GUIDELINES FOR ASSIGNING ALLOWABLE PROPERTIES TO MECHANICALLY GRADED LUMBER FROM FOREIGN SPECIES

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Introduction

In the United States, there is growing interest in the assignment of allowable properties to lumber produced from species not grown in the United States or Canada. This interest is a direct result of:

1. A diminishing supply of logs from softwood species in the West due to increased emphasis on alternative uses.
2. Increased interest in trade with east European governments. Generally their currency is not recognized in the west, and so wood is an obvious barter item for many east European countries, especially for the former Soviet Union countries.
3. A desire to use naturally durable tropical hardwood species for certain structural applications.
4. An expected dramatic increase in the availability of softwood lumber from foreign countries as plantation stocks reach merchantable size within the next few years.

When coupled with an expected increase in demand for natural building products from renewable forest sources, these trends highlight the need for efficient procedures for assigning properties to imported lumber.

Currently there are several alternatives for assigning allowable properties to domestic species. For visually graded lumber two methods have been found appropriate by the Department of Commerce under the American Lumber Standards (ALS) system. They are:

a. using test results based on small, clear specimens (ASTM D 143) by applying the criteria given in ASTM D 245 and D 2555, or
b. using test results based on full-size, commercially graded lumber (ASTM D 4761 or D 198) by applying the criteria given in ASTM D1990.

Domestic species may also be graded by mechanical, or other automated, procedures (ASTM D 6570) approved by the Board of Review (Board) of the American Lumber Standards Committee (ALSC). These procedures were developed for lumber produced from species grown in the United States or Canada and incorporates the knowledge and experience gained with these species over the last eighty years. The existing procedures may not be applicable to lumber produced from species grown in a foreign country without further technical guidance.

For dimension lumber produced from species not grown in the United States or Canada, the Board of Review has approved grading by visual procedures with property assignment by procedures given in "Guidelines for Assigning Allowable Properties to Visually Graded Foreign Species Based on Test Data for Full Sized Specimens" (Green and

Shelley, 1992). This procedure replaced an older procedure that was adopted in 1975, but never used to produce structural lumber (Galligan and Ethington, 1975). Machine stress rating of foreign species has also been recognized. However, no documentation exists to guide the assignment of properties to lumber produced from foreign species using the MSR process. Because the MSR process is based on the direct measurement of the stiffness and utilizes quality control for critical strength properties, it offers the most flexible, and least restrictive, alternative for grading foreign species.

Objective

ASTM D 6570, and past Board practices, provide methodology of grade assignment, assignment of design properties, and the requirements for the quality control of mechanically graded solid-sawn lumber. The objective of this document is to provide philosophy and guidelines for the application of ASTM and Board approved procedures to MSR lumber produced from species not grown in the United States or Canada.

Scope

When discussing options for assigning allowable properties to lumber produced from imported species there are many options that could be considered. The procedures described in this document assume that:

1. The procedures are applicable to lumber produced from both imported softwood and imported hardwood species.
2. The lumber has been graded under supervision of ALSC accredited agencies.
3. The procedures are referenced to machine stress-rated grading procedures of ASTM D 6570 as approved by the ALSC.
4. The procedures are applicable for development of allowable strength in bending, tension parallel to the grain, compression parallel to the grain, compression perpendicular to the grain, and shear parallel to the grain, bending , modulus of elasticity and assessment of specific gravity.
5. Mechanical property test data, if required, is assumed to be obtained on full size lumber tested according to procedures given in ASTM D 4761 or D 198, or clear wood procedures given in ASTM D143. Specific gravity is determined according to method A of ASTM D 2395.

Discussion of Guidelines

Approach

The approach to assignment of allowable properties will be based on ALSC approved procedures for assigning allowable properties to domestic species graded into MSR grades. In the United States, we have limited experience with grading foreign species.

Adoption of the ALSC procedures for use with foreign species therefore requires judgmental decisions about applicability of ALSC procedures to foreign species. The approach taken here is to obtain data on some properties to assure that critical relationships between properties assumed in ALSC based procedures are valid for foreign species. This initial data set is called the "species qualification" data. Once the species is qualified, authorization to produce specific grades is based on standard ALSC procedures, Because of the lack of experience and the necessity to make judgments, some additional quality control requirements may be needed when grading foreign species. All these requirements are discussed below. As experience is gained with grading foreign species, some of the more restrictive guidelines given here may be relaxed in future editions of this document. It is also possible to supply test data in lieu of judgmental decisions about property relationships. Such data shall he taken on samples representative of the lumber to be graded, and testing shall follow procedures given in approved ASTM standards. To avoid possible delays due to the collection of inappropriate data, it is suggested that such sampling and testing studies be discussed with the Board prior to sampling.

Validation of Property Relationships

Species for which grading approval is sought shall be classified into one of four categories: 1) softwood species from temperate regions, 2) hardwood species from temperate regions, 3) softwood species from tropical regions, and 4) hardwood species from tropical regions.

Temperate softwoods. Current ALSC approved procedures for MSR lumber are based on data and commercial grading experience on softwood species native to the United States and Canada. Considerable data exists on property relationships for these domestic species (Barrett and Griffin, 1989; Green and Kretschmann, 1991). Comparisons of property relationships assumed in proposed design codes for European temperate softwood species show that relationships between MOE and MOR, density and MOE, density and MOR, density and shear strength, density and compression strength perpendicular to the grain, and MOR and UCS generally parallel those of domestic softwood species (Green and Kretschmann, 1989, 91, Green et al., 1994). The relationship between MOR and UTS currently used for historical MSR property assignments differs from that used with European softwoods (Green and Kretschmann, 1989).

Temperate hardwoods. Hardwood species from temperate regions would be expected to have defect patterns and property relationships similar to those of domestic hardwood species. Research has verified the applicability of ALSC procedures for MSR lumber to domestic hardwood species (Green and McDonald, 1993-a, -b). Thus property relationships for most temperate hardwood species from foreign sources would be assumed to be similar to those of domestic softwood species. A few domestic hardwoods typically contain higher percentages of interlocked grain, a form of cross grain caused by alternating bands of fibers that slope in opposite directions. Research on tropical

hardwoods suggests that property relationships, especially that between Fb and Fc, may be altered by the presence of interlocked grain (Green and Rosales, 2006; Davis, 1992). Any assumed property relationships for MSR lumber should be verified for similar foreign species that contain interlocked grain.

Tropical softwoods. Softwood species from tropical regions may contain few knots compared to domestic species. However, such species may also contain a much wider range in specific gravity than temperate softwoods. Little information is currently available on the properties of lumber tested in full size dimensions for tropical softwoods. However, it is assumed that procedures currently used to assign allowable properties to domestic softwoods are also applicable to softwood species from tropical climates.

Tropical hardwoods. Hardwood species imported from tropical regions are the most variable and least understood of the four classifications discussed above. The majority of data on full size lumber is for lumber tested in bending. This data indicates that MOE-MOR relations are sufficiently correlated to allow mechanical sorting of most species (Senft and Lucia, 1979; Appiah, 1984). lnterlocked grain frequently occurs in tropical hardwoods (Chudnoff, 1984). Limited research suggests that for tropical hardwoods without interlocked grain property relationships are the same as those of temperate hardwoods and softwoods. For species that typically have interlocked grain, property relationships currently assumed for domestic species may not apply (Green and Rosales, 2006). Available literature also indicates that certain tropical hardwood species may have growth characteristics, such as brittle heart, which are not always apparent from visual inspection (Chudnoff, 1986). Species which tend to have such problems may not be reliably sorted by mechanical procedures based on strength- stiffness relationships (Collins and Amin, 1990). Because of the lack of information on the properties of tropical hardwoods, it is necessary to qualify the applicability of all ALSC procedures to tropical hardwoods.

Description of Geographic Distribution.

Lumber properties are known to vary considerably with the conditions under which the lumber is grown. Less is known, however, about the effect of growth conditions on relationships between lumber strength properties. To assure that property relationships are evaluated fairly, and to avoid quality control problems with future shipments, it is imperative that the qualification sample be representative of the entire quality range over which future samples are anticipated. To increase the Board's knowledge of potential effects and to allow for future refinement of these guidelines, a description shall be provided of the general geographic range over which the shipment was obtained (for example, northern Siberia, northern Europe, Guatemala. etc.).

Testing Procedures.

Mechanical testing is to be conducted according to procedures given in ASTM D 4761 or D198. For bending tests, specimens shall be tested on edge, with a minimum span to depth ratio in the range from 17:1 to 21:1. The controlling defect, low point MOE, or strength reducing growth characteristic, shall be placed within the test span. The edge to be stressed in tension shall be randomly located. Tension and compression tests parallel to the grain shall have the controlling defect within the test span.

Compression perpendicular to the grain (C-perp) and shear tests shall be conducted according to procedures given in ASTM D 143. It may not be possible to cut C-perp and shear specimens according to D143 specifications. In the absence of alternative data, we note that studies by Bendtsen and Porter (1979) indicate that a 1.5 by 2.0 inch shear specimen gives results equivalent to that obtained using the standard 2.0 by 2.0 inch specimen. Also note that a study by Kunesh, 1968, indicates that a 1.5 inch by 6 inch long specimen, 2 inches thick, will give results comparable to the standard 2 by 6 inch long, by 2 inch thick specimen. The specimen geometry's are acceptable for determining lumber properties. For both shear strength and c-perp, stresses are calculated using actual stressed area of the specimen. Note that determination of the shear strength for species with interlocked grain requires estimation of the area of the failure surface, not simply assuming a surface area from the specimen dimensions, to avoid over estimation of shear strength (Green and Rosales, 2006).

Specific gravity shall be determined by method A of ASTM D 2395 and moisture content determined by method A of ASTM D 4442. Moisture contents taken using a electrical resistance moisture meter are acceptable if information is available on how to calibrate the meter for the species being tested.

Moisture Content at Time of Test.

It is recommended that all mechanical testing be done at moisture contents (MC) between 12 and 15%. This is because, in general, we do not know moisture content adjustment procedures for foreign species (some information on moisture meter correction factors for foreign species is given in Simpson, 1994). With lumber cut from temperate softwood and hardwood species, and with tropical softwood species, the moisture adjustment procedures of ASTM D1990 are applicable. Thus, while it is highly recommended that such lumber be equilibrated to 15% moisture content prior to testing, the lumber may be allowed to reach a uniform MC other than 15% and the properties then adjusted by D 1990 procedures. The applicability of MC adjustment procedures to tropical species is unknown. It is recommended that lumber be conditioned to a moisture content of 12 to 15% prior to testing. Oven dry specific gravity determinations are also acceptable.

Specimen Sizes for Determination of Property Relationships.

Research has shown that the minimum ratio between UCS/MOR and UTS/MOR is obtained with narrow width lumber (Green and Kretschmann, 1991). Therefore it is suggested that lumber used to verify the applicability of these relationships to a foreign species be based on tests of 2x4's.

Requirements

Species Validation.

For temperate softwoods, most temperate hardwoods, and tropical softwoods it is necessary to validate that the current MSR property relationships between tension and bending, between C-perp and density and between shear and density, are applicable to the foreign species, or species group. The species qualification sample is a minimum of 240 pieces of 2x4 No. 3 and better visually graded lumber. All pieces are then E-rated, ranked by MOE, and alternate pieces randomly assigned to two test groups. One group is tested to failure in 3rd point bending and the other in tension parallel to the grain. All pieces are tested to failure. Specific gravity, compression perpendicular to the grain, and shear strength is determined from a minimum of 60 samples per species. These samples may be cut from clear sections cut from the unbroken ends of the bending specimens, or determined from clear wood specimens cut from logs. It is cautioned that even with careful sample preparation, 10-15% of the C-perp and shear specimens may exhibit unacceptable failures according to the criteria of D 143. Therefore, it is strongly recommended that more samples be prepared than the minimum specified above. Regression equations fit to the data will then be compared to ALSC assumed relationships for Ft-Fb, Fcp-density, and Fv-density. The MOE-MOR relationship is useful in setting up grade boundaries. For tropical hardwoods, it is necessary to verify all assumed property relationships.

When selecting the samples for species validation, it is important to obtain as wide a range in lumber quality as possible to properly characterize the properties of the species. For this purpose, quality should be defined in terms of characteristics which influence properties (i.e. knots, cross grain, specific gravity, and MOE). If possible, the sample shall be selected from a wide geographic distribution. In addition, if specific gravity, C-perp, and shear specimens are cut from the unbroken ends of the bending specimens, these specimens should come from the entire range of MOE's obtained during the bending test.

Approval and Reporting.

As with domestic species, grading agencies shall obtain Board approval to grade a foreign species or species group (ALSC, 1998). Because of the lack of experience with

mechanical grading of foreign species, a report on the results of the grade qualification tests shall be submitted to the Board for approval. This report shall include a copy of the data and any judgments or restrictions placed on the species or grade by the agency.

Grade Qualification and Property Assignments for Temperate Species.

Grade qualification will follow grading agency procedures approved by the Board. These may be modified at Board discretion, depending upon the results of the species qualification tests and the recommendations of the grading agency. As with domestic species, allowable properties shall be assigned to six properties; Fb, MOE, Ft, Fc, Fcp, and Fv. In addition, specific gravity shall be determined. For lumber from temperate regions (categories 1 and 2) it is necessary to qualify the grade in Fb and MOE. Assignment of Ft may be done by qualification, or by the conservative relationship of ASTM D 1990, Equation 1.

$$Ft = 0.45 \times Fb \qquad \text{Equ (1)}$$

The relationship between Fb and Fc is particularly stable for temperate species (Green and Kretschmann, 1991). Fc may be assigned by qualification, or based on the relationship used for domestic species, Equation 2.

$$\text{if } Fb \geq 1350 \text{ psi}$$
$$Fc = (0.7098 \times Fb + 2060.7)/1.9$$

or Equ (2)

$$\text{if } Fb < 1350 \text{ psi}$$
$$Fc = 1.1765 \times Fb$$

Specific gravity is determined from a sample representative of the species or species group, or from a representative sample taken from the same shipment used to obtain the qualification sample.

Evidence shall be provided that indicates the applicability of Fcp, Fv assignment procedures to the species or group. This can be test data on the compression and shear strength obtained from tests of pieces representative of the entire quality range of material expected for the species, or from a relationship between Fcp (or Fv) and specific gravity. If a relationship with specific gravity is used, evidence shall be provided to show the validity of this relationship. This can be obtained from test data on the pieces being qualified. Note that a limited range in specific gravity may result in a poor relationship. It is advisable to assure as wide a range in specific gravity values as possible in order to obtain good estimates of the relationship.

Property Assignments for Tropical Hardwoods and Softwoods.

Properties may be assigned to tropical softwoods (category 3) using the same procedures as given for temperate species, above. For hardwood species from tropical regions (category 4) it is necessary to qualify the species in all properties: Fb, MOE, Ft, Fc, Fcp, Fv, and specific gravity.

Quality Control.

The quality control program recognizes the need to assure that the individual units of lumber from the foreign source have the same quality as the lumber that was tested in the qualification sample. The quality control program will include any property required to be monitored by the agency for domestic species. In general MOE and Fb are monitored, although additional properties may sometimes be required to be monitored. At the time of submission the submitting agency shall specify the basis for picking additional properties to be monitored as an indication of lumber quality. These-additional quality control procedures may emphasize nondestructive tests such as MOE and specific gravity. Growth rate may also he monitored as an indication of lumber quality. Where Fcp and Fv are estimated from a relationship with specific gravity, specific gravity shall be determined in the quality control process.

Falldowns.

If a full grade-size matrix of visually graded lumber has previously been tested by the procedures of ASTM D 1990, then the specimens that fail to make the intended grade are treated just like domestic species (Green and Shelley, 1992). In this instance the highest visual grade that can be assigned to the falldown material shall have an allowable Fb less than that of the MSR grade from which it was rejected. If, however, data for a full grade-size matrix is not available, data shall be obtained at the time of grade qualification that would enable property assignment to the falldown material according to the grouping provisions of ASTM D 1990. Thus a minimum of 60 pieces of falldown material per grade-size category shall he tested. Choice of grade and property to be tested shall be selected following guidelines given in ASTM D 1990. Depending upon the primary MSR grade and the level of property assignment, it may be advisable to monitor the properties of the falldowns for an initial period of time.

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