Comparing the Flatwise Modulus of Elasticity (E_{flat}) of Green Lodgepole Pine Lumber & Grey-Stage Dry MPB Lumber

Prepared for
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Forestry Innovation would also like to recognize the efforts of Lanny Pedersen and Wes Peterson running the lumber through the Metriguard HCLT 7200 MSR machine and recording the flatwise MOE for each tested piece on this project on December 28th, 2006.

Executive Summary

Forestry Innovation Investment Ltd. carried out a manufacturing trial at the L&M Lumber Ltd. and Nechako Lumber Company Inc. facilities in Vanderhoof, B.C. in November 2006. This manufacturing trial produced “stud” grade lumber from a control sample of green lodgepole pine logs and from a sample of grey-stage mountain pine beetle killed logs. The mountain pine beetle logs were harvested from a timber stand that had been dead for 5+ years (died between 1998 and 2001).

In this report the control sample will be referred to as “green lodgepole pine lumber” which means the lumber has been manufactured from live lodgepole pine trees or green attacked trees which had not been killed by mountain pine beetles at the time of harvest. The lumber has been kiln dried to less than 19 percent moisture content as per normal CLS lumber production standards.

Approximately 500 cubic meter samples, each from live green lodgepole pine logs and grey-stage 5+ years dead MPB logs were scaled, graded and recorded prior to feeding into the sawmill on November 4, 2006. The lumber outturn was tracked and recorded prior to kiln drying. On November 18, 2006 the dried lumber from both samples was processed through the planermill, packaged and recorded. The predominant product manufactured was 96 inch long 2x4 stud grade lumber. Three randomly chosen sample packages from both the green lodgepole pine lumber control sample and the grey-stage MPB lumber sample were set aside for a flatwise bending property evaluation (MOE_{flat}) using a regular commercial high capacity lumber tester or MSR machine.

The six packages of 96 inch long 2x4 lumber set aside for bending property testing were transported to Plateau Division, Canadian Forest Products Ltd. They were run through the in-line Metriguard HCLT 7200 Continuous Lumber Tester (CLT) MSR machine and the individual piece flatwise average Modulus of Elasticity values (MOE_{flat} or E_{flat}) were recorded. The data was then analyzed to determine if the E_{flat} were different between the green lodgepole pine lumber sample and the grey-stage dry MPB lumber sample. The statistical analysis of the data showed no significant difference between the E_{flat} values of the two types of samples.

The average E_{flat} value for the sampled green lodgepole pine lumber was 1.73 million psi and the average E_{flat} value for the sampled grey-stage dry MPB lumber was 1.66 million psi. The overall distribution of the average E_{flat} for the MPB lumber sample (1127 pieces) was slightly lower than the lumber manufactured from the live (green) lodgepole pine sample (1136 pieces).

Base on the CLT E_{flat} readings, the material was sorted into different E_{flat} classes. Overall the number of pieces falling within a particular MOE range varied between the MPB lumber and the green pine lumber. Fewer pieces of the MPB lumber were able to meet the highest two E_{flat} classes. There were more MPB lumber pieces that met the middle E_{flat} class than the green pine lumber. And

there were very similar numbers of pieces for both the MPB and the green pine lumber that met the lower E_{flat} classes. A greater proportion of the MPB lumber pieces could not meet the lowest E_{flat} rating compared to the green pine lumber pieces.

The findings of this test provide a general indication that the flatwise bending MOE of the grey-stage MPB lumber does not appear to be a significant concern when manufactured into studs or short length lumber.

As the test results portrayed here are relevant to the specific test samples obtained, these results should not be extrapolated across grey-stage MPB lumber, in general. It should also be noted that the test was performed with short length (96 inch) lumber. Lumber length may affect the accuracy of the average flatwise E-value for an individual piece. Longer length (16 foot to 20 foot) and wider width dimension lumber would likely yield a more reliable assessment of full length average MOE values.

Furthermore it should be noted that all of the modulus of elasticity measurements reported are flatwise properties measured using the in-line Metriguard HCLT 7200 MSR machine located at the Plateau Division, Canadian Forest Products Ltd. The results show the *relative* differences in flatwise modulus of elasticity for the two samples tested. The lumber tested in this project was not subjected to edge bending stress or modulus of elasticity quality control tests such as those required in the NLGA SPS 2 product standard[1]. The lumber was also not subjected to Visual Quality Level inspection required in NLGA SPS 2. Therefore it is not possible to make absolute statements about the relative bending strength of the two samples nor MSR grade outturns based on this data.

[1] SPS 2: NLGA Special Products Standard For Machine Graded Lumber, National Lumber Grades Authority, New Westminster, BC

Introduction

Forestry Innovation Investment Ltd. (FII) operates a Mountain Pine Beetle Program (MPB) that is focused on wood products research. The research program investigates fibre quality issues, manufacturing processes, new product development, new markets opportunities, marketplace communications and product promotion.

One of the important elements of the wood products research program is gaining an understanding of the fibre characteristics of the old grey-stage dead MPB affected fibre because this will be the majority of fibre available for wood products manufacture in the Interior of British Columbia within five years. In order to fully understand the linkages between the changing fibre characteristics and their effects on the manufacturing processes and the quality and properties of the products manufactured FII has commenced a program of mill manufacturing trials in the high-speed dimension sawmills located around the Interior of B.C.

Background

In order to test the dynamics of operating verifiable and statistically sound mill trials in a large commercial operation producing CLS dimension lumber FII conducted an initial mill manufacturing trial at the L&M Lumber Ltd. and Nechako Lumber Company Inc. milling complex in Vanderhoof, B.C. in November 2006. The objective was to study the differences between green lodgepole pine and old 5+ years dead grey-stage MPB affected fibre. These facilities annually produce over 210 million board feet of studs and related dimension products from the spruce, lodgepole pine and balsam stands in the North Central Interior. The equipment used in the facility is high speed and handles approximately 90 000 pieces per 8 hour shift.

The L&M mill trial utilized a control sample of approximately 570 m^3 of green lodgepole pine logs and a grey-stage 5+ years dead MPB log sample of approximately 485 m^3. Both samples were processed through the L&M sawmill under controlled production conditions and the lumber produced for each sample was tallied, piled for drying and the volume recorded, by dimension. The lumber from the two samples was then kiln dried under regular commercial conditions and run through the Nechako Lumber Company planermill two weeks later for finishing, packaging, grading and final tally by dimension. The packages were then labelled as to which test sample they belonged to and were stored in the yard until released for sale. A representative of the Quality Control Department of the Council of Forest Industries, the lumber grading inspection agency responsible for certifying lumber grading accuracy, was in attendance during the planermill run

The single largest item produced from the two sample runs was a 96 inch 2x4 stud grade lumber. The green lodgepole pine control sample yielded 46

packages of the finished product as a 96 inch 2x4 stud. The grey-stage dry 5+ years dead MPB sample yielded 33 packages of the finished product as a 96 inch long 2x4 studs.

After observing the production of both the green pine control sample and grey-stage dry MPB sample (96 inch 2x4 studs) there appeared to be little visual difference in the "on-grade" products from the two samples. Because there was little visual difference in the two samples FII determined there was an opportunity to conduct a supplementary flatwise bending modulus of elasticity (E_{flat}) test on a portion of the two samples of the 96 inch 2x4 on-grade stud products to compare this physical characteristic of the two samples.

Objectives of Supplementary Bending MOE Testing

FII conducted a controlled conditions manufacturing trial at a high-speed dimension lumber sawmill complex to assess the relative recovery and grade outturn differences between lumber manufactured from green lodgepole pine logs and grey-stage dead 5+ years MPB logs. The on-grade lumber manufactured in the trial appeared to be visually similar for both samples of lumber produced.

A supplementary testing trial was designed to explore the E_{flat} property of the green lodgepole pine control sample lumber and the dry grey-stage MPB sample lumber.

The specific objectives for the supplementary testing were:

- To determine if the physical E_{flat} properties of the green lodgepole pine lumber differs significantly from grey-stage MPB lumber.
- To determine if further comprehensive testing of grey-stage dry MPB lumber should be scheduled

An E_{flat} test protocol was developed that would allow the test of this physical characteristic utilizing a commercially available High Capacity Lumber Testing machine (MSR machine) that is used by many high-speed dimension facilities to rate their lumber output and establish the average E_{flat} reading for each rated piece of lumber. It is noted that the MSR machine also evaluates the low point E_{flat} value of each piece and uses both the average and low point E_{flat} value to grade the material. In this study only the average E_{flat} values were considered.

An arrangement was made with Plateau Division, Canadian Forest Products Ltd. in Vanderhoof to use their Metriguard HCLT 7200 MSR machine to test and record the modulus of elasticity for a test sample of both the green control lumber and the grey-stage dry MPB lumber.

Three packages of 96 inch 2x4 studs were randomly selected from the 46 packages produced along with three randomly selected packages from the 33

packages of grey-stage dry MPB studs produced for MSR testing in the Plateau Division equipment.

The six packages of test lumber were shipped to the Plateau Division and run through one of their HCLT 7200 Metriguard machines on December 28, 2006 where the average E_{flat} value registered by the grading machine was recorded for every individual piece of both samples.

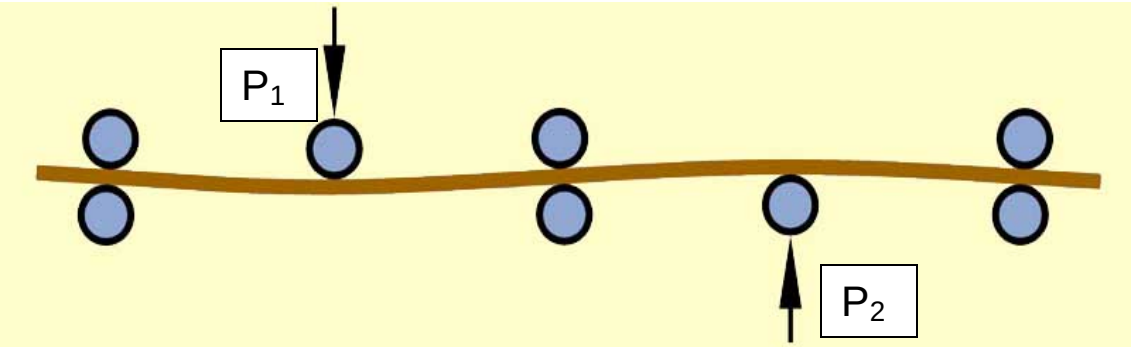
Measuring Flatwise Bending MOE Values

Many high speed dimension lumber manufacturers in the Interior of BC have installed MSR machines in-line in their planermill complexes in order to recover high grade quality-certified MSR products. Most utilize equipment manufactured and supplied by Metriguard Inc. The use of the HCLT 7200 provides an extra level of quality assurance for MSR lumber which has been produced in accordance with the NLGA SPS 2 Special Product Standard For MSR Lumber.

Canfor Plateau Line 2 Metriguard HCLT 7200 MSR Machine

[7] Description of Metriguard HCLT 7200 obtained from materials prepared by James D. Logan, P.E., President, Metriguard Inc.

The HCLT lumber stress grading machine measures the flatwise bending MOE by means of a rolling stiffness test in which the material is deflected downward, then upward to a prescribed deflection while the force at the center of each bending span is monitored. As a direct result of this induced deflection, a bending stress is applied in the flatwise direction. The MOE measurement zone extends along the length to within approximately 27.5 inches from the ends of each piece. The full-reversing 100 percent flow process is used to compensate for lack of straightness in the lumber. For 1.5 inch thick lumber the machine is set to produce a fixed deflection of 5/16 inches at the mid-span for each of the two test zones. The loads P_1 and P_2 are measured by load cells located at the mid-span position. These loads are averaged for the purpose of calculating the MOE profile along the length of the lumber. The MOE profile is calculated for each piece of lumber. Typically the average MOE and a minimum MOE are used to determine the MOE grade of the board.



Metriguard HCLT Model 7200 Operating Principle Diagram

Grade boundary limits (average flatwise MOE and minimum flatwise MOE) are set for the grades to be produced. The board average MOE (and minimum MOE) are compared with the grade boundary settings approved by the mill grading agency to determine the MOE grade for each piece of lumber.

Following the MOE grade evaluation each piece is also visually graded to meet the minimum requirements for visual characteristics for MSR lumber according to the NLGA SPS 2 Product Standard.

The allowable design properties for MSR lumber are given in SPS 2. For Instance the $1650F_b$ – 1.3E grade has an average edge bending MOE of 1.3 million psi and an allowable edge bending strength[1] of 1650 psi. The permissible combinations of MOE and F_b for MSR lumber are specified in SPS 2. A selection of common MSR grades is shown in Table 1

[1] The allowable bending strength is expected to be the lower 5th percentile divided by 2.1

The NLGA SPS 2 standard requires that mills maintain a daily quality control program for edge bending MOE (E_{edge}) and bending strength. Quality control charts derived from the results of daily average E and bending strength test data are used to monitor the difference between process quality level and a predetermined conformance quality level. These charts indicate when changes in the process settings are needed to bring the MSR grading process back into conformance with SPS2 requirements[2].

Table 1: Allowable Design Properties for MSR Lumber

Allowable Bending Stress	***Average Modulus of Elasticity (E_{edge}) million psi***
2400	***2.0***
2100	***1.80***
1800	***1.60***
1650	***1.50***
1450	***1.30***

Flatwise Bending Test Results

The flatwise bending tests of the green lodgepole pine lumber sample and grey-stage dry MPB lumber sample were carried out on December 28, 2006 on the Number 2 planer line at Plateau Division, Canadian Forest Products Ltd. in Vanderhoof, B.C. The three packages of green lodgepole pine lumber were placed on the planer infeed tilt hoist and run through the planer (which had been opened up so it did not touch the pieces). After passing through the planer the lumber then passed through the Metriguard HCLT 7200 MSR testing machine. Each individual average E_{flat} value was recorded manually from the reading appearing on the computer monitor after the piece passed through the machine. The feed speed was significantly reduced to ensure that the reading for each individual piece could be recorded accurately. A total of 1,136 pieces of green lodgepole lumber were recorded. All MOE tested green lodgepole pine lumber was transferred to the lumber piling and packaging system where it was repackaged.

Upon completion of collection of the MOE data for the green lodgepole pine lumber the three packages of grey-stage dry MPB lumber were placed on the tilt hoist and run through the planer to the Metriguard MSR testing machine. Again

[2] See NLGA SPS 2 for complete details on the quality control programs.

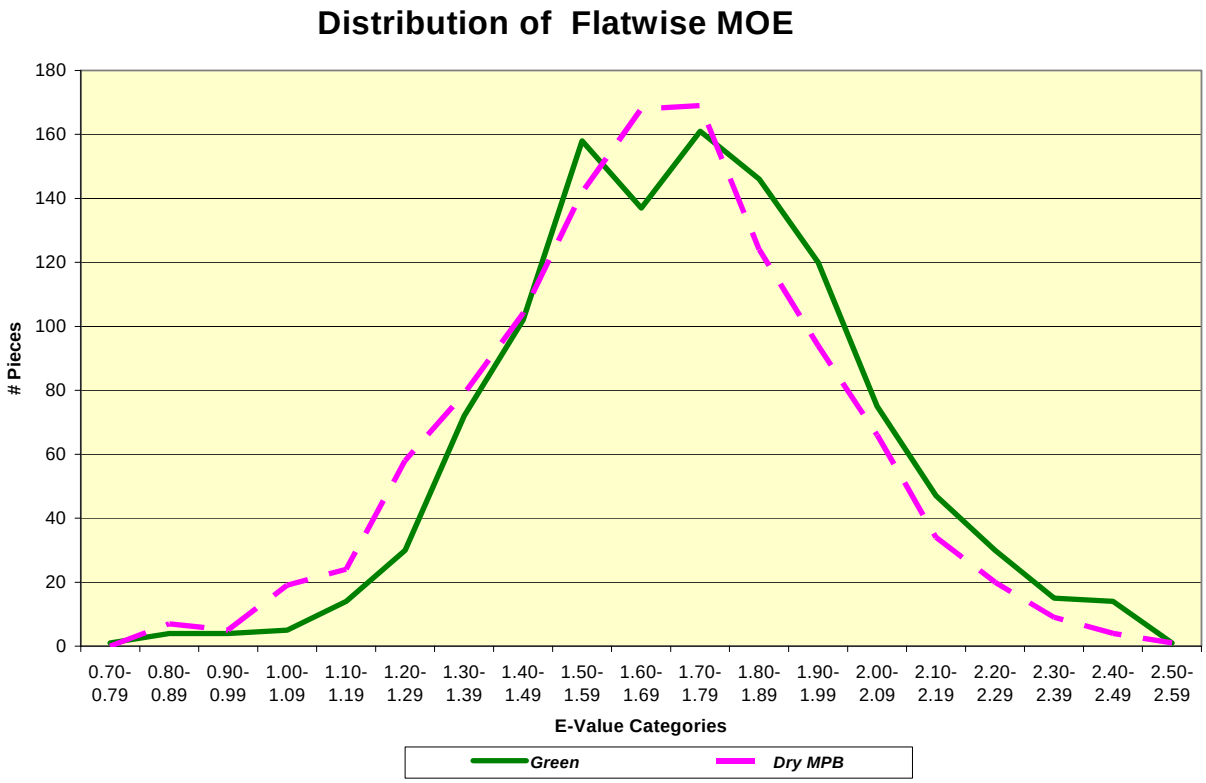
each individual average E_{flat} value was recorded manually from the reading appearing on the computer monitor when the piece passed through the machine.

A total of 1,127 pieces of grey-stage dry MPB lumber were recorded. All MSR tested grey-stage dry MPB lumber was transferred to the lumber piling and packaging system where it was repackaged.

Table 2:

MOE_{flat} Distribution for Green Pine and Grey-Stage MPB Lumber

MOE Category	***Green Pine Lumber # pieces***	***Grey-Stage MPB Lumber # pieces***
0.70 - 0.79	1	0
0.80 - 0.89	4	7
0.90 - 0.99	4	5
1.00 - 1.09	5	19
1.10 - 1.19	14	24
1.20 - 1.29	30	58
1.30 - 1.39	72	79
1.40 - 1.49	102	104
1.50 - 1.59	158	142
1.60 - 1.69	137	168
1.70 - 1.79	161	169
1.80 - 1.89	146	124
1.90 - 1.99	120	94
2.00 - 2.09	75	66
2.10 - 2.19	47	34
2.20 - 2.29	30	20
2.30 - 2.39	15	9
2.40 - 2.49	14	4
2.50 - 2.59	1	1
Total All	1136	1127



Lumber products with MSR (machine stress rating) values are generally sold for a premium because the individual pieces have been non-destructively tested and the product properties are monitored to achieve the specified product properties using statistical quality control requirements recognized by code authorities.

A comparison was made between the E_{flat} distribution for the green lodgepole pine lumber samples and the grey-stage dry MPB lumber samples. Table 3 shows the E_{flat} ranges adopted for 5 MOE classes used in the subsequent comparisons.

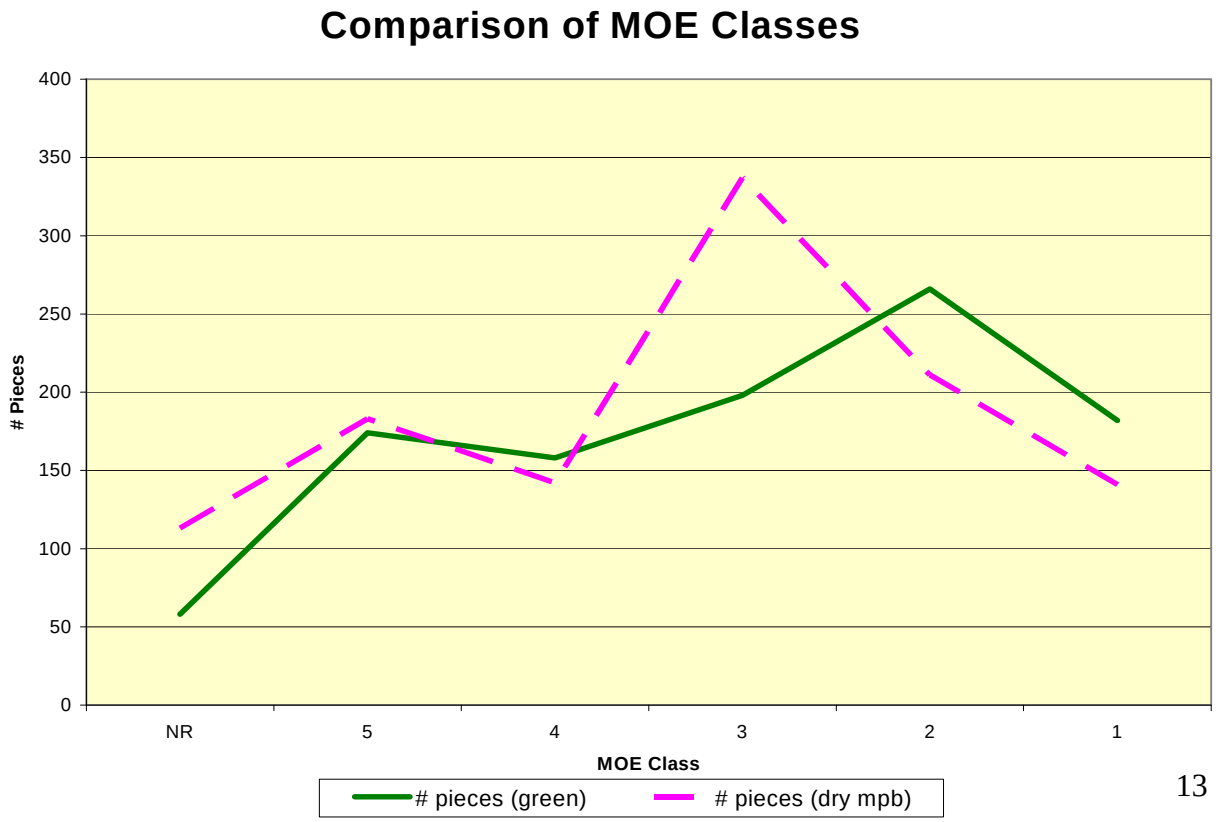
Table 3: MOE Classes and Related E_{flat} Ranges

MOE Class	***E_{flat} Range*** ***(million psi)***
1	***2.0+***
2	***1.80 - 1.99***
3	***1.60 – 1.79***
4	***1.50 – 1.59***
5	***1.30 – 1.49***

Table 4:

MOE Class Distribution for Green Pine and Grey-Stage MPB Lumber

MOE Class	***Green Pine Lumber Number of pieces***	***Grey-Stage MPB Lumber Number of pieces***
1	182	141
2	266	211
3	198	337
4	158	142
5	174	183
Not Rated	58	113



Statistical Description of the Sample Data[8]

The sample design was a one-stage cluster sample. For the green lodgepole pine lumber, 3 packages (primary sampling unit) were randomly selected from 46 total packages. All boards (secondary sampling units) within each of these 3 packages were tested. For the grey-stage dry MPB lumber, 3 packages were randomly selected from 33 total packages. All boards within each of these 3 packages were also tested. A basic statistical description of the data from each of the two test groups is provided in Table 4. Note that analyzing the data as a simple random sample (SRS) inflates the precision of the estimate. Analyzing the sample as a one-stage cluster provides a more realistic estimate of precision for the results.

The higher sampling error for the grey-stage dry MPB lumber (15.5% compared with 5.7%) is indicative of higher mean E-rating variability among the sampled packages[3]. Sampling error is often used to assess statistical acceptability of a sampling process. The achieved sampling error is usually compared to a target sampling error, set prior to sampling.

Table 5: Basic statistics for E-ratings for the green lodgepole pine lumber sample and the grey-stage dry MPB lumber sample.

Statistic	***Test group***	
	Green pine lumber	***Dry MPB lumber***
Total number packages	46	33
# packages sampled ("clusters")	3	3
Total number boards sampled	1136	1127
Mean E-rating	1.723	1.663
SE[4] of mean (cluster sample)[5]	0.022984	0.060031
95% CI (cluster sample[6])	1.624 – 1.822	1.405 – 1.922
Sampling error as % of the mean (at 95% confidence level)	5.7%	15.5%

[3] For green lumber, the individual package means were 1.77, 1.69 and 1.71. For dry MPB lumber, the individual package means were 1.70, 1.54 and 1.75.
[4] SE = standard error; calculation of the SE incorporates a finite population correction (fpc) factor
[5] Analyzing the data as a simple random sample (SRS) inflates the precision of estimate, i.e. gives the impression that the results are more precise than they actually are.

SRS statistics	*Test Group*	
	Green Pine Lumber	Grey-stage dry MPB lumber
n	1136	1127
Mean E-rating	1.723	1.663
Variance (assuming SRS)	0.07864	0.07918
SE of mean (assuming SRS)	0.008044	0.007992
95% CI (assuming SRS)	1.707 – 1.739	1.648 – 1.679

[6] assumes 2 df i.e. #clusters – 1

[8] Jahraus & Associates Consulting Inc. has provided the statistical analysis for the sampling methodology and significance of the results obtained

Hypothesis Tests on the Data:

The general ("null") hypothesis to be tested was: "there is no difference between the mean E-rating of green lumber and the mean E-rating of dry MPB lumber". A two-sample t-test was used to test this hypothesis[9]. At a 5% significance level, we could not reject the null hypothesis based on this sample (assuming a one-stage cluster sample). In other words, based on this sample, there was not enough evidence to detect a statistically significant difference between the mean E-rating for green lumber and the mean E-rating for dry MPB lumber, with 95% confidence.

In addition to looking at the mean difference in E-ratings, the distribution of MSR ratings for green lumber and dry MPB lumber were also compared. A Chi-Square test on the distribution of samples by MSR rating[10] indicates that the proportion of samples across the MSR rating classes is significantly different for the dry MPB lumber compared with the green lumber (see table 5). There was a higher proportion of grey-stage dry MPB boards that were "not rated" (10.0%) compared with the green lodgepole pine lumber (only 5.1%). A lower percentage of the grey stage dry MPB lumber achieved MSR ratings above 1800 (i.e. only 31.2% with MSR ratings of 2100 or 2400), compared with the green lodgepole pine lumber (39.4%).

Table 6: Distribution of samples by MSR rating class: green lodgepole pine lumber versus grey-stage dry MPB lumber.

Test group	Number of samples by MSR rating category						
	Not rated	*1450*	*1650*	*1800*	*2100*	*2400*	*Total*
Green lumber	58 (5.1%)	174 (15.3%)	158 (13.9%)	298 (26.2%)	266 (23.4%)	182 (16.0%)	1136 (100%)
Dry MPB lumber	113 (10.0%)	183 (16.2%)	142 (12.6%)	337 (29.9%)	218 (19.3%)	134 (11.9%)	1127 (100%)

Statistical Data Analysis Summary:

The mean E-rating for the green lumber sample was 1.72 (± 5.7% with 95% confidence) whereas the mean E-rating for the dry MPB lumber sample was 1.66 (± 15.5% with 95% confidence). There was much higher variability in E-ratings within the dry MPB sample compared with the green lumber sample. Based on this one-stage cluster sample, a statistically significant difference between the mean E-ratings of the two test groups could not be detected. It was also noted that the mean E-ratings for both test groups fell within the same MOE class (i.e.

[9] The standard error for the t-test was based on the sample standard errors computed using one-stage cluster sampling formulae. If SRS were to have been assumed, the null hypothesis would have been rejected and we would have concluded that the two mean E-ratings *were significantly different!*

[10] ignoring clusters

MOE Class 3). Hence there may also be no practical difference in *average* strength between the two groups, based on MOE class class. However, some distributional differences in MOE class were noted. In particular, there was a higher proportion of grey-stage dry MPB lumber that did not met the minimum MOE class. On the other end of the MOE distribution, a higher proportion of green lodgepole pine lumber was able to achieve the highest MOE ratings of MOE classes 1 and 2.

Conclusions:

It appears there is very little difference in the E_{flat} values for the grey-stage MPB 2x4 96" long stud grade lumber when compared to the green lodgepole pine control sample The statistical analysis has indicated that this difference is not significant for the mean E values although the average E_{flat} is slightly lower in the MPB pieces (1.66 million psi) than the green lodgepole pieces (1.73 million psi).

There is a difference in the distribution of the pieces within the E classes chosen for this study. The grey-stage MPB lumber tends to have a lower number of pieces in the higher value E classes (1 and 2) and a greater concentration in the intermediate E class (3). The concentrations of pieces that fall within the lower E classes (4 and 5) are very similar. There are a larger proportion of the grey-stage MPB pieces that fall below the minimum E class chosen in this study and consequently classified as not rated.

Recognizing that the MOE evaluations are based only on average flatwise measurements and that the lumber was not subjected to visual checks nor the MOE and bending strength quality control testing required in SPS 2, the findings of this study suggest that the MOE distributions of grey-stage MPB lumber do not appear to be a significant concern when manufactured into studs or short length lumber.

It should be recognized the assessment results portrayed here are relevant to the specific test samples and MOE test methodology obtained from the milling test run at the L&M Lumber Ltd. facilities in Vanderhoof in November 2006 and the specific characteristics of the grey-stage MPB fibre obtained from a single source location in the Vanderhoof Forest District. These results should not be extrapolated across grey-stage MPB stud grade lumber in general because there may be individual fibre characteristics that vary from location to location depending on the growing site, climatic conditions, time of harvest, time-since-death of the stems or any other number of unidentified conditions.

High capacity lumber testing for the modulus of elasticity in short length (96 inch) sample pieces may also impact grade yields as essentially only 4 feet of the 8 foot piece length are tallied for average E value. Longer length dimension lumber (16 ft. to 20 ft.) may yield a more reliable (typical) assessment of E values from the mechanical testing method of the HCLT MSR machine.

It is important to recognize that this study cannot be used to make specific direct inferences about the different grade outturns for grey stage and green MSR lumber produced according to the NLGA SPS 2 product standard. In order to make such inferences it would be necessary to classify the lumber using appropriate grade boundary settings and verify that the output for both grey stage and green MSR lumber meets the quality control requirements of the NLGA SPS 2 Special Product Standard.

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