1995 and NF B52-001-1:2011+A1:2013

Mechanical properties		Visual grades			
		NP 4305		NF B52-001-1+A1	
		EE	E	ST-III	ST-IV
Bending strength (N/mm²)	$f_{m,k}$	21	18	23	19
Modulus of elasticity in bending (N/mm²) Parallel to the grain: – mean value – characteristic value	$E_{0,mean}$ $E_{0,05}$	6900 4600	6700 4490	6900 4600	6200 4200
Density (kg/m³) – mean value – characteristic value	ρ_{mean} ρ_k	330 260	320 260	410 400	310 260
Strength class		< C14	< C14	< C14	< C14

The causes for rejection for the different visual grades are presented in figure 3.25.

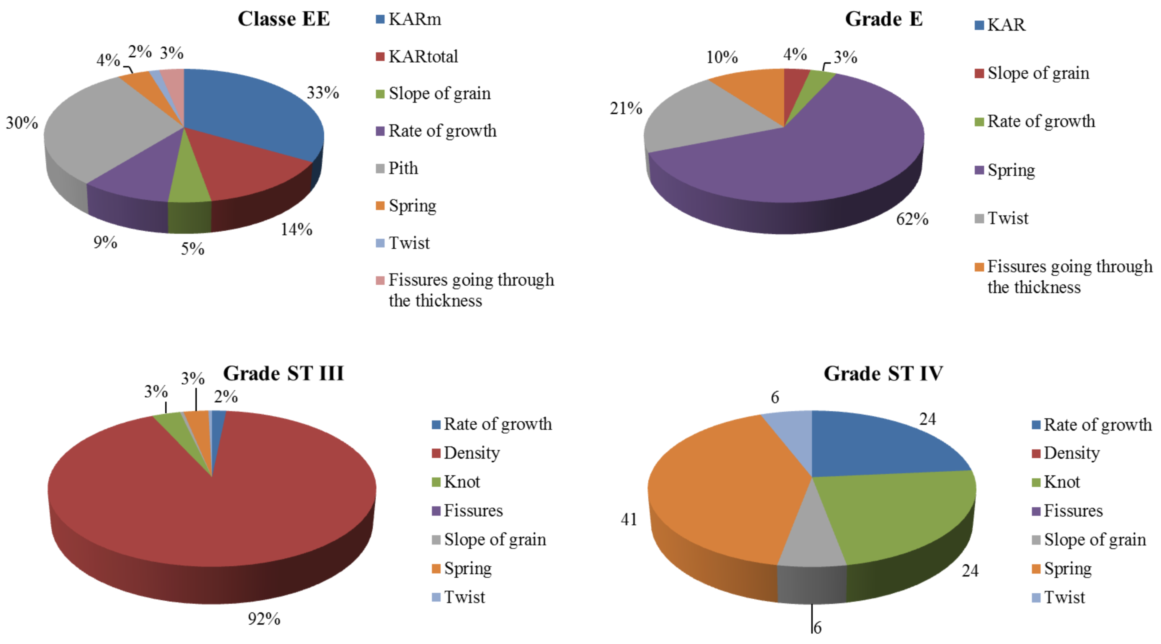

Figure 3.25 – Causes for rejection for the visual grades defined by NP 4305 and NF B52-001-1+A1

4 | Proposal for a visual strength grading standard

4.1 Proposal for a visual strength grading standard for sugi

Considering the results presented in section 3 a proposal is made for the publication of a visual strength grading based on two visual grades. The higher grade (CYS I) is defined by presenting pieces with density values equal or superior to 310 kg/m^3. Considering the material tested the establishment of this criterion presumes that about 68% of the pieces can be classified for structural purposes in the upper grade, figure 4.1.

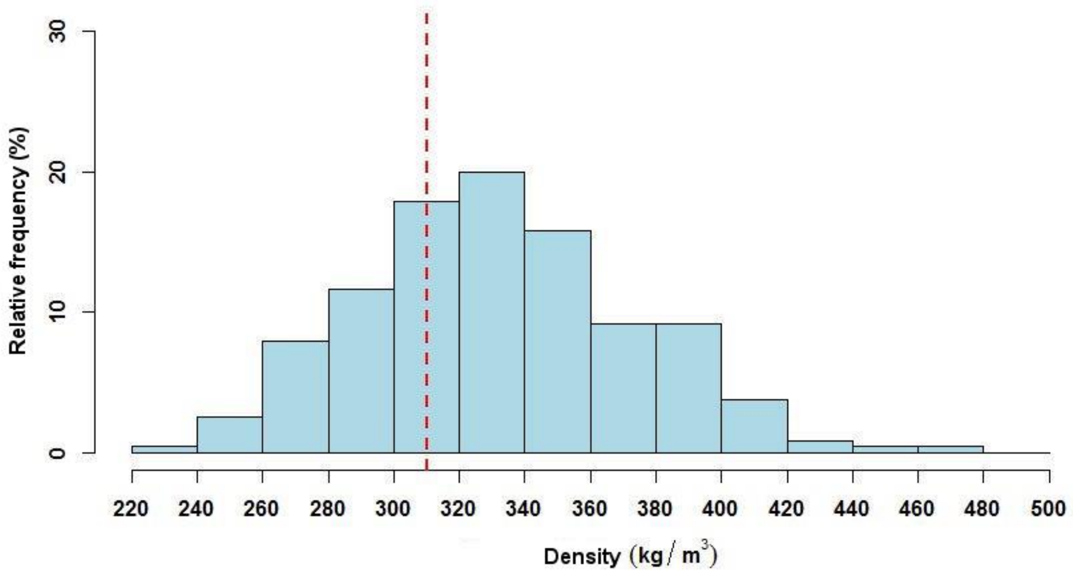

Figure 4.1 – Relative distribution of density (dashed line shows the limit of 310 kg/m^3)

The timber grading according with this limit can only be done by limiting the rate of growth, figure 3.23, or by the direct determination of density (more time consuming). These two procedures are considered for the upper grade (grade ST III) of the French standard NF B 52-001:2011+A1:2013.

If using the rate of growth parameter and applying the regression equation showed in the figure 3.23 this parameter should be equal or inferior to 6mm/year. Analysing figure 4.2 (transposed from figure 3.23) it appears that the choice of a 6mm/year threshold for rate of growth corresponds to a 22.0% probability of occurrence of pieces with density values below 310 kg/m^3. This situation implies an unacceptable error associated with the use of the grading parameter rate of growth. Thus, on the grading of the upper grade (CYS I) one of the criteria requires (as in the French standard) the direct determination of the density to ensure the minimum limit of 310 kg/m^3. This requirement becomes necessary in order to be able to put forward a visual grade adjusted to strength classes defined in European Standard EN 338 (CEN; 2009).

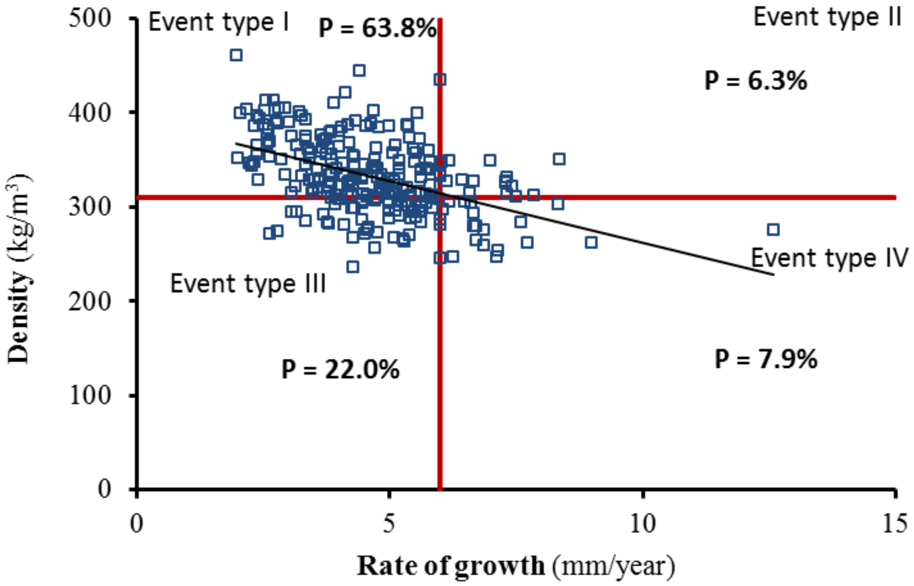

Figure 4.2 – Constrain to rate of growth (≤ 6mm/year) and relation with the criterion expected for density (≥ 310 kg/m^3). Probability (*P*) linked to the use of the rate of growth for each type of event: I – Pieces accepted and obeying to the limit for rate of growth and also for the criterion for density; II – Pieces rejected although obeying to the criterion density; III – Pieces accepted but not obeying to the criterion density; IV – Pieces rejected not obeying to the criteria density and rate of growth

The grading proposal showed in table 4.1 also contains a second visual grade (lower grade - CYS II) not included in the strength classes. Besides the issue of density control, in the definition of features and criteria to be included in the standard the requirements of the harmonized standard EN 14081-1 (CEN; 2011) (section 5.2 and Annex A) and the results of visual assessment contained in the LNEC report 66/2015 have been taken into consideration.

Table 4.1 presents the general grading criteria and table 4.2 presents the characteristic values associated with the two visual grades. In the determination of the bending strength characteristic value it was taken into consideration the k_s factor (a single sample was considered) set in the EN 384 (CEN; 2010).

Table 4.1 – Grading requirements

Features		Grade CYS I	Grade CYS II
Knots	On the face	∅ ≤ 60mm; ≤1/2 *W*	∅ ≤ 100mm; ≤3/4 *W*
	On the edge	∅ ≤ 50mm; ≤3/4 *T*	∅ ≤ 50mm; ≤3/4 *T*
Rate of growth		≤ 6mm/year	
Density		≥ 310kg/m³*	≥ 290kg/m³*
Fissures	Not going through the thickness	Fissures with depth less than half the thickness may be ignored	
		≤ 1,5m or 0,5 x *L***	
	Going through the thickness	At the ends: ≤ 2 x *W* Not present at the ends: ≤ 1m or ≤ 0,25 x *L***	
Slope of the grain		< 1:6	
Warp	Bow (em 2m)	< 20 mm	
	Spring (em 2m)	< 12 mm	
	Twist (em 2m)	< 2 mm for each 25 mm of piece *W*	
	Cup	No restrictions	
Wane	Length Width	< 1/3 of the *L or* < 0,1 m in length** < 1/3of the *T*	
Inbark	Not going through the thickness	Without restrictions if shorter than the width of the piece If not the case the limits for fissures are applicable	
	Going through the thickness	Without limits if the length is < 1/2 of the width of the piece If not the case the limits for fissures are applicable	
Biological deterioration		Signs of deterioration by insects or rot fungi are not allowed Deterioration permitted by chromogenic fungi as long as their presence is incipient	
Compression wood***		Accepted in one quarter of the *W* or of the *T* and until a length of 1m. Timber pieces presented compression wood in two opposite faces (going through the thickness) must be excluded.	

* Value having as reference 12% moisture content
** The most restricted condition is applied; *L* – Piece width; T –Piece thickness; L – Piece length
*** Text adjusted to the final version of the Portuguese standard NP 4544 published after the Portuguese version of the present report.

Table 4.2 – Characteristic values for the mechanical properties of sugi sawn timber for the different CYS visual grades

Mechanical properties		Grade CYS I	Grade CYS II
Bending strength (N/mm²)[a)]	$f_{m,k}$	19	12
Tension strength parallel to grain (N/mm²)	$f_{t,0,k}$	13	9
Tension strength perpendicular to grain (N/mm²)	$f_{t,90,k}$	0.4	0.4
Compression strength parallel to grain (N/mm²)	$f_{c,0,k}$	20	17
Compression strength perpendicular to grain (N/mm²)	$f_{c,90,k}$	2.2	1.8
Shear strength (N/mm²)	$f_{v,k}$	3.0	3.0
Modulus of elasticity (kN/mm²)			
Parallel to grain:[a)]			
– mean value	$E_{0,mean}$	7	5.8
– characteristic value	$E_{0,05}$	4.7	3.9
Perpendicular to grain:			
– mean value	$E_{90,mean}$	0.24	0.19
Shear modulus (kN/mm²)	G_{mean}	0.44	0.36
Density (kg/m³)[a)]			
– mean value	ρ_{mean}	350	290
– characteristic value	ρ_k	312	250

[a)] Characteristics determined experimentally

The CYS I grade meets the requirements of the C14 strength class. CYS II grade presents physical and mechanical characteristics that are below those specified for C14 class (lowest strength class considered by EN 338 (CEN; 2009)). Figure 4.3 shows the estimated yield for both visual grades given the results obtained.

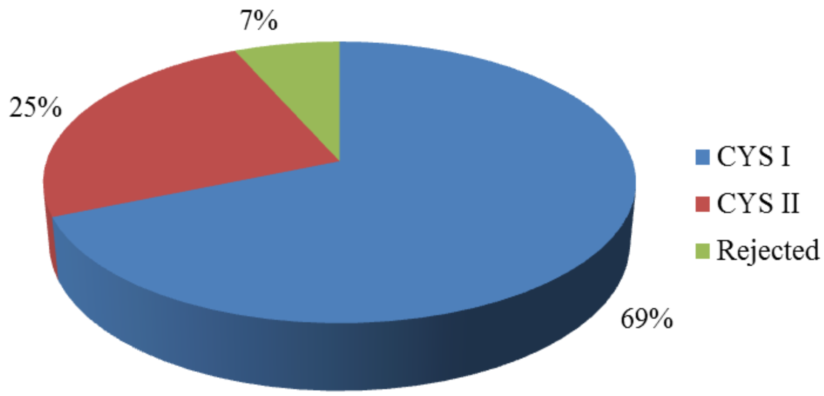

Figure 4.3 – Relative distribution of test pieces by the visual grades CYS I and CYS II and percentage of pieces rejected

4.2 CE marking

The visual grading proposal allows the CE marking through the application of the harmonized European standard EN 14081-1+A1 (CEN; 2011). This marking requires the submission to the Instituto Português de Qualidade (IPQ) (Portuguese Institute for Quality) of an application for regulatory initiative on the development of a visual strength grading standard for sugi. After the publication of the standard it can be submitted a proposal for inclusion of visual grade CYS I (and the visual strength grading standard) in the European Standard EN 1912 to the Technical Committee TC124 “Timber Structures” of the European Standardization Commission (CEN).

The CE marking process imposes the system of assessment and verification of constancy of performance 2+ with the intervention of a Notified Body of Inspection (list of Portuguese entities should be requested to IPQ) - see Annex ZA of the harmonized standard.

5 | Conclusions

The study allows concluding that sugi timber shows weak or non-existent correlations between its physical and mechanical properties and the features of timber that is usually used for visual strength grading timber.

Therefore and as already established by the French standard applicable to sugi timber wood from the Island of Réunion, it becomes necessary to impose limits on density to ensure minimum variability and enable the association of one of the visual grades (CYS I) to one strength class (C14).

The impossibility of defining a visual grade associated with higher strength classes (the French standard associates the visual grade ST IV to the strength class C18) is due to the weak correlation between density and modulus of elasticity in bending. The study indicates that it is not possible to set a visual parameter to ensure a class above C14, namely meeting the characteristic values of the modulus of elasticity and at the same time ensuring a minimum of yield for that grade (percentage of pieces available on the market for that visual grade / strength class).

The possibility of obtaining higher strength classes is thus apparently restricted to the application of machine grading standards. In the present study this possibility was evaluated using the Timber grader MTG equipment. This equipment is based on determining the dynamic modulus of elasticity and density. Preliminary results obtained by the application of this equipment and the correlation obtained between the static module of elasticity and the bending strength sustain the viability of using the MTG in the definition of visual grades showing higher performance than CYS I, Figure 5.1.

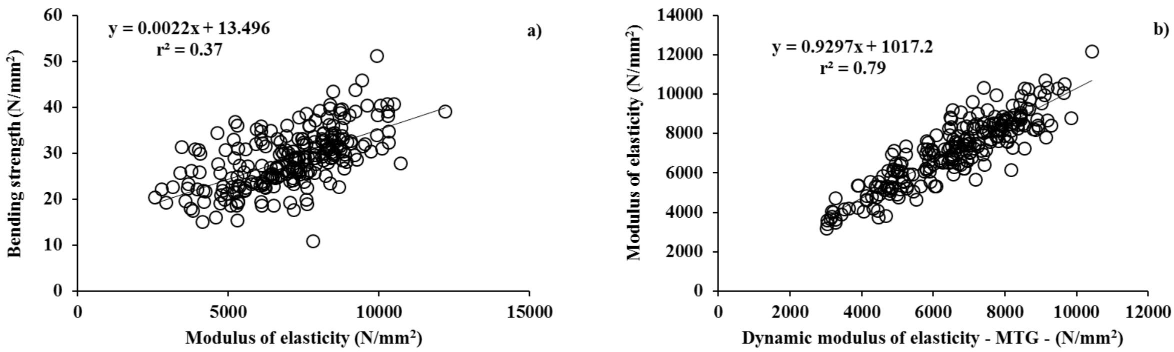

Figure 5.1 – Correlation between: a) bending strength and static modulus of elasticity in bending; b) static modulus of elasticity and dynamic modulus of elasticity obtained by application of MTG

Lisboa, LNEC, April de 2015

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ANNEX

Individual mechanical and physical characterization of the pieces under test

Test piece identification									
LNEC	Island	Stand	Tree	Position of the log in the tree	Class of diameter	Test piece identification	Density	Bending strength	Modulus of elasticity
1	T	P1	A1	T2	D3	5	329.0	26.7	8846
2	T	P1	A1	T2	D3	6	332.0	29.8	8151
3	T	P1	A1	T1	D4	16	365.2	33.1	8102
4	T	P1	A1	T1	D4	17	335.7	28.6	7208
5	T	P1	A2	T4	D2	7	317.8	28.9	7878
6	T	P1	A2	T4	D2	8	329.2	31.0	8261
7	T	P1	A2	T4	D2	9	340.3	33.8	8767
8	T	P1	A2	T4	D2	10	321.9	28.8	7244
9	T	P1	A2	T3	D3	11	288.0	26.4	7394
10	T	P1	A2	T3	D3	12	282.4	34.5	8159
11	T	P1	A2	T3	D3	13	297.9	27.9	8303
12	T	P1	A2	T3	D3	14	444.2	30.8	8727
13	T	P1	A3	T3	D2	3	304.4	25.8	7649
14	T	P1	A3	T3	D2	4	294.6	28.6	7520
15	T	P1	A3	T4	D2	15	329.3	28.7	9263
16	T	P1	A4	T2	D3	1	359.5	32.0	9548
17	T	P1	A4	T2	D3	2	332.8	31.6	8692
18	T	P1	A4	T1	D4	18	283.4	26.7	7198
19	T	P1	A4	T1	D4	19	325.9	32.8	8172
20	T	P1	A4	T1	D4	20	330.5	32.7	8521
21	T	P1	A4	T1	D4	21	360.9	39.2	10293
22	T	P1	A4	T1	D4	22	421.6	38.9	8725
23	T	P1	A4	T1	D4	23	312.9	26.1	6948
24	T	P1	A5	T1	D2	24	334.6	19.0	7608
25	T	P1	A6	T3	D2	25	318.6	31.3	8595
26	T	P1	A6	T3	D2	26	312.9	33.2	8792
27	T	P1	A6	T3	D2	27	318.4	29.5	9188
28	T	P1	A6	T3	D2	28	318.5	29.9	8514
29	T	P1	A6	T4	D2	34	303.3	29.1	8487
30	T	P1	A6	T4	D2	35	309.0	31.5	8239
31	T	P1	A6	T4	D2	36	328.8	32.5	8948
32	T	P1	A6	T4	D2	37	316.2	29.7	8870
33	T	P1	A7	T4	D2	29	401.8	40.3	10067
34	T	P1	A7	T3	D2	30	399.2	39.1	12199
35	T	P1	A7	T3	D2	31	391.8	40.7	10508
36	T	P1	A7	T3	D2	32	372.7	38.1	10294
37	T	P1	A7	T3	D2	33	386.1	28.5	8800
38	T	P1	A8	T4	D2	38	340.0	34.0	8442
39	T	P1	A8	T4	D2	39	351.4	32.4	8107
40	T	P1	A8	T4	D2	40	295.2	28.6	7216
41	T	P2	A1	T2	D2	1	314.1	19.9	7595

Test piece identification									
LNEC	Island	Stand	Tree	Position of the log in the tree	Class of diameter	Test piece identification	Density	Bending strength	Modulus of elasticity
42	T	P2	A1	T2	D2	2	305.4	25.0	8244
43	T	P2	A2	T1	D2	6	352.9	24.2	7157
44	T	P2	A2	T1	D2	7	323.6	29.5	8497
45	T	P2	A2	T1	D2	8	385.8	30.3	8816
46	T	P2	A3	T1	D2	3	344.2	25.2	5842
47	T	P2	A3	T1	D2	9	334.2	29.7	7855
48	T	P2	A4	T3	D2	4	326.0	31.9	8239
49	T	P2	A4	T3	D2	5	378.3	31.0	8315
50	T	P2	A5	T2	D2	10	288.6	31.1	8349
51	T	P2	A5	T2	D2	11	320.3	28.9	7834
52	T	P2	A5	T2	D2	12	304.1	28.4	8800
53	T	P2	A6	T1	D2	13	297.9	22.5	7624
54	T	P2	A6	T1	D2	14	291.6	29.8	6717
55	T	P2	A6	T1	D2	15	326.8	27.0	7145
56	T	P2	A7	T2	D2	16	297.3	26.9	6597
57	T	P2	A7	T2	D2	17	277.8	22.7	6516
58	T	P2	A8	T3	D2	18	296.0	29.1	7654
59	T	P2	A8	T3	D2	19	280.2	24.9	6462
60	T	P2	A8	T3	D2	20	322.9	25.5	6938
61	T	P2	A9	T1	D4	22	246.7	19.5	4203
62	T	P2	A9	T1	D4	21	256.1	19.5	5317
63	T	P2	A9	T1	D4	23	280.5	25.5	6439
64	T	P2	A9	T1	D4	24	236.4	17.5	3826
65	T	P2	A9	T1	D4	25	247.1	18.6	5068
66	T	P2	A9	T1	D4	26	270.1	24.6	6556
67	T	P2	A10	T1	D4	27	307.0	27.1	6611
68	T	P2	A10	T1	D4	28	307.7	21.8	5550
69	T	P2	A10	T1	D4	29	320.4	19.4	6081
70	T	P2	A10	T1	D4	30	315.3	22.7	6211
71	T	P2	A10	T1	D4	31	305.3	23.4	5932
72	T	P2	A10	T1	D4	32	312.1	26.3	7282
73	T	P2	A10	T1	D4	33	278.8	22.7	5139
74	T	P3	A11	T1	D4	34	275.0	18.6	6107
75	T	P3	A11	T1	D4	35	305.1	21.9	5539
76	T	P3	A11	T1	D4	36	266.7	21.8	4797
77	T	P3	A11	T1	D4	37	263.9	20.9	4755
78	T	P3	A11	T1	D4	38	273.0	23.0	5337
79	T	P3	A11	T1	D4	39	274.7	24.6	5095
80	T	P3	A11	T2	D3	40	287.8	26.0	7029
101	SM	P1	A8	T1	D2	1	311.3	32.6	9064
102	SM	P1	A8	T1	D2	2	310.6	17.6	7162

Test piece identification									
LNEC	Island	Stand	Tree	Position of the log in the tree	Class of diameter	Test piece identification	Density	Bending strength	Modulus of elasticity
103	SM	P1	A8	T1	D2	3	298.4	26.9	6414
104	SM	P1	A8	T2	D2	1	340.2	22.6	8682
105	SM	P1	A8	T2	D2	2	301.1	25.2	6753
106	SM	P1	A8	T3	D2	1	295.2	29.9	8531
107	SM	P1	A8	T4	D2	1	326.5	28.9	8404
108	SM	P1	A9	T1	D3	1	311.8	30.8	4028
109	SM	P1	A9	T1	D3	2	341.1	27.7	4654
110	SM	P1	A9	T1	D3	3	346.3	30.9	3899
111	SM	P1	A9	T2	D2	1	385.4	35.0	6406
112	SM	P1	A9	T2	D2	2	340.0	29.0	5198
113	SM	P1	A9	T3	D2	1	327.8	24.6	7139
114	SM	P1	A9	T4	D2	1	332.6	39.2	8036
115	SM	P1	A10	T1	D3	1	310.9	27.1	6674
116	SM	P1	A10	T1	D3	2	361.7	23.8	7509
117	SM	P1	A10	T1	D3	3	296.3	23.3	5776
118	SM	P1	A10	T2	D2	1	331.4	23.3	7178
119	SM	P1	A10	T2	D2	2	324.9	19.3	7053
120	SM	P1	A10	T3	D3	1	355.2	34.4	8532
121	SM	P1	A10	T4	D2	1	274.5	28.1	8924
122	SM	P1	A11	T1	D3	1	404.7	33.2	7438
123	SM	P1	A11	T1	D3	2	372.3	36.9	5224
124	SM	P1	A11	T1	D3	3	396.6	36.1	7688
125	SM	P1	A11	T2	D2	1	379.6	33.6	7839
126	SM	P1	A11	T2	D2	2	387.8	35.3	5939
127	SM	P1	A11	T3	D2	1	369.6	30.4	9736
128	SM	P1	A11	T4	D2	1	368.1	29.0	7234
129	SM	P1	A12	T1	D3	1	350.9	24.8	6282
130	SM	P1	A12	T1	D3	2	275.1	20.4	2566
131	SM	P1	A12	T1	D3	3	262.0	21.6	4231
132	SM	P1	A12	T2	D2	2	286.9	22.5	5560
133	SM	P1	A12	T2	D2	1	302.0	20.0	4891
134	SM	P1	A12	T3	D2	1	335.4	25.7	7868
135	SM	P1	A13	T1	D3	1	391.0	34.5	4639
136	SM	P1	A13	T1	D3	2	329.2	32.1	6148
137	SM	P1	A13	T1	D3	3	392.8	32.5	6737
138	SM	P1	A13	T2	D3	1	383.3	23.0	6055
139	SM	P1	A13	T2	D3	2	353.8	25.4	7360
140	SM	P1	A13	T3	D2	1	357.3	37.7	8860
141	SM	P2	A8	T1	D2	1	374.8	36.1	5305
142	SM	P2	A8	T1	D2	2	394.3	30.4	6787
143	SM	P2	A8	T1	D2	3	347.1	35.9	7690

Test piece identification									
LNEC	Island	Stand	Tree	Position of the log in the tree	Class of diameter	Test piece identification	Density	Bending strength	Modulus of elasticity
144	SM	P2	A8	T2	D2	1	403.5	23.5	6160
145	SM	P2	A8	T2	D2	2	384.7	32.0	7591
146	SM	P2	A8	T3	D2	1	388.9	34.3	8171
147	SM	P2	A8	T4	D2	1	351.3	39.2	9225
148	SM	P2	A9	T1	D2	1	314.7	23.1	6169
149	SM	P2	A9	T1	D2	2	306.1	25.8	5533
150	SM	P2	A9	T1	D2	3	263.5	15.0	4141
151	SM	P2	A9	T2	D2	1	327.4	24.8	6643
152	SM	P2	A9	T2	D2	2	279.8	18.6	5279
153	SM	P2	A9	T3	D2	1	310.1	22.5	6228
154	SM	P2	A9	T4	D2	1	313.8	26.3	7284
155	SM	P2	A10	T1	D3	1	460.8	27.2	5651
156	SM	P2	A10	T1	D3	2	434.9	32.9	5177
157	SM	P2	A13	T2	D2	1	399.0	40.7	10270
158	SM	P2	A13	T2	D2	2	336.5	25.8	7345
159	SM	P2	A13	T3	D2	1	348.5	26.2	7712
160	SM	P2	A10	T1	D3	3	396.2	32.3	7488
161	SM	P2	A10	T2	D3	1	313.6	29.2	8111
162	SM	P2	A10	T2	D3	2	376.5	38.4	9951
163	SM	P2	A10	T3	D2	1	355.1	30.3	8426
164	SM	P2	A10	T4	D2	1	413.4	33.0	8450
165	SM	P2	A11	T1	D4	1	314.8	26.6	6572
166	SM	P2	A11	T1	D4	2	355.1	33.2	6623
167	SM	P2	A11	T1	D4	3	332.1	23.8	6109
168	SM	P2	A11	T2	D3	1	316.2	18.6	6516
169	SM	P2	A11	T2	D3	2	324.4	24.7	6296
170	SM	P2	A11	T3	D3	1	353.2	39.6	8770
171	SM	P2	A11	T4	D2	1	271.2	29.0	7349
172	SM	P2	A12	T1	D2	1	302.5	25.9	4057
173	SM	P2	A12	T1	D2	2	343.8	23.3	3669
174	SM	P2	A12	T1	D2	3	300.0	19.2	2931
175	SM	P2	A12	T2	D2	1	332.1	21.5	5214
176	SM	P2	A12	T2	D2	2	329.2	22.4	3642
177	SM	P2	A12	T3	D2	1	345.4	31.9	7494
178	SM	P2	A13	T1	D3	1	347.6	35.9	6079
179	SM	P2	A13	T1	D3	2	341.3	37.2	7891
180	SM	P2	A13	T1	D3	3	345.3	28.5	8157
181	SM	P1	A1	T1	D3	1	357.3	38.3	9026
182	SM	P1	A1	T1	D3	2	333.4	34.7	6090
183	SM	P1	A1	T1	D3	3	347.5	31.9	5926
184	SM	P1	A1	T2	D2	1	390.3	33.9	9941

Test piece identification									
LNEC	Island	Stand	Tree	Position of the log in the tree	Class of diameter	Test piece identification	Density	Bending strength	Modulus of elasticity
185	SM	P1	A1	T2	D2	2	357.5	37.6	8277
186	SM	P1	A1	T3	D2	1	384.7	34.7	10321
187	SM	P1	A2	T1	D3	1	294.2	23.9	7047
188	SM	P1	A2	T1	D3	2	265.2	15.4	5307
189	SM	P1	A2	T1	D3	3	293.9	16.1	4591
190	SM	P1	A2	T2	D2	1	284.6	30.9	8400
191	SM	P1	A2	T2	D2	2	284.1	29.1	7539
192	SM	P1	A2	T3	D2	1	312.1	23.4	8393
193	SM	P1	A3	T1	D2	1	362.3	24.9	5296
194	SM	P1	A3	T1	D2	2	409.6	26.7	7133
195	SM	P1	A3	T1	D2	3	348.6	22.8	4844
196	SM	P1	A3	T2	D2	1	362.2	36.2	8353
197	SM	P1	A3	T2	D2	2	350.1	27.3	6115
198	SM	P1	A3	T3	D2	1	267.7	27.6	7908
199	SM	P1	A4	T1	D3	1	355.3	31.4	7911
200	SM	P1	A4	T1	D3	2	340.6	33.2	7323
201	SM	P1	A4	T1	D3	3	348.7	29.6	6971
202	SM	P1	A4	T2	D2	1	380.1	43.4	8473
203	SM	P1	A4	T2	D2	2	365.6	36.1	8476
204	SM	P1	A4	T3	D2	1	404.6	31.5	9455
205	SM	P1	A5	T1	D3	1	283.3	31.5	6227
206	SM	P1	A5	T1	D3	2	253.6	18.0	3745
207	SM	P1	A5	T1	D3	3	245.6	19.3	5317
208	SM	P1	A5	T2	D2	1	259.7	21.2	4956
209	SM	P1	A5	T2	D2	2	279.3	21.6	5268
210	SM	P1	A5	T3	D2	1	290.9	25.3	6396
211	SM	P1	A6	T1	D4	1	327.9	30.5	7160
212	SM	P1	A6	T1	D4	2	326.7	22.6	3158
213	SM	P1	A6	T1	D4	3	303.8	33.0	6098
214	SM	P1	A6	T2	D3	1	333.9	32.5	7853
215	SM	P1	A6	T2	D3	2	322.5	25.6	6461
216	SM	P1	A7	T1	D4	1	292.9	21.8	4179
217	SM	P1	A7	T1	D4	2	286.4	22.1	2791
218	SM	P1	A7	T1	D4	3	271.5	26.2	3763
219	SM	P1	A7	T2	D3	1	310.9	25.7	3414
220	SM	P1	A7	T2	D3	2	262.4	19.6	3579
221	SM	P2	A1	T1	D3	1	295.4	30.0	6834
222	SM	P2	A1	T1	D3	2	328.4	33.1	7460
223	SM	P2	A1	T1	D3	3	306.2	29.9	4075
224	SM	P2	A1	T2	D3	1	387.2	27.8	10718
225	SM	P2	A1	T2	D3	2	339.0	32.3	10322

Test piece identification									
LNEC	Island	Stand	Tree	Position of the log in the tree	Class of diameter	Test piece identification	Density	Bending strength	Modulus of elasticity
226	SM	P2	A1	T3	D2	1	309.3	28.8	7122
227	SM	P2	A2	T1	D3	1	413.2	33.1	8681
228	SM	P2	A2	T1	D3	2	322.8	23.7	5768
229	SM	P2	A2	T1	D3	3	330.7	25.7	4738
230	SM	P2	A2	T2	D2	1	373.9	30.0	6996
231	SM	P2	A2	T2	D2	2	402.0	31.0	10106
232	SM	P2	A2	T3	D2	1	387.2	10.8	7814
233	SM	P2	A3	T1	D3	1	321.5	30.7	6904
234	SM	P2	A3	T1	D3	2	374.2	27.3	5373
235	SM	P2	A3	T1	D3	3	326.0	37.8	7357
236	SM	P2	A3	T2	D2	1	366.3	39.4	8693
237	SM	P2	A3	T2	D2	2	387.2	35.5	8759
238	SM	P2	A3	T3	D2	1	400.2	40.5	8375
239	SM	P2	A4	T1	D3	1	363.4	29.1	7316
240	SM	P2	A4	T1	D3	2	347.4	22.1	3984
241	SM	P2	A4	T1	D3	3	310.8	31.1	5324
242	SM	P2	A4	T2	D2	1	365.5	34.3	8459
243	SM	P2	A4	T2	D2	2	327.1	24.7	6494
244	SM	P2	A4	T3	D2	1	375.6	32.8	8406
245	SM	P2	A5	T1	D3	1	350.0	27.5	7584
246	SM	P2	A5	T1	D3	2	305.0	19.1	4723
247	SM	P2	A5	T1	D3	3	312.2	22.8	5364
248	SM	P2	A5	T2	D2	1	344.0	45.9	9429
249	SM	P2	A5	T2	D2	2	321.1	33.8	6940
250	SM	P2	A5	T3	D2	1	349.7	25.6	7581
251	SM	P2	A6	T1	D2	1	331.4	43.8	9209
252	SM	P2	A6	T1	D2	2	322.3	36.0	6943
254	SM	P2	A6	T2	D2	1	371.0	51.3	9928
255	SM	P2	A6	T2	D2	2	358.8	40.4	9607
256	SM	P2	A7	T2	D4	1	370.5	39.8	8380
257	SM	P2	A7	T2	D4	2	385.1	38.7	7601
258	SM	P2	A7	T1	D5	1	308.1	30.7	4918
259	SM	P2	A7	T1	D5	2	312.4	31.3	3459
260	SM	P2	A7	T1	D5	3	345.9	30.8	5582
261	SM	P2	A5	T2	D3	1	340.6	32.1	9076

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