Proposal of visual grading rules for Uruguayan loblolly and slash pine timber

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Abstract

This paper presents a proposal for visual grading of loblolly and slash pine lumber from Uruguayan plantations. A previous database with bending and density data was used to characterize the material according to European Standards (EN). The database, with material being representative of currently produced lumber, became from a 25-year-old west and 15-year- old southern-west plantations, and consisted of test results from two samples of 261 total specimens (50x150x3300 mm). Testing methods differed from EN guidelines, so a partial objective was to compare the data parameters with those of EN, and when necessary, to propose adjustment coefficients to comply with EN requirements. Density and mechanical properties of each tested beam were calculated following the requirements of EN 408 and characteristic values were computed according to EN 384. Typical visual parameters of each specimen (i.e., knots, fissures, deformations, etc) were evaluated and the relationship between their presence and the characteristic value of the corresponding sample was statistically analyzed using MATLAB software. As a result, all specimens were grouped in one visual grade, named “EC7” for Uruguayan pine lumber, with engineered properties similar to those of the C14 strength class established in EN 338. Longitudinal MOE and characteristic bending strength were the defining properties for class assignation. Knot diameter and warp were the visual parameters with more influence on bending properties.

Key words: Lumber, Visual grading, Uruguayan pine, Pinus elliottii, Pinus taeda

Introduction

In the last thirty years, Uruguay, a country with no tradition in timber construction significantly increased the availability of local produced wood due to a governmental policy to promote forest plantations. A quarter of a total of 1 million planted areas corresponds to *Pinus* sp. intended for sawn lumber and engineered wood products. Lack of strength graded timber in the market along with the fact that no design specification or building code for wood construction is available are the main reasons that prevent contractors, architects and engineers from using timber in structural applications. With the aim of promoting the use of timber for structural applications, the government commissioned to the timber research group (Forest Project Department LATU, School of Engineering Universidad de la República and School of Architecture Universidad ORT Uruguay) to set up a comprehensive project (DNI 2014) to determine, and when was possible, to propose the technical documents needed to generate or to adopt a design specification for timber construction in Uruguay. After reviewing the state of the art and the amount of work needed to write a local specification, it was decided to adopt the European standards package, including from testing methods, to design specifications (EN 1995-1-1, 2004/AC:2006 and EN 1995-1-2 2004/AC:2009). This decision implied to make a series of adjustments and considerations on previous research works, to determine and to propose specific basic documents (i.e. grading rules, design properties for locally produce timber, national annexes, etc) and to identify research needs.

One of the most important issues to boost the use of structural timber, is availability of strength graded material. Visual grading is still a method commonly used by producers, and does not required complicated equipment or labor. Visual grading of structural lumber imposes limits on the singularities or visual parameters shown on the piece to be graded. The visual parameters frequently considered in strength grading of timber are: knots, slope of grain, pith, fissures and warp, among others. Most visual grading standards establish these parameters and their allowable limits, which are generally based on the associated strength reduction of a piece of timber. A logical initial step to generate new grading rules involved makes use of an available standard (e.g., foreign standard) to grade home-grown material, and to evaluate its application. Since timber is very variable in strength and appearance depending on species and provenance, a literal adoption of a grading rule would be unrealistic, and a local grading rule must be written for each species, provenance and cross section. Therefore, the European standard prEN 1912 (2015) establishes the relationships between visual grading for different species and origins and the strength class assigned.

The aim of this study was to propose a visual grading rule for Uruguayan loblolly/slash pine lumber and the correspondent limits for the visual parameters, and to assign a strength class in accordance to prEN 338 (2012).

Materials & Methods

Material

A previous database from a timber strength grading project (FMV, 2012) comprised of bending properties and density data was used to characterize pine lumber in accordance to European standards (EN). The database with material being representative of currently produced loblolly and slash pine lumber became from two commercial plantations in Uruguay, a 25-year-old west and 15-year- old south-west plantations, and consisted of test results from two samples totaling 261 structural size specimens of 3300 mm-long. Table 1 shows number of specimens and dimensions according to origin and age.

Table 1. Number of specimens according to origin and age

Sample	Provenance	Age (yr-old)	Nominal section (mm)	Number of pieces
1	West	25	49 x 147	115
2	Southwest	15	49 x 147	146
			Total	261

The database comprised of results from stiffness and strength determined in 4-point bending test, density and moisture content values. Specimens were conditioned at 65% relative humidity and 20ºC temperature. In addition, the database included a description of typical visual parameters for each specimen: knots, slope of grain, wane, fissures, pith and warp.

Due to the fact that testing and initial analyses were performed following typical ASTM procedures (ASTM D 198, ASTM D 2395, ASTM D2915), bending and density data were reviewed in accordance with European guidelines. Relevant property values, mostly related to modulus of elasticity were adjusted to comply with EN 408 (2011) requirements. Coefficients of 0.9950 and 0.9882, previously determined as reported elsewhere, were applied on specimen modulus of elasticity values in order to correct the MOE values below the 10% and 20% below the rupture load, respectively. Global modulus of elasticity was adjusted in accordance to EN 408 (2011). Mean modulus of elasticity, characteristic bending strength and characteristic density values were determined in accordance to EN 384 (2014).

Methodology for analysis of visual parameters and strength class assignment

A method to statistically analyze the visual parameters using MATLAB (Mathworks, 2012) was proposed in accordance with the procedure as follows, and presented in Figure 1:

1) A preliminary analysis involved selection of the most influential parameters on mean stiffness, characteristic strength and characteristic density, with the aim to establish allowable limits for each parameter;

2) A first script (a function in Matlab environment) was written to compute mean stiffness, characteristic strength and characteristic density, with test data and allowable limits defined in 1);

3) A second script (order-processing file) was developed in order to evaluate different allowable limit combinations and to return, for each combination, values of mean stiffness, characteristic strength, and characteristic density, plus the number of rejected specimens;

4) Selection of the limit combination that returned the less amount of rejected specimens, on a minimum basis of C14 strength class.

The limits were then compared with those established on the Spanish standard UNE 56544 (2011) and Argentinean IRAM 9662-1 (2005) and IRAM 9662-3 (2005) for coniferous lumber.

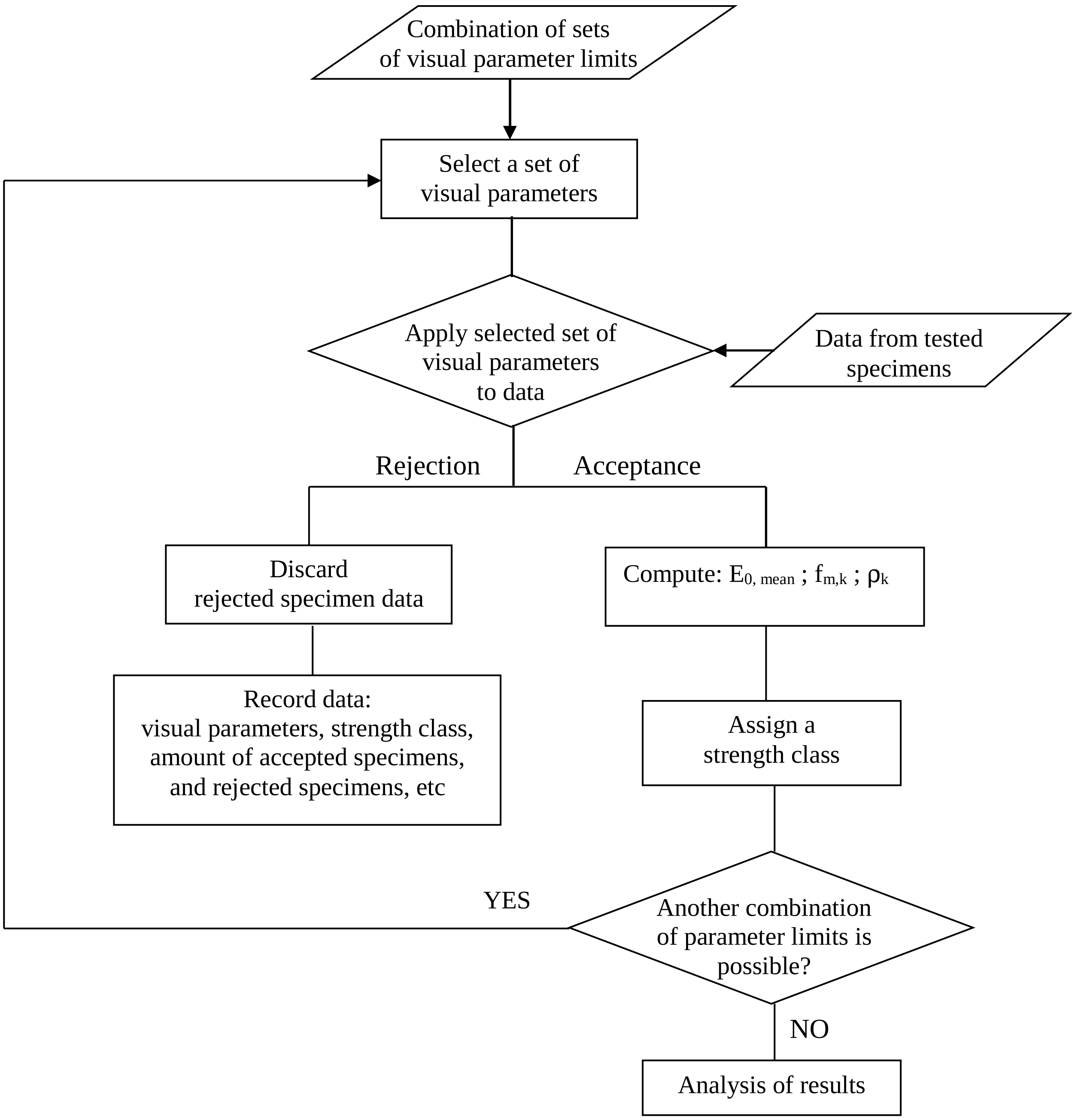

Figure 1. Flowchart of the analysis process

Results and Discussion

Table 2 shows the proposed specifications for visual grading of nominal 2 by 6 Uruguayan pine (*Pinus taeda*/*P. elliottii*) boards, based on data from two representative samples. Actual cross section dimensions of tested specimens were 49 mm x 147 mm. Visual grading was performed under dry conditions (boards moisture content ranged 14-18%) .

Table 2. Specifications for visual grading[1] of Uruguayan loblolly/slash pine 2 by 6 boards[2]

Parameter	**Visual EC7**
Face knot diameter (d)	d ≤ 2/5 h
Edge knot diameter (d)	d ≤ 2/5 b
Pith	Allowed
Slope of grain	≤ 1:6
Maximum width of annual ring	-
Fissures	
- Seasoning checks	≤1.0 m ó ≤ ¼ l
- Seasoning splits	≤1.5 m ó ≤ ½ l
Wane	≤1/5h
Resin pockets	≤ 2 h
Reaction: compression wood	-
Biological damage	
- Blue stain	Allowed
- Fungi decay	Not allowed
- Insect´s galleries	Holes diameter <2 mm
Warp	
- Bow	≤ 12 mm
- Crook	≤ 9 mm
- Twist	≤1.5 mm per 25 mm of h
- Cup	-

[1] Dry condition (MC= 14-18%)
[2] Referred to mean cross section of 49 x 147 mm

Specimens complying with Table 2 specifications were grouped in a single visual grade named as “EC7” (coniferous structural lumber).

Table 3 presents results of the visual grading. Percentages of pieces rejected in both samples are high, being knot size and warp the main reasons. To explain this poor outcome it is necessary to point out that the present specification resulted from analysis of two samples comprised of mature wood, and juvenile wood with low physical and mechanical properties. It is widely accepted that warp due to the drying process is more severe in juvenile wood, whereas annual ring usually is wider than in mature wood. Measurement of annual ring width is not frequently included in visual grading rules for coniferous timber; few grading standards (UNE 56544, 2011) include measurement of annual ring width but only for grading in wet condition, to account for warping due to the drying process. Annual ring width is also an indicator of growth rate and age, which in turn is associated with density, stiffness and strength. Therefore, inclusion of measurement of annual ring and its allowable maximum limit may improve this rule.

Table 3. Visual strength grading results. Percentage of specimens complying with EC7 visual grade and rejections

Sample	Provenance	Age (yr-old)	Mean section (mm)	EC7 (%)	Rejected (%)
1	West	25	49 x 146	50	50
2	South-west	15	49 x 148	29	71
All				38	62

Values of mechanical and physical properties of specimens graded as EC7 ($E_{0,men}$=7.04 kN/mm^2, $f_{m,k}$= 14.63 N/mm^2 and ρ_k=348 kg/m^3) correspond to the strength class C14 established in prEN 338 (2012). Longitudinal MOE and characteristic bending strength were the defining properties for class assignment.

Summary and Conclusions

With the aim of establishing the basis for a future grading rule for Uruguayan pines, a previous database was analyzed and used to define the allowable limits for the visual parameters. A method to obtain the better correlation between the limit values of visual parameters and the strength class was developed. The limits were then compared with those established on the Spanish standard UNE 56544 and Argentinean IRAM 9662-1 and IRAM 9662-3 for coniferous timber.

Specimens were grouped in one visual grade, named "EC7" for Uruguayan pine lumber, with engineered properties similar to those of the C14 strength class established in prEN 338. Knot size and warp were the main visual parameters that defined the strength class. Modulus of elasticity and characteristic bending strength were the defining properties for class assignment.

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References

ASTM D 198-09 (2011). Standard test methods of static tests of lumber in structural sizes. American Society for Testing and Materials, West Conshohocken, PA.

ASTM D 2395-97 (2011). Standard test methods for specific gravity of wood and wood based-materials. American Society for Testing and Materials, West Conshohocken, PA.

ASTM D 2915-10 (2011). Standard practice for evaluating allowable properties for grades of structural lumber. American Society for Testing and Materials, West Conshohocken, PA.

DNI (2014). Technical documents for standardization of timber structures and buildings. Dirección Nacional de Industria. Ministerio de Agricultura y Pesca. Uruguay

EN 384 (2010). Structural timber. Determination of characteristic values of mechanical properties and density. CEN, Committee for Standardization, Brussels.

EN 1995-1-1 (2004/AC:2006). Eurocode 5. Design of timber structures. Part 1-1: General Common rules and rules for building. CEN, European Committee for Standardization, Brussels.

EN 1995-1-2 (2004/AC:2009). Eurocode 5. Design of timber structures. Part 1-2: General Structural fire design. CEN, European Committee for Standardization, Brussels.

FMV (2012). Structural characterization of Uruguayan pine (*Pinus elliottii*, *P. taeda*) wood. Fondo María Viñas. FMV-2009-1-2772. Agencia Nacional de Investigación e Innovación. Uruguay

IRAM 9662-1 (2005). Madera laminada encolada estructural. Clasificación visual de las tablas por resistencia. Parte 1: Tablas de pino Paraná (*Araucaria angustifolia*). Instituto Argentino de Normalización y Certificación, Buenos Aires.

IRAM 9662-3 (2005). Madera laminada encolada estructural. Clasificación visual de las tablas por resistencia. Parte 3: Tablas de pino taeda y elliotti (*Pinus taeda y elliottii*). Instituto Argentino de Normalización y Certificación, Buenos Aires.

prEN 338(2012). Structural timber. Strength classes. CEN, European Committee for Standardization, Brussels.

prEN 384 (2014). Structural timber. Determination of characteristic values of mechanical properties and density. CEN, European Committee for Standardization, Brussels.

prEN 1912 (2015). Structural timber. Strength classes. Assignment of visual grades and species. CEN, European Committee for Standardization, Brussels.

UNE EN 408 (2011). Estructuras de madera. Madera aserrada y madera laminada encolada para uso estructural. Determinación de algunas propiedades físicas y mecánicas. AENOR, Madrid.

UNE 56544 (2011). Clasificación visual de la madera aserrada para uso estructural. Madera de coníferas. AENOR, Madrid.