The knowledge we take for granted today on MSR lumber is due in large part to the pioneering work of Professor Robert Hoyle, P.E. In the early 1960s at Potlatch Forest, Inc., he conducted basic research on the relationship between stiffness and strength of lumber, paving the way for the MSR process. Later, he and his colleagues at Washington State University (WSU) conducted the research needed for the acceptance and use of MSR in the U.S.

As a PhD student at Purdue University in the early 1970s, I got to know Bob Hoyle in a couple of ways. Older truss folks will remember Dr. Stan Suddarth, P. E. who introduced me to Hoyle’s fine book, Wood Technology in the Design of Structures, 2nd ed. For the most part, I studied every paragraph in the book. Surprising to me, the book didn’t have an index, so I offered to create one and Professor Hoyle graciously used it in the next edition. As a graduate student, my fondest memory of Professor Hoyle was a trip from Seattle to his home in Lewiston, ID. The purpose of the trip was to help him with Purdue Plan Structures Analyzer, a computerized system for truss analysis based on the “matrix method” now used throughout the truss industry. I suspect he was an awesome professor at WSU as he started his career as a practicing structural engineer and had work experience in the lumber industry.

In 1988, Professor Hoyle invited me to co-author the 5th Edition of his book. To this day, it feels good to share his kind and generous ways.

MSR—How It Works

In honor of Professor Hoyle, I offer the following discussion of machine stress rated (MSR) lumber that is sorted by machine with a visual grading override as well. One of the earliest tables of allowable design stresses for structural timbers that I am aware of was published in 1922 by National Lumber Manufacturers. The MSR system is relatively new and builds on the body of knowledge of the mechanical properties lumber acquired over a century. The Modulus of Rupture (or Bending Strength) and E data in Figure 1 can be viewed as mill output for a specific size and species (or species group) of lumber prior to sorting and grading. The plot gives pairs of simulated bending strength and E values for 100 pieces of lumber. The lumber strength and stiffness simulation model is based on the full-size lumber test data publicly available in the early 1970s.
Figure 1. Note the large variation in both bending strength and $E$ of the simulated lumber data before grading. The MSR process efficiently reduces the random variation of $E$ in MSR grades.

Conceptual View of the MSR Process

To help understand how MSR is sorted and graded, Figure 1 depicts the hypothetical grading of three MSR grades—A, B, and C. A modern grading machine, Metriguard’s 7200 HCLT, is depicted in Figure 2.

The machine collects data related to flatwise stiffness at a lengthwise interval of about 1/4-in (0.274 in) as a piece of lumber passes through the machine. Using the data, the machine calculates a minimum $E$ and average $E$ for the piece. Based upon the average of all $E$-measurements and the minimum-$E$ for the piece, the piece is marked with a code that permits it to become part of the coded grade (A, B, or C in my example) provided it passes visual inspection requirements for the grade.

The visual inspection includes characteristics that can’t be accurately detected by the $E$-measurement process, yet are important to strength and product use (examples: edge knots and wane, respectively). Due to the post-machine visual inspection, some pieces that were stamped with a B-code might be downgraded to the A grade, and likewise, some pieces that were stamped with a C-code might be downgraded to the B grade. The end results of the machine sorting and subsequent visual inspection are grades that have:

- a valuable set of strength design values ($F_b$, $F_t$, and $F_c$),
- a range of design $E$ values with much less variation, and
- higher design $F_{c,perp}$ values for some higher grades.

Truss designers may appreciate the fact that long span trusses requiring wider lumber and higher tension design values are well served by MSR lumber. For example, 2x10 SS Southern Pine (SP) has a tabulated tension parallel-to-grain value of 1,100 psi, whereas the same value for 2250f-1.9E SP is 1,750 psi.
Regarding higher design Fc-perp values for mechanically graded lumber, Table 4C Footnotes of the 2015 NDS Supplement gives Fc-perp values based on the published E-value and Specific Gravity (G) for the different grades and species. For example, Southern Pine MSR with an E-value of “1.9 and higher” has a tabulated Fc-perp design value of 805 psi. The higher design values can be useful for longer truss spans that have higher Fc-perp stresses at bearing walls or supports. (A read-only version of the 2015 NDS Supplement is available as a free download from AWC: http://www.awc.org/pdf/codes-standards/publications/nds/AWC-NDS2015-Supplement-ViewOnly-1411.pdf.)

In current practice, there are a variety of machine technologies used to sort MSR lumber into grade categories. These can include acoustic evaluation of E, transverse vibration E, and x-ray analysis of density and variations in density.

Some MSR Benefits

One substantial difference between MSR and Visually Graded (VG) lumber is the variability of the Modulus of Elasticity, or “E” values within a specific size and grade. The National Design Specification for Wood Construction (NDS) gives the “coefficient of variation” of E (COV_E) for VG and MSR lumber (Table F1 from the 2015 NDS shown here). COV_E is a measure of variation about the average E of a population (or grade in this case). For VG lumber it is 0.25, and for MSR it is 0.11.

<table>
<thead>
<tr>
<th>Lumber Type</th>
<th>E-average (Million PSI)</th>
<th>Range of E-values in Grade (Million psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VG</td>
<td>1.6</td>
<td>0.80 &lt; E &lt; 2.40</td>
</tr>
<tr>
<td>MSR</td>
<td>1.6</td>
<td>1.25 &lt; E &lt; 1.95</td>
</tr>
</tbody>
</table>

The COV statistic begs the question—what does it mean? A statistical rule-of-thumb helps answer the question—given a population having a random characteristic (such as E), the range of data will be approximately plus or minus two standard deviations (another statistical term). Using the COV information for VG and MSR lumber, the results follow for an example 1,600,000 psi E-grade of VG and MSR lumber:

<table>
<thead>
<tr>
<th>Lumber Type</th>
<th>E-average (Million PSI)</th>
<th>Range of E-values in Grade (Million psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visually graded sawn lumber (Tables 4A, 4B, 4D, 4E, and 4F)</td>
<td>1.6</td>
<td>0.80 &lt; E &lt; 2.40</td>
</tr>
<tr>
<td>Machine Evaluated Lumber (MEL) (Table 4C)</td>
<td>1.6</td>
<td>1.25 &lt; E &lt; 1.95</td>
</tr>
<tr>
<td>Machine Stress Rated (MSR) lumber (Table 4C)</td>
<td>1.6</td>
<td>1.25 &lt; E &lt; 1.95</td>
</tr>
<tr>
<td>Structural glued laminated timber (Tables 5A, 5B, 5C, and 5D)</td>
<td>1.6</td>
<td>1.25 &lt; E &lt; 1.95</td>
</tr>
</tbody>
</table>

Note that the lowest E-value in the VG grade is 36% less than the lowest E-value in the same MSR E-grade. For example, such differences can impact the performance of joists in-service because a lower E-value automatically yields a greater predicted deflection value.
Practical Considerations

MSR lumber is an excellent option for “deflection sensitive” framing components because the predicted range of deflection in-service will be less than the range for the same VG E-grade. For example, consider a header over a large window or double door. Typical design practice for both VG and MSR lumber would involve a deflection calculation based on the tabulated E-value for the grade, for example, 1.6 million psi. The impact of the natural variability of E on deflection behavior is not required by U.S. design standards.

For a demonstration, assume a piece of MSR lumber having the lowest possible E-value was selected by “chance” by the contractor and was cut in half to form a two-ply header. The average E for the header would be 1.25 million (by ignoring the impact of a strip of ½” sheathing). The actual header deflection would be more than expected based on the use of the tabulated E value (specifically, 1.6/1.25 more). In comparison, for a VG header and the same assumptions, the actual header deflection would be substantially more than expected based on the use of the tabulated E value (specifically, 1.6/0.8 or two times the design deflection value).

As recommended by Professor Hoyle in his 5th ed. textbook, “If maximum deflection is highly critical to a particular design, a 50% reduction in the elastic modulus would ensure that the computed deflection would not be exceeded, with a confidence exceeding 99%.” Applying the same reasoning to MSR lumber, the tabulated E-value would be multiplied by 0.78 before starting the design process.

Another benefit of MSR lumber is enhanced structural reliability that stems from the manufacturing process. In addition to machine evaluation and visual inspection of each piece by a lumber grader, lumber samples are tested for each 4-hour portion of a production shift for strength and stiffness by proof-testing. The required physical testing for each production shift provides for on-going adjustments to the grading system that reacts to numerous factors such as differences in the log supply. In short, the MSR production output is subject to an “active” quality evaluation.

The Face of MSR

With Professor Hoyle’s contributions to the development of the MSR grading methodology, it is not an overstatement to consider him the face of MSR in the 1960s and 1970s. Others who have worked and written on the topic are indebted to him as well. In fact, in 2012, Professor Don Bender of WSU and I had the privilege of writing about the properties of MSR lumber for an article in Frame Building News, “Effect of Variability on Lumber Design Values.” (visit http://www.nfba.org/view/download.php/resources/technical/technical-articles/effect-of-variability). Although Bob is no longer with us, his legacy remains. Through the machine sorting of the lumber, the visual grading override, and the daily quality control testing, all users can capitalize on the beneficial strength and stiffness properties of MSR lumber.

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