NEW CONCEPTS OF GRADES

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Introduction

There is a considerable history to the selection or grading of lumber for structural purposes and progress continues, particularly at the international level. The publication of Standard Grading Rules for Canadian Lumber (9) is a recent and notable achievement in Canada. These rules, written by the National Lumber Grades Authority in 1970, apply to all regions of the country and are referenced by the National Building Code of Canada. Additionally, there is very close agreement with grading rules in the United States. The National Grading Rule, which is certified as conforming to the American Softwood Lumber Standard (10), is the common denominator.

Although the standardization accomplished at this time in North America is noteworthy, a multiplicity of grades remain. For example, for nominal 2 x 4 and smaller framing lumber, there are up to eight grades available and for each grade there are eight possible species groups. Multiply this by the three sizes, at least, that are assigned different allowable stresses and the total number of combinations approaches 200. Unquestionably, there is efficiency in sorting lumber for a variety of uses. In frame-construction, there are sills, joists, studs, plates, rafters, trusses, etc. and the strength property or properties important to each may differ. Such differences can be related to lumber characteristics and appropriate grades can be established. Further, there is a range in the quality of lumber produced and prices will reflect this variation in quality. Again, suitable characteristics can be defined to establish the grades which will provide a satisfactory return.

There are, of course, practical constraints which restrict the number of grades that can be established. Lumber travels quickly through high-production Canadian sawmills and the characteristics which distinguish between grades must be readily detectable and measurable in the time and with the facilities available for grading. There is another factor, not so obvious, that should be considered, too. A grade of lumber that has been sensibly defined and carefully selected will still display a continual and perhaps substantial variation in properties of strength and stiffness. This has to be accepted when grades are based on a minimum strength ratio, which is the case for the NLGA grades (5).

By definition, the strength ratio of a structural timber is the hypothetical ratio of its strength to that which it would have if no weakening characteristics were present (2). To give an example, the NLGA Select Structural Grade of Joists and Planks has a strength ratio of 0.65; that is, the weakest piece in the grade is said to have 65 percent of the strength of lumber free from any defects. The proportion of pieces which approach the minimum ratio for a grade will vary over a period of time in a mill, or between mills at a given time and thus, the strength and stiffness of a grade will fluctuate accordingly. And, since strength and stiffness do fluctuate, some shipments of a lower grade or species groups may at times have minimum and/or average strength and stiffness properties which equal those of a higher grade or species group. Considering the complexity of maintaining the supervising present grading operations and the fact that such overlapping may occur, there is good reason to determine whether the assigned differences in strength and stiffness consistently exist between NLGA species groups and grades. Surely, if these differences which justify the process of separation cannot be detected regularly then there is the opportunity for further consolidation.

The Western Forest Products Laboratory began a survey of the strength and stiffness of structural light framing, joists, and planks when the NLGA grades were introduced in 1970. Although the study remains active for tests in compression and tension, the flexural tests have been completed. The results for these tests are used in this paper to emphasize some points perhaps overlooked but potentially important to effective stress grading.

Experimental Work

Over a period approaching three years, 99 parcels of dimension lumber were selected, delivered to the laboratory, and tested. Each parcel of about 30 pieces represented one combination of species group, grade, size, and mill and was selected randomly during four to eight hours of one day's production. Two parcels were taken from a mill for each combination, with an interval of a month or more between to make 60-piece samples. Lumber associations and larger companies were polled to determine species groups, grades, and sizes which were common to certain regions. Forest inventory and mill production figures were reviewed, also, to ensure that the samples were representative of dimension lumber shipped from Western Canada. Three major species groups, four grades and four nominal sizes were covered. The species groups sampled were Douglas fir-Larch, Hem-Fir, and Spruce-Pine-Fir, as defined in the NLGA rules. The grades were Select Structural, No. 1, No. 2, and No. 3, and the nominal sizes in inches were 2 x 4, 2 x 6, 2 x 8, and 2 x 10. The survey encompassed the western Canadian provinces of British Columbia and Alberta. A total of eight forest districts were covered and about 40 mills, responsible for almost one-half of Canada's lumber production, were sampled.

Samples were selected directly from the planer chain or from packages built up at the chain during the period of production already noted. Off-grade pieces were retained but an equal number of on-grade pieces were added so that later analyses could either include or exclude the effect of imprecise grading. This report considers only material verified as on-grade. The Douglas fir-larch and Hem-Fir samples were unseasoned for the most part, whereas those of Spruce-Pine-Fir were, with one exception, kiln dried. Wherever possible the log source for the mill was noted as well as general sawing procedures and drying schedules. The unseasoned samples were dried in a small kiln under mild and carefully controlled conditions. All lumber was stored at the WFPL for some time before testing. The dimensions of a piece and the moisture content were determined at the time of sampling and again at the time of testing. Average moisture content at the time of testing was 12 percent with the range of moisture content in a sample being less than 3 percent.

All of the approximately 3000 pieces were tested in flexure, in accordance with ASTM D198-67, Standard Methods of Static Tests of Timbers in Structural Sizes (1). The weaker edge of the piece, when obvious, was loaded in tension. Span to depth ratios of 21, plus or minus 10 percent, were used for the 2 x 6, 2 x 8, and 2 x 10 sizes; ratios considerably larger than 21 were used for 2 x 4's longer than eight feet. The properties of modulus of rupture (MOR) and modulus of elasticity (MOE) were determined, and grade characteristics and primary and secondary causes of failure were recorded.

Results and Conclusions

Differences between species groups and between grades are examined respectively, in Figures 1 and 2 for both MOE and MOR. The comparisons between species groups are based on the same grades and sizes of lumber and the comparisons between grades are based on the same species groups and sizes. A student "t" test was used to determine whether differences in MOE were significant, whereas a "U" or Mann-Whitney test was used for MOR. Since allowable stresses are governed by near minimum values, the significance tests for MOR were applied to the lowest ten values from each of the 60-piece samples. The uncertain distribution of such values is not critical to the U test. The significance tests for MOE were based on complete samples because the allowable modulus is derived from the average value.

For the most part, differences between sample means of more than 100,000 psi for MOE were found to be significant at the $\alpha = 0.05$ level. Differences between sample means of 500 psi or more for MOR were similarly significant. These differences, allowing for the usual reduction factor of 2.1 for MOR, are of the order expected between grades and between species groups. The results of Figures 1 and 2 therefore provide a valid indication whether such differences exist in practice. There was not equal sampling of all species groups, grades, and sizes as noted previously. However, as also noted, the sampling was related to lumber production, and the patterns that emerge for differences in strength and stiffness form a fair appraisal of whether selection and separation by the NLGA Rule is realistic and worthwhile.

The species groups listed in the NLGA Rule take into account the ease and benefit of marketing woods that come from the same general region and have similar properties of strength and stiffness. Of the

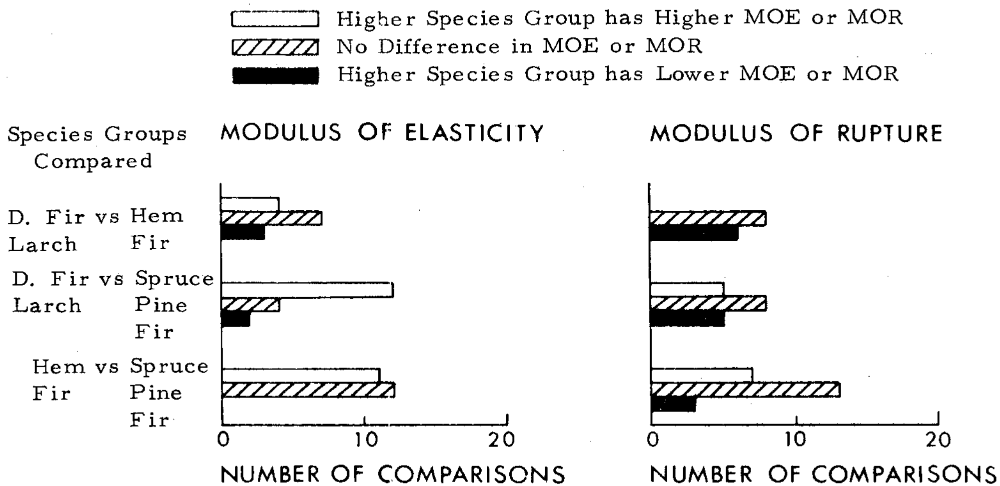

Figure 1. Differences in Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) Between NLGA Species Groups. Each Comparison Based on Samples of 60 Pieces.

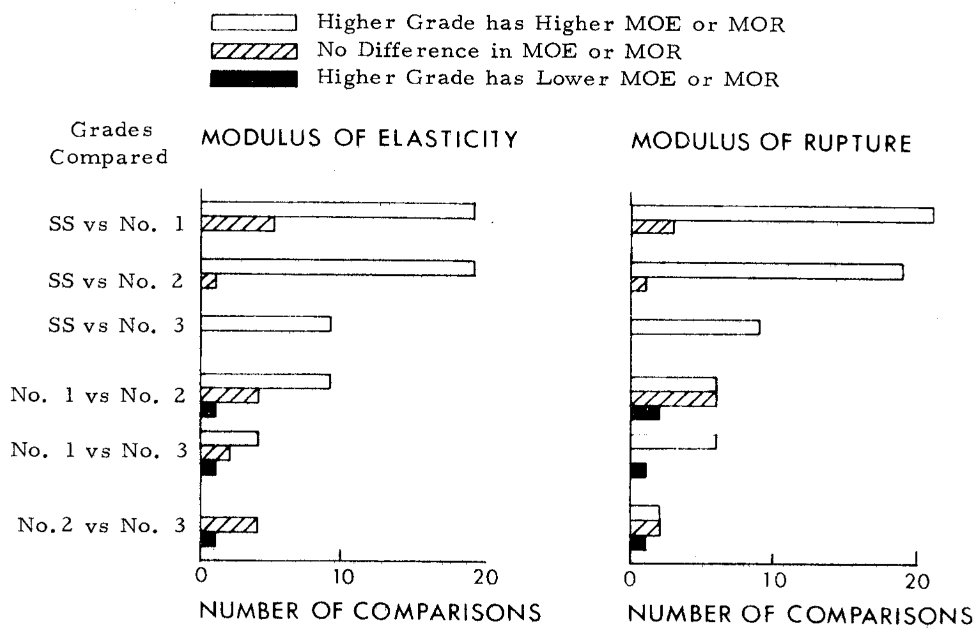

Figure 2. Differences in Modulus of Elasticity (MOE) and Modulus of Rupture Between NLGA Grades. Each Comparison Based on Samples of 60 Test-Pieces.

three foremost groups, Douglas fir-Larch has the highest allowable values, with Hem-Fir and Spruce-Pine-Fir following in decreasing order.

From Figure 1, far less than one-half of the comparisons (size and grade hold constant) between Douglas fir-larch and Hem-Fir substantiate a higher value of modulus of elasticity for the former, and there are no comparisons that substantiate a higher value for modulus of rupture. The comparisons between Douglas fir-Larch and Spruce-Pine-Fir, and between Hem-Fir and Spruce-Pine-Fir, do not provide such a pronounced rebuttal of the presently accepted differences between groups but about one-half the comparisons fail to corroborate any consistent order of grouping. This is not to deny that broadly speaking there are differences between species. Tests on small clear specimens from many trees of Canadian species have shown this to be true some time ago (7). Nevertheless, Figure 1 indicates that such differences do not always prevail when the variation in strength and stiffness which occurs within and between mills is taken into account. It is reasonable to conclude, therefore, that differences in strength and stiffness between species are attenuated and assume less importance for shipments of lumber which arrive at the construction site. This suggests, additionally, that some species groups may be either currently underrated or overrated, and since the NLGA groups are performing adequately underrating would seem to be the more probable event. It appears profitable, in consequence to determine the merits of a further consolidation of species based on tests of full-size dimension lumber.

The four grades defined in the NLGA rule for structural light framing and joists and planks are Select Structural, No. 1, No. 2, and No. 3. Allowable properties are assigned to these grades on the basis of the maximum strength-reducing characteristic in the grade. In other words, minimum properties are defined which have a high probability of being exceeded by all mills at all times. The consequence of this necessary but conservative approach, which possibly has not been fully appreciated, can be seen from Figure 2. Only those comparisons which involve Select Structural show a consistent difference in strength and stiffness between grades. Again, as for species, the differences between the remaining lower grades are overshadowed by the variation which occurs in properties within and between mills.

Although there are four NLGA stress grades, the common practice is to combine and sell Select Structural with No. 1 or with No. 1 and No. 2 grades. The results of Figure 2, while supporting such practice of combining grades, suggests that from a technical viewpoint Select Structural warrants separation from the other grades and that the proper combinations should be No. 1 and No. 2 or No. 1, No. 2 and No. 3. A more reasoned approach, however, would be to determine the severity and frequency of failures associated with the strength reducing characteristics permitted in current grades and from this analysis obtain optimum discrimination between fewer new grades. Because the establishment of fewer grades can detract from specific potential uses for structural lumber, however, it is important, also, to explore alternative grading systems which are capable of a higher degree of selectivity than that achieved now. In this context, the draft of the ECE standard for stress grading of coniferous sawn timber (6) proposes an interlocking of visual and machine grades. Presumably this follows the concept developed earlier in BS4978:1973 (4), since both specifications describe two basic visual grades and provide for equivalent and additional machine grades.

The ECE/BSI concept is particularly pertinent to the lumber industry in Canada at this time. Firstly, metric conversion is underway and provides the ideal opportunity to consolidate species and grades, as well as sizes, in order to improve production and minimize inventory problems. Secondary, Limit States design has been introduced in the National Building Code of Canada as an alternate procedure to existing design methods (3) and a further combining of species and grades would surely simplify new design procedures and lighten the test program to determine the prerequisite characteristic values and performance factors. The importance of testing in-grade material to obtain these values is discussed in a recent report on structural wood and Limit States design (8).

The argument for a consolidation of species and grades in Canada is naturally tempered by benefits gained with the United States through mutual use of the National Grading Rule. The most probable and promising changes will clearly depend on both countries moving in the same direction at the same time.

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