

VISUAL STRESS GRADES OF DAHURIAN LARCH LUMBER

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ABSTRACT

Allowable properties for dahurian larch (*Larix dahurica*) lumber from the Russian Far East were estimated. Although sample limitations prevented exact adherence to current U.S. standards, analyses were made in the spirit of a protocol accepted by the Board of Review of the American Lumber Standard Committee. For the four structural light framing grades contained in the National Grading Rule, modulus of elasticity (MOE) and bending allowable properties of dahurian larch were higher than that of Douglas Fir-Larch, compression parallel to grain and shear were about the same as that of Spruce-Pine-Fir South, and tension and compression perpendicular to grain were more like Hem-Fir. Because of the sampling limitations, a more conservative analysis was then performed. By this analysis, MOE of dahurian larch was still somewhat higher than that of Douglas Fir-Larch, but bending, tensile, and compressive allowable properties were more similar to those of Spruce-Pine-Fir South. We suspect that a more complete evaluation would yield results intermediate to those of these two analyses, showing that the properties of dahurian larch are not very different from those of Douglas Fir-Larch.

Results from tests on a sample of machine-stress-rated dahurian larch (*Larix dahurica*) lumber (12) permit at least a cursory examination of this species for visual stress grades as described in the National Grading Rule (15,16). This sample consisted of 215 12-foot-long boards of 2 by 4 lumber that were tested in edgewise bending, shear, and compression perpendicular to grain.¹ This paper reports the results of the tests analyzed from the perspective of visual grading.

The lumber was taken from logs that originated in two forests between Khabarovsk and Vladivostok in the far southeastern corner of Russia. Detailed descriptions of the species (13) and the

sample (11) have been reported. Researchers from a research institute in Khabarovsk gathered the logs from their forests; the logs were sawn into lumber and dried at the institute.

Guidelines for establishing allowable properties for visual stress grades of foreign lumber were first adopted by the Board of Review of the American Lumber Standard Committee (ALSC) in 1973 (8). These guidelines only addressed equivalency — the demonstration that grades of a foreign species had properties at least as high as those of

some domestic counterpart. As interest in foreign lumber waned, the guidelines were seldom used. By the 1990s, interest in introducing foreign structural lumber reawakened. Green and Shelley (9,10) crafted new guidelines that incorporated the evolution of thought of the preceding 20 years. These new guidelines were adopted by the ALSC Board of Review in 1992.

The sample used in our study, which was designed to answer certain questions about machine-stress-rated dahurian larch, did not meet all the requirements of the Green-Shelley (9) protocol. However, it is the only substantial body of full-size test data on this species, and it should be possible to extract an approximate set of allowable properties. For example, these properties can be used to decide what additional sampling and testing should be done or whether there is further interest in importing dahurian larch.

EXPERIMENTAL METHODS

To obtain a good estimate of allowable properties for a grade, the visual grading protocol of Green and Shelley requires "...approximately 360 specimens...per size, grade, and test mode" taken from "as many geographic locations as possible." Our sample did not contain that many specimens. Because

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¹ 2 by 4 refers to nominal 2-by 4-inch (standard (38-by 89-mm) dimension lumber.

TABLE 1. — SI conversion factors.

English unit of measurement	Conversion factor	SI unit of measurement
Foot (ft.)	0.3048	Meter (m)
Inch (in.)	25.4	Millimeter (mm)
Pound-force per square inch (psi)	6.894	Kilopascal (kPa)
Mile	1.609	Kilometer (km)

TABLE 2. — Distribution of pieces in each grade.

Grade	No. of pieces	
	Strength-grade criteria	In-grade criteria
Select Structural	98	54
No. 1	38	24
No. 2	46	62
No. 3	33	72
Below No. 3	0	3

TABLE 3. — Bending properties of dahurian larch lumber adjusted to 15 percent moisture content.^a

Property	Statistic	Grade			
		Select Structural	No. 1	No. 2	No. 3
In-grade sort					
Sample size	--	54	24	62	72
MOE ($\times 10^6$ psi)	Average	2.039	1.816	1.696	1.610
	SD	0.345	0.233	0.293	0.415
MOR (psi)	Average	9,779	7,580	7,062	6,564
	SD	2,174	1,589	2,210	2,747
	NPE	6,460	4,195	3,942	2,741
	NTL	6,442	3,882 ^b	3,667	2,582
Specific gravity	Average	0.546	0.509	0.518	0.535
	SD	0.068	0.042	0.053	0.066
Strength-grade sort					
Sample size	--	98	38	46	33
MOE ($\times 10^6$ psi)	Average	1.959	1.769	1.563	1.436
	SD	0.362	0.275	0.235	0.389
MOR (psi)	Average	9,007	6,884	6,401	5,790
	SD	2,519	1,871	2,133	2,612
	NPE	4,611	3,830	3,063	2,526
	NTL	3,941	2,842	2,587	2,396
Specific gravity	Average	0.546	0.515	0.506	0.528
	SD	0.061	0.046	0.054	0.077

^a SD = standard deviation; NPE = nonparametric point estimate; NTL = nonparametric tolerance limit. NPE was for the 5th percentile according to section 4.5.4, ASTM D 2915 (6). NTL was with 75 percent confidence, according to table 2, ASTM D 2915.

^b Sample size was four specimens too few to use the first-order statistic, according to table 2, ASTM D 2915. The value shown is the first order statistic.

we chose to sample 4 visual grades, we would have needed 1,440 specimens for this 1 size evenly distributed across grades for bending tests alone. We had only 215 specimens, but we did not succeed in obtaining an equal number in each grade.² In addition, our sample was collected from two locations about

35 miles apart in a vast growing range (11). (See Table 1 for SI conversion factors.)

We are unable to clearly define the population from which the sample was taken. We presume that it reasonably represents dahurian larch in the far southeastern corner of Russia, but we cannot draw a line on the map that delineates the geographic scope of this species. This was simply the material we could fairly readily obtain under circumstances in the Soviet Union in 1991.

When the lumber was received in the United States, West Coast Lumber

Inspection Bureau (WCLIB) inspectors were asked to examine each piece, identify it with one of the four structural light-framing grades given in the WCLIB rulebook (15) on the basis of knots and slope of grain alone, and mark the cross-section that established the grade. The inspectors then were asked to evaluate the lot a second time using all of the grading criteria in the rulebook.

Thus, for purposes of analysis, the sample was sorted according to: 1) growth characteristics that affect mechanical properties and are restricted in the derivation of allowable properties (strength-grade criteria); and 2) grading criteria such as straightness, wane, and the like, in addition to the strength criteria (in-grade criteria). Throughout this paper, statements referring to *strength-grade* and *in-grade* pertain to pieces as sorted by the WCLIB inspectors. The distribution of pieces in the grades is shown in Table 2.

It can be deduced from the table that from a strength-grade perspective, there were far too many pieces in the highest grade, with an approximately uniform distribution of pieces in the three lower grades. When the same pieces were sorted by in-grade criteria, many pieces were lowered in grade; there was an approximately uniform distribution across all grades except No. 1; three pieces had some characteristic that prevented them from entering even the lowest grade.

A 5-foot length of each piece was tested to failure in edgewise static bending. From the remaining 7 feet of each piece, a clear, straight-grained 10-inch length was selected to provide one shear specimen and one compression perpendicular-to-grain specimen. The test methods were described in detail previously (11,12). The specimens and tests were consistent with the Green-Shelley protocol.

All analyses described in this report were conducted on the basis of mechanical properties adjusted to 15.0 percent moisture content (MC),³ unless otherwise specified, using Annex A1 of ASTM D 1990 (4). The average MC prior to adjustment was 15.6 percent, with individual values ranging from about 14 to 20 percent. Specific gravity was adjusted to a basis of volume at

² We initially had 232 specimens. Some specimens were rejected because of problems encountered in the bending and shear tests or because of errors in recording measurements.

³ The recommended target MC in section 8.3.2.1, ASTM D 1990 (4).

15.0 percent MC using the equations in the appendix of ASTM D 2395 (5).

ANALYSES AND RESULTS

QUALIFICATION OF SPECIES

To qualify the species according to the Green-Shelley protocol, actual testing of either bending strength (modulus of rupture (MOR)) or ultimate tensile stress (UTS) is required, with the untested property and ultimate compressive stress (UCS) parallel to grain predicted from the tested property using ASTM D 1990. We chose to use MOR as the tested property. Qualification also required tests in shear and compression perpendicular to grain.

Table 3 provides summary statistics from the bending tests. The modulus of elasticity (MOE) and MOR values are for the standard dressed size (1.5 by 3.5 in.). To obtain the MOR at this size from the MOR at test adjusted to 15 percent MC, a two-step procedure was used. First, all cross-sectional dimensions at the time of test were adjusted to the dimensions at 15 percent MC, per section 8.4.1 of ASTM D 1990. Second, the MOR at 15 percent MC was adjusted from the test size at 15 percent MC to the standard dressed size, using equation (1) of ASTM D 1990.

The 5 percent nonparametric point estimate (NPE) in Table 3 was obtained from equation (8) of ASTM D 2915 (6). The 75 percent confidence-95 percent content nonparametric tolerance limit (0.75 NTL) was obtained using Table 2 of ASTM D 2915 (6).

Predictive equations for estimating UTS and UCS are given in section 9.5 of ASTM D 1990:

$$T = 0.45R \quad [1]$$

$$C = [1.55 - (0.32 \times R/1,000) + (0.022 \times (R/1,000)^2)]R \quad [2]$$

In Equations [1] and [2], R , T , and C are the 0.75 NTL for MOR, UTS, and UCS, respectively. R is the same as 0.75 NTL in Table 3. Table 4 contains the solutions of Equations [1] and [2] for the in-grade and strength-grade sorts, and for all four grades. The tabulated values have the character of *predicted*

TABLE 4. — Calculated ultimate tensile stress (UTS) and ultimate compressive stress (UCS) by sorting criterion and grade.

Property ^a	Grade			
	Select Structural	No. 1	No. 2	No. 3
In-grade sort				
UTS (psi)	2,899	1,747	1,650	1,162
UCS (psi)	2,587	2,482	2,466	2,247
Strength-grade sort				
UTS (psi)	1,773	1,279	1,164	1,078
UCS (psi)	2,485	2,325	2,249	2,179

^a Nonparametric tolerance limit with 75 percent confidence as per Equations [1] and [2].

TABLE 5. Comparison of certain mechanical properties of dahurian larch clear wood at 15 and 27 percent MC.

Statistic	Shear strength (psi)		Compression perpendicular to grain ^a (psi)	
	Direct method (MC = 15%)	DeBonis method (MC = 27%)	Direct method (MC = 15%)	DeBonis method (MC = 27%)
Sample size	212	212	232	232
Average value	1,031	877	857	545
Standard deviation	276	234	216	143
Normal 5th ^b	577	491	502	310

^a Stress at 0.04-inch offset.

^b The 5 percent exclusion value by the method in note 9 of reference (1). Assumes a normal distribution of the property.

tolerance limits (75% confidence and 95% content) for 1.50-inch by 3.50-inch by 5.0-foot pieces at 15.0 percent MC.

The Green-Shelley protocol prescribes that shear and compression perpendicular-to-grain tests are to be consistent with ASTM D 143 (2), with certain thickness modifications permitted. The protocol leaves moot how to analyze test results. Because ASTM D 245 (3) is the major standard for establishing allowable properties for visual stress grades, one would expect that it was intended as a guide. However, this standard anticipates that tests would be conducted on green lumber, with a concomitant dry/green ratio for each property and the species under consideration published in ASTM D 2555 (1). For dahurian larch, lumber was tested at about 15 percent MC, and there is no dry/green ratio for either property in ASTM D 2555.

Shear and compression perpendicular-to-grain test results were analyzed in two ways. One was a very direct method; since we tested at nearly the target MC of 15 percent, we adjusted all summarizing statistics to 15.0 percent using equation A1.5 of ASTM D 1990. The other analysis was the one em-

ployed by DeBonis,⁴ in which results from tests on dry lumber were hypothesized as being from green lumber. This technique had the effect of adjusting shear and compression perpendicular-to-grain strengths to near 12 percent MC using the function:

$$S_{12} = S_t[(P - 12)/(P - MC_t)] \quad [3]$$

where:

S = strength

t = test condition

P = fiber saturation point, taken by DeBonis at 27 percent

DeBonis used the average MC, for all test specimens; thus, he adjusted the strength, S_{12} , to correspond to an average of 12 percent. He then divided by an average dry/green ratio for each property and all species listed in ASTM D 2555 except cedars, thus converting each observation of strength to a hypothetical value for the green condition. The DeBonis average dry/green ratios are 1.47 for shear and 1.99 for compression perpendicular to grain.

Where we used the DeBonis method, rather than using the average MC, in Equation [3], we used the actual MC measured for each specimen at time of test. Thus we calculated an "exact"

⁴ DeBonis, A1. Recommended allowable properties for Russian spruce. Wood Advisory Services, Inc. Unpublished report to the ALS, Dec. 27, 1994.

TABLE 6. — Factors used to convert test statistics to allowable properties.

Property	Size and configuration multiplier	Adjustment factor
MOE	1.0166	1.0
MOR	0.8846	2.1
Tension	0.8846	2.1
Compression parallel to grain	1.0	1.9
Shear	0.50	4.1
Compression perpendicular to grain	1.0	1.67

TABLE 7. — Allowable properties for dahurian larch.³

Property (psi)	Criterion	Grade			
		Select Structural	No. 1	No. 2	No. 3
MOE ($\times 10^6$)	In grade	2.1	1.8	1.7	1.6
	Strength grade	2.0	1.8	1.6	1.5
F_b	In grade	2,700	1,650	1,550	1,100
	Strength grade	1,650	1,200	1,100	1,000
F_t	In grade	1,200	725	700	500
	Strength grade	750	550	500	450
F_c	In grade	1,350	1,300	1,300	1,200
	Strength grade	1,300	1,200	1,200	1,150
F_v	Direct	70	70	70	70
	DeBonis	65	65	65	65
F_{cp}	Direct	515	515	515	515
	DeBonis	490	490	490	490

S_{12} for each specimen (recognizing that all of these calculations are approximations).

Property statistics obtained by both the direct method and the DeBonis method are shown in Table 5. These methods cannot be directly compared on the basis of the tabulated values because they used different MC values. However, each set of values was properly developed as an intermediate step in deriving allowable properties, as described in the following section.

ALLOWABLE PROPERTIES FOR VISUAL GRADES

When a species has been qualified, adjustments must be made to property statistics to reduce them to the level of allowable properties. ASTM D 1990 provides two checks (sections 9.3 and 12.6) to assure that strength statistics used for deriving allowable properties are within reasonable bounds based on the test data at hand. These checks have meaning only if more than one width is tested. Therefore, we ignored them in the study reported here. In addition,

section 8.2 of ASTM D 1990 alludes to the need for some action if the nonparametric estimate of strength ratio (called GQI in the standard) 5 percent point falls outside the range associated with the grade in the National Grading Rule. We did not obtain satisfactory strength ratios on the broken pieces, and thus could not make this check. However, we assumed that the inspectors' judgments were correct in establishing grade for these samples. In that case, for the strength-grade sort, the pieces in each grade had strength ratios appropriate for that grade and the 5 percent point of strength ratio necessarily fell within the desired range. For the in-grade sort, it is possible that the 5 percent point fell above the desired range (as found by DeBonis, for example).

We needed to adjust MOR to a 12-foot length, using equation 1 of ASTM D 1990, and to adjust MOE to a 21:1 span-depth ratio and an assumed uniformly distributed load, using equation 4 and Table 5 of ASTM D 2915.⁵ Moreover, both properties needed to be divided by the factors in table 2 of ASTM D 1990. Shear and compression strength perpendicular to grain were similarly divided by factors given in table 9 of ASTM D 245 (3). In addition,

by custom, allowable shear stress was reduced by half, as if each piece contained a full-length split (see section 4.2.3 of ASTM D245). The factors derived from these references are consolidated in Table 6.

Each allowable property was obtained by finding the appropriate statistic in Tables 3 to 5 and then applying the multiplier and dividing by the adjustment factor (Table 6). The appropriate starting statistic was the sample average for MOE and compression perpendicular to grain; NTL (0.75) for MOR; T and C for tension and compression parallel to grain, respectively; and normal 5th percentile for shear. Allowable properties in shear and compression perpendicular to grain derived using DeBonis statistics as a starting point needed to be multiplied by 1.08 and 1.50, respectively, to convert them from values for green lumber to standard values for dry lumber (reference (3), table 11).

In our study, the allowable property computations generated two values (an in-grade and a strength-grade version) for bending strength and stiffness or MOE, tension, and compression parallel to grain, for each of four visual grades. Two values were also generated for shear and compression perpendicular-to-grain strengths (by the direct method and the DeBonis method), and these values applied to all grades. Allowable properties obtained from these calculations are shown in Table 7.

DISCUSSION

As previously discussed, this sample was smaller and less disperse than that required by the Green-Shelley protocol. In addition, the study did not include the measurement of strength ratios after failure that are required in ASTM D 1990. However, the results give the magnitude of allowable properties that might be anticipated if all of those conditions were met.

Grade clearly had an effect on MOE. Although that effect was about the same for either sort, the MOE of pieces in the in-grade sort was about 100,000 psi higher than that of pieces in the strength-grade sort. Also, by either sort, the MOE was typically 100,000 to 200,000 psi higher than that for Douglas Fir-Larch (15,16).

Figure 1 shows the relationship of allowable bending stress to strength ra-

⁵The size adjustment for MOE obtained from equation (1) of ASTM D 1990 is unity.

tio. The allowable bending stress values from Table 7 were plotted against the strength ratio assigned to each of the four grades by the National Grading Rule. We superimposed the values currently assigned to Douglas Fir-Larch in WCLIB grading rules (15,16). To make the values comparable, WCLIB rule-book F_b values were adjusted to a 4-inch width.⁶ In Figure 1, the parallelism of the three lines of data is striking. If the allowable bending stress for the No. 3 grade, strength-grade sort were lower (on the order of 500 psi), the three lines would follow very similar trends. Note that the sample size for No. 3 grade in the strength-grade sort was 33 observations, compared to 72 observations for the in-grade sort. It seems likely that larger sample sizes, as required by the Green-Shelley protocol, would resolve anomalies of this kind.

The nonmandatory section X.8 of ASTM D 1990 provides some philosophy about forcing a "...logical relationship between grade description and assigned property values."

In section X.8.2, it is recommended that No. 1 bending and tension values be set at 85 percent, and compression parallel to grain be set at 95 percent of values interpolated from Select Structural and No. 2 data. Furthermore, it recommends allowable strengths for grades lower than No. 2 be interpolated from a straight line through the origin and the No. 2 value on the basis of strength ratios assigned to the grades. Ostensibly these concepts are derived from observations from the North American In-Grade Program.

We used this method to obtain estimates of F_b for No. 1 and No. 3. The results are shown in Figure 2, again with Douglas Fir-Larch superimposed. Now exactly the same trends are shown in all three lines because the section X.8 criteria force them to be that way. But,

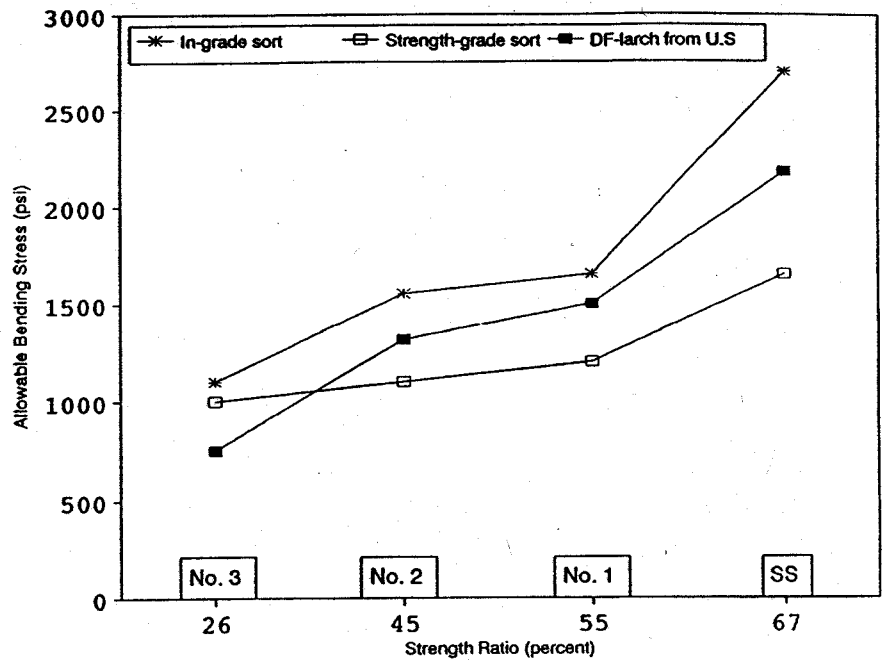


Figure 1. — Relationship of allowable bending stress to strength ratio for lumber in various sorts.

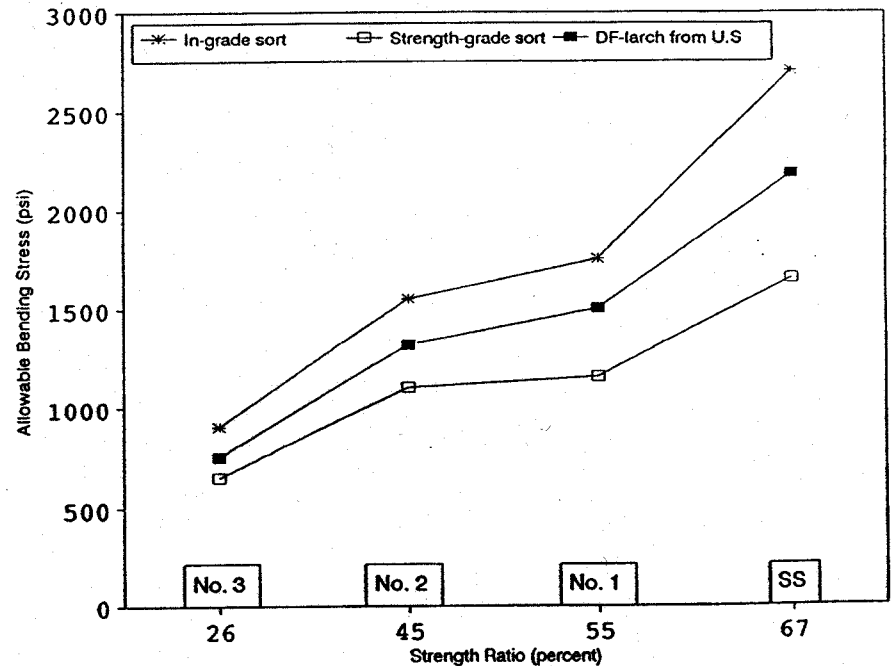


Figure 2. — Figure 1 modified by the criteria of section X.8, ASTM D 1990.

comparing Figure 2 to Figure 1, the major changes are in No. 3, strength-grade sort, and in No. 1, in-grade sort. We suspect these two categories are at least affected by the small sample size (Table 2), and it is that kind of problem that the X.8 criteria are intended to solve.

The in-grade sort yielded higher allowable bending properties than did the strength-grade sort for all four grades. This should be expected for all but the highest grade — the shift from strength-grade to in-grade moved some pieces to lower grades because of grading criteria

⁶ For the width adjustment, we used table 4 of reference (11), which equals table A in reference (14). The values for Douglas-Fir-Larch are also based on tests of three widths from the North American In-Grade Program (14). ASTM D 1990, section 9, provides a way to combine data from several test widths to harmonize allowable properties across widths. This procedure probably has the effect of lowering allowable bending stress for the 4-inch width below what is observed in tests. In our study, we made no test of wider widths that could show this kind of moderating effect.

TABLE 8. — Pieces in in-grade sort resulting from shifts from higher grades of strength-grade sort.

Statistic	Grade			
	Select Structural	No. 1	No. 2	No. 3
In-grade sample size	54	24	62	72
No. of pieces shifting from higher grades	0	0	Select Structural = 18 No. 1 = 6	Select Structural = 25 No. 1 = 7 No. 2 = 7

TABLE 9. — Comparison of allowable shear and compression perpendicular to grain stress to several domestic species groups.

Species group	Allowable stress (psi)	
	F_v	F_{cp}
Dahurian larch	70	515
Douglas Fir-Larch	95	625
Hem-Fir	75	405
Spruce-Pine-Fir South	70	335

that do not affect strength. This movement tended to raise the test statistics in the lower three grades. Since the highest grade could only lose pieces to the lower grades, it is difficult to estimate *a priori* how that would affect property statistics. In this study, there was a substantial increase in allowable bending stress and MOE of Select Structural pieces in moving from the strength-grade to the in-grade sort, even though that meant moving 44 pieces to lower grades. We take that to be a happenstance of the study; the same trend might not occur if an independent study were made.

The strength-grade sort contained only pieces that had strength-reducing characteristics (knots or general slope of grain) prescribed for that grade by the National Grading Rule. As visually graded lumber is taken from a sawmill and into commerce, a parcel of any grade below the highest grade typically contains pieces that are not limited by these strength-reducing characteristics, but rather fall into that grade (instead of a higher grade) because of crook, wane, or some other limiting characteristic that does not affect strength. Thus, the strength-grade sort has the characteristics of a worst case that rarely, if ever, occurs.

The in-grade sort is meant to be more typical of the commercial parcel; however, if allowable properties are established by the in-grade sort, this im-

mediately raises several questions: How much lumber is in that sort because of those non-strength-limiting characteristics? How does that higher strength material affect the allowable property designation for the grade? Can that proportion of higher strength material or better material typically be expected in commercial parcels?

We examined how many pieces in each grade, for the in-grade sort, fell into the grade for non-strength reasons. Those results are shown in Table 8. By definition, no such pieces can be graded Select Structural. An examination of the National Grading Rule revealed that the limitations for non-strength-reducing characteristics are the same for Select Structural as for No. 1. Thus, in Table 8, there is also a zero for No. 1. Thirty-nine percent of No. 2 pieces and 54 percent of No. 3 pieces in the in-grade sample should have strength more like that of a higher grade. In most cases, that higher grade is Select Structural, even for those pieces that are graded as No. 3.

Whether strength-grade or in-grade sorts are more appropriate in representing a species is a matter of philosophy, and such questions are usually settled in formulating a standard. The Green-Shelley protocol and ASTM D 1990 establish in-grade as the appropriate criterion. However, that was done in the context of the North American In-Grade Program (14), where many sawmills were sampled throughout the producing range in the United States and Canada. Properly graded pieces were accepted into the sample for non-strength-reducing reasons as well as for the knots and slope of grain with the claim that "these data represent the global strength and stiffness qualities of lumber in the marketplace."

From this study of dahurian larch, we can make no such claim. Thus, in this limited study — limited because

the lumber was obtained from only two nearby locations in a vast range, because it was not obtained from a sawmill that funnels lumber into commerce, and because our sample sizes were below those required by the protocol — we would argue that the strength-grade results reasonably represent the grades of dahurian larch, on the safe side. A larger sample that overcomes the limitations would probably yield higher allowable properties in bending and the properties might equal or exceed those of Douglas Fir-Larch from the northwestern United States.

In effect, F_t and F_c are derived from F_b by formula. Thus all observations about the bending allowable stress will be reflected in the tension and compression parallel-to-grain stresses. That is the requirement of the Green-Shelley protocol. However, in National Grading Rules, tension and compression values for northwest species groups were obtained from actual tests in tension and compression. For this reason, these two published allowable stresses for a domestic species group will not so closely follow F_b trends. In fact, the F_t value for No. 3 Douglas Fir-Larch is the same as that shown in Table 7 for dahurian larch, but increases above dahurian larch progressively for higher grades, and is 1,500 psi for Select Structural Douglas Fir-Larch. Dahurian larch tension values are more like published values for Hem-Fir. The F_c for dahurian larch is well below that published for Douglas Fir-Larch, and is more like that of Spruce-Pine-Fir South. Perhaps the relation of tension and compression properties to bending strength for dahurian larch is unlike that shown in ASTM D 1990, section X.4. However, Gupta et al. (12) reported the UTS/MOR relationship very similar, with the suggestion that a higher tensile property would be predicted for dahurian larch than for Douglas Fir-Larch. A plausible argument can be made that the tension and compression values would generally be higher for dahurian larch if obtained from test than if obtained from formula.

The direct method and the DeBonis method resulted in surprisingly similar allowable stresses for shear and compression perpendicular to grain. The direct method is far simpler and closely tied to what was measured in the experiment. The DeBonis method is

fraught with assumptions and adjustments; but it does follow ASTM D 245 closely. However, ASTM D 245 and ASTM D 2555 were clearly developed on and for North American species and rely on dry/green ratios that are not generally available for foreign species.

In a previous report (7), we discussed the effect of ring angle on strength in compression perpendicular to grain and argued that the allowable stress for that property might appropriately be increased because of the uncontrolled ring angle that existed in the dahurian larch test specimens. That argument holds equally well here; however, current standards do not permit this increase.

Allowable stresses in shear and compression perpendicular to grain for several domestic softwood groups are contrasted with those for dahurian larch in Table 9. Allowable shear stress for dahurian larch appears to be about the same as that for Spruce-Pine-Fir South, or perhaps Hem-Fir; compression perpendicular to grain of dahurian larch is between that of Hem-Fir and Douglas Fir-Larch.

CONCLUDING REMARKS

The sample size of dahurian larch (*Larix dahurica*) 2 by 4 lumber in this study was only 15 percent of that required by contemporary standards. However, the study gives an idea of the approximate allowable properties appropriate under the ALSC standard for dimension lumber of the species.

Allowable bending properties were determined on the basis of knots and cross-grain (strength-grade) prescribed for Select Structural, No. 1, No. 2, and No. 3 grades in the National Grading Rule. These properties were also obtained for the same grades using all the characteristics that are limited in the National Grading Rule (in-grade), including many features that do not affect mechanical properties. The ALSC guideline (9) for deriving allowable properties specifies that the in-grade sort will be used. For that case, allowable MOE for dahurian larch was 100,000 to 200,000 psi higher than that currently accepted for Douglas Fir-Larch of the same grades. Similarly, al-

lowable bending stress (F_b) was calculated to be from 150 to 525 psi higher than that for Douglas Fir-Larch, depending on grade.

The strength-grade sort gave more conservative values, probably more appropriate given the limitations in our sample. In this case, MOE for dahurian larch was 100,000 psi higher than that for Douglas Fir-Larch, and F_b was from 200 to 550 psi lower, except for No. 3. We suspect that our in-grade and strength-grade sorts provided upper and lower bounds; if a much larger sample were taken in a way more representative of the growth range of dahurian larch, the results would likely be between those for our two sorts — perhaps much like Douglas Fir-Larch in the United States.

Values for tension (F_t) and compression parallel to grain (F_c) were derived by formula from bending strength values. F_t derived this way is about like that for Hem-Fir; F_c is similar to Spruce-Pine-Fir South. Green and Shelley (9) indicate it is believed equations (1) and (2) are conservative, and we suspect that is why dahurian larch bending allowable properties are about like Douglas Fir-Larch, but tension and compression properties are comparatively lower. The current procedure (9) enjoins standards for deriving allowable shear and compression perpendicular-to-grain stresses based on tests on green lumber with a dry/green ratio known for the species. We tested at near 15 percent MC, and no dry/green ratios were available to us. Therefore, we used two different non-standard procedures to derive these allowable properties. The results were not greatly different in either case and yielded values approximate to those for Spruce-Pine-Fir South and nearly as high as those for Hem-Fir.

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