

Statistical Process Control for Visually Graded Structural Lumber

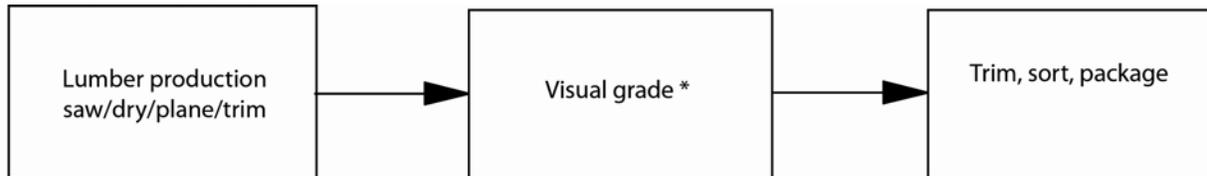
James D. Logan, PE, President
James R. Allen, PE, GM
Daniel A. Uskoski, VP Sales
Dean Nelson, Engineering Mgr
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Executive Summary

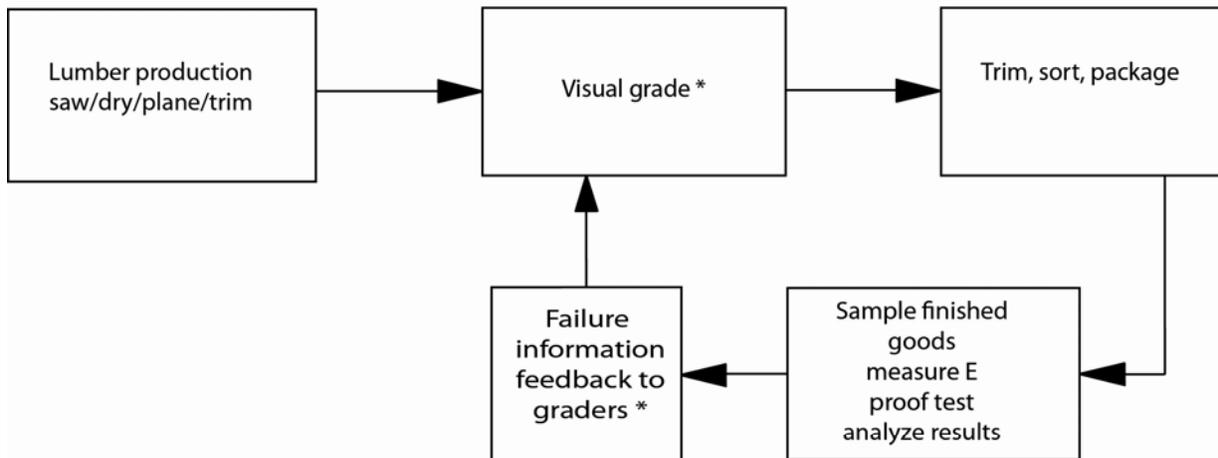
- ***Problem***
 - **Failed design value compliance for visually graded dimension lumber by authoritative notice**
 - **No ongoing quality testing program to verify structural properties for visually graded structural lumber**
 - **Avoidable liability exposure and business risk**
 - **Loss of customers, potential liability from failure**
 - **Potential public safety issues**
- ***Solution***
 - **A quality testing program similar to that used for MSR**
 - **Equipment and processes readily available**
 - **Physical tests on daily sample of product**
 - **Training is simple and straightforward**
 - **Easy to implement in current production processes using existing plant personnel**
 - **Industry standard statistical process**
 - **In wide use throughout general manufacturing**
 - **Mandated and in use for MSR lumber production with more than 20 billion board feet subjected to the process in the last decade**
 - **Feedback information provided to grading process**
- ***Benefits***
 - **Avoid disruption of revisiting the visual grade design values with another In-Grade program that changes design values and grading rules**
 - **Recapture design value credibility and reduce liability exposure**
 - **Provides a record of diligent conformance to standards**

Introduction

The purpose of this paper is to describe how the quality control process for Machine Stress Rated (MSR), Machine Evaluated Lumber (MEL) and E-Rated Lam stock may be applied directly to visually graded structural dimension lumber to verify the distribution of structural properties. This quality control process may be applied to any structural grade of lumber for which it is desirable to control and monitor conformance with design values. It is currently used only on machine graded lumber, but can have equal relevance to material graded visually.¹



Visual Grading Process



Visual Grading Process with QC Testing

Figure 1. A simplified flow diagram is shown for statistical process control of dimension lumber properties. *- The “graders” in this process may be trained human visual graders or the function may be performed by scanning equipment.

Background

MSR lumber grades have been formalized, recognized with official sanction and in production in North America since the ‘60s. The process, tools and techniques for quality assurance have evolved into a system that provides reliability and confidence in the structural properties and design values. While manufacture of MSR grades requires production equipment to measure the characteristics of each piece the quality control, or quality assurance, process does not require production-line equipment to operate effectively.

The quality control process is fundamental to the reliability of MSR lumber. In addition to the mechanical and visual assessments of the lumber, each producer of MSR lumber performs a set of daily machine calibration checks

and mechanical lumber tests. During each shift of production, the machines are checked for calibration and a representative sample of material is selected and tested to verify that the physical properties of the sample are sufficient for the assigned grade thereby assuring with a specified confidence that the underlying population meets the requirements. Each lot is released after testing results show in-control results. The term “in-control” means that the testing results indicate the underlying population of material meets the requirements for the indicated grade. All calibration and production records are periodically checked by a grading agency.

The information derived from quality control tests is used to adjust machine grade threshold settings and to adjust visual characteristics allowed in the grades when necessary to maintain in-control status. This feedback allows the grading process to “home in” on optimal machine settings and visual allowances so the required structural characteristics may be maintained while maximizing grade yield and mill profits.

Figure 1 is a simplified flow diagram for the quality control process comparing conventional process with one that includes quality assurance testing similar to that used in MSR production. Normal in-control processing involves sampling, testing and record keeping each shift. The first indication of an out-of-control process triggers a more intensive sample, the results of which may return the process to in-control status or trigger out-of-control processing. The out-of-control process requires that the production lot be held and regraded after process adjustments are made. The failure information from the tests provides guidance for adjusting the limits placed on characteristics allowed in a grade.

History

Quality control testing was introduced for MSR in the early '60s as a matter of establishing credibility in the marketplace with proof that the equipment was in fact doing its job and the machine settings were appropriate for the grades being produced. There were no QC requirements for MSR grades in 1962. Initially a simple dead-load flat-wise bending test was introduced by Stan Pelster to assure that the equipment was operating as desired. During each shift a small sample was drawn and tested to see if the lumber being produced did actually conform to the E value on the grade stamp. The requirements for quality control testing came after the introduction of the quality control process, and were necessary to establish a uniform process across the industry. The initial benefit from quality control was in marketing the tested goods, and customers developed a preference for MSR lumber grades because they had fewer problems with the material.

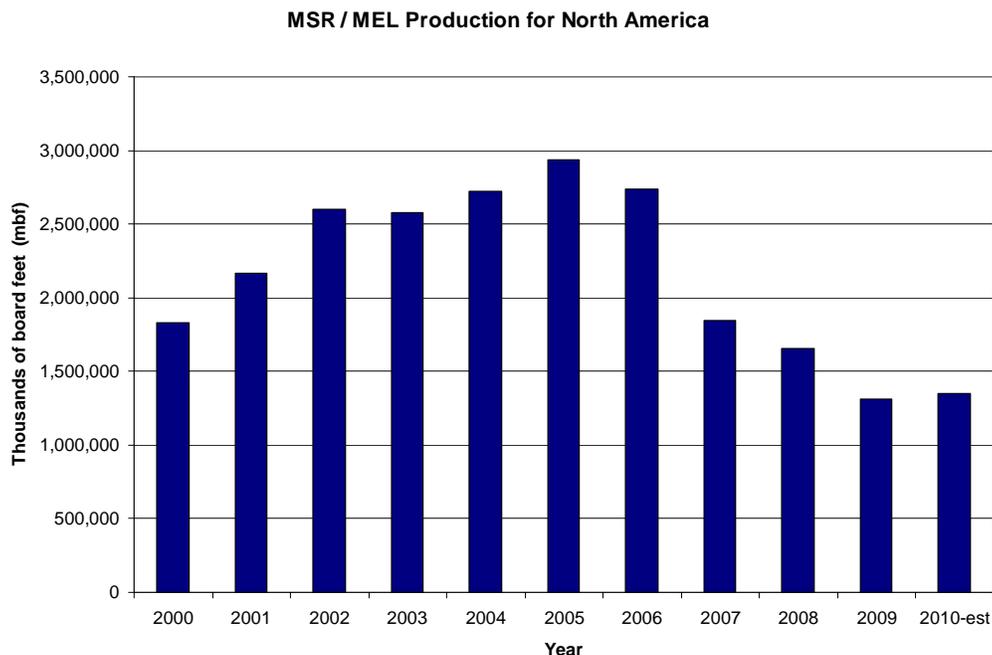


Figure 2. MSR / MEL Production for North America, estimates based on adjusted survey figures. All of this material, about 21 billion board feet from 2000 to 2009, has been subjected to lot-basis quality testing.

Matching Graded Lumber Properties to Design Value

While visual grades are subject to periodic sample inspection for conformance to visual grade criteria, the issue here is the relationship between the visual grade criteria and the assigned structural properties. Current design values for the visual grades were revised from historical design values after testing approximately 70,000 pieces of structural dimension lumber across North America in the In-Grade test completed in 1989. Verification of this relationship has been sparse since the In-Grade test program was completed.

The production volume of MSR lumber grades for the past 10 years is illustrated in Figure 2. Typically, 10 specimens are drawn for each grade, every production shift. Across the industry approximately 750,000 test specimens have been tested in MSR quality control programs over the past ten years by our estimates. This continues to produce lot-basis quality information about lumber structural values, with the further benefit to the consumer that production is only released for shipment after the QC testing indicates the grading process is in control.

QC Sample Size for MSR and Visually Graded Lumber in the US

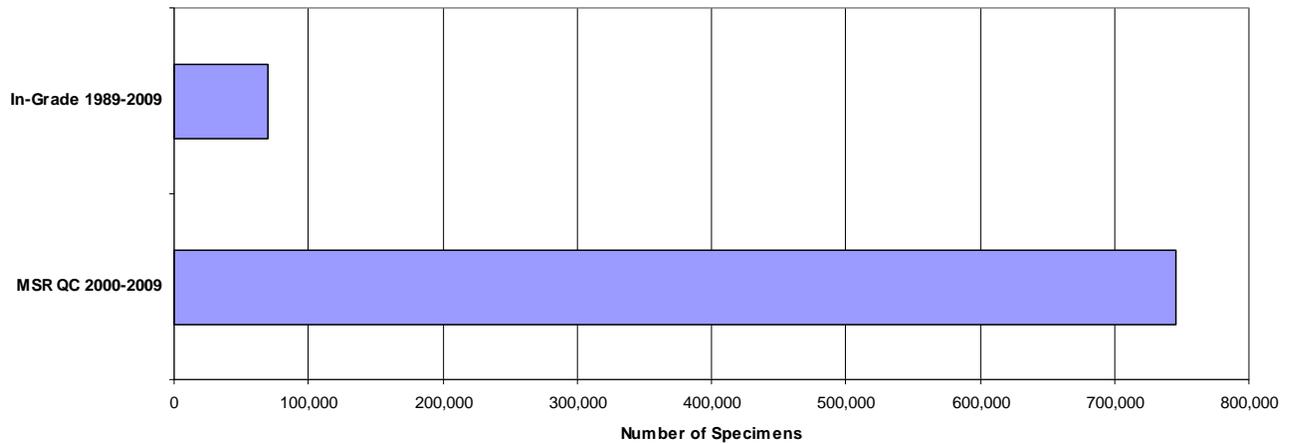


Figure 3. Quality control sample size for MSR is compared with the In-Grade sample size. For the period 2000-2009, MSR quality control specimens averaged 75,000 per year, or 750,000 for the ten-year period. The In-Grade sample size of about 70,000 specimens provided the design values in use for the 21 years of production of visually graded structural dimension lumber from 1989 to 2010.

Less than one specimen per grade per shift is broken in the process so the material costs for testing is low. The cost of performing these tests has been found to be acceptable for a large segment of the industry. Figure 3 provides a comparison of QC sampling for MSR and visual grading (In-Grade) tests which shows that there is much more intense sampling for the MSR lumber grades.

Equipment

The equipment most widely used today for MSR QC is a commercially available bending proof test apparatus manufactured by Metriguard Inc. The present equipment was developed from a design by Delos Snodgrass and Arnold Zweig at Simpson Timber Company in 1978.² A mechanical schematic of the bending E and bending proof test apparatus is shown in Figure 4. Recent improvements in the equipment include computerized data acquisition, automatic capture of deflection and force readings and load rate feedback. Figure 4 shows the configuration for the Metriguard Model 312 machine. The span length (L) is adjustable for the various lumber sizes and deflection is

measured either with a dial indicator gauge as shown or by an electronic displacement sensor that feeds the deflection information directly into a computer. This equipment is used for QC tests on machine rated grades and can be used directly on any structural dimension lumber grade to verify bending E and strength values for ongoing QC work or for lot acceptance testing.

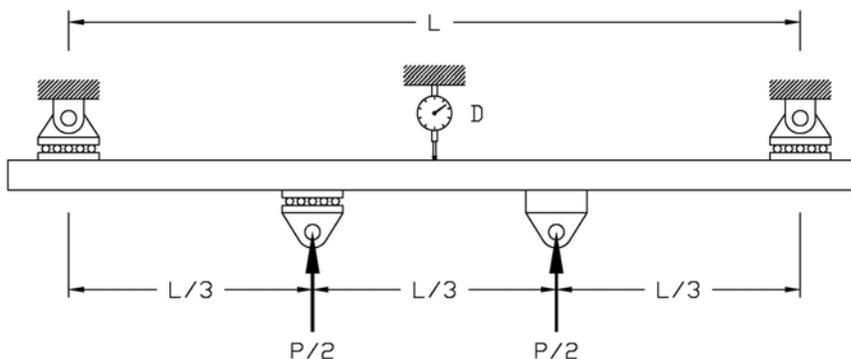


Figure 4. A bending proof tester provides E measurement and bending strength tests for dimension lumber. Digital data processing is available with loading rate feedback, automatic data collection and networking capability.

Tension proof testing equipment is available for statistical quality control of tensile strength. The same equipment, sampling, testing and data processing may be applied to visual structural dimension lumber grades with appropriate adjustments for the grade structural characteristics.

CUSUM

The CUSUM (CUMulative SUM) statistical quality control system in use today for MSR lumber grades in the United States was developed from a technical paper by Bill Warren in 1978³. Further work⁴ has placed these methods into use in a wide variety of applications. It provides for statistical conclusions to be drawn from a limited number of regularly drawn test specimens. In the case of machine graded lumber, the average E, 5th percentile E, 5th percentile of bending strength and optionally 5th percentile of tensile strength are confirmed to meet the American Lumber Standards Committee (ALSC) requirements⁵ with a specified confidence level.

A typical CUSUM control chart is shown as Table 1. Additional tools are also used, including procedures for out-of-control and intensive sampling charts, all of which are available through the lumber grading agencies.

Practical sample based estimation of population statistics has a conflict between a large enough sample to detect changes in statistics and a small enough sample so that it can be tested quickly for rapid detection of changes and to make it affordable. CUSUM quality assurance provides a method to monitor the population statistics and promptly detect problems with a minimum of sample testing. This process makes use of the current test results and the results of prior sample tests to get the statistical benefit of a larger sample

Design Value Verification for Visually Graded Structural Lumber

There is no requirement at this time for lot-basis quality control for visually graded structural lumber. However, nothing in the policies and procedures for manufacturing visually graded lumber prevents additional testing for product conformance with published design values.

Structural properties of structural materials need to be verified. This was the reason for the In-Grade lumber test program, a massive testing program involving some 70,000 specimens, carried out under peer-reviewed ASTM⁶ protocol and completed in 1989. Further review of visual graded structural lumber design values was reported by USDA Forest Products Laboratory.⁷

It now appears that some of the material in visual grades may *not* be meeting the published design values and performing as desired and assumed by those designing structures that use the products⁸. Lumber stiffness and strength properties are non-uniform across the regions and variable within and between species groups. A number of significant events have occurred since 1989 when the In-Grade work was completed. Vast quantities of timber have been consumed by construction, beetle kills and fires. Over the 21 years since the In-Grade program was completed, log sizes, rate of growth and juvenile fiber percentages have all changed. Forestry practices have changed. Harvest areas have changed with the industry slow-down. These events have had a profound effect on the nature of timber in the market, and there is ample reason to suspect that the sample taken for the In-Grade program may no longer be representative. More intensive product verification is needed to demonstrate continued conformance with the assigned design values.

Implementation

QC testing of visually graded lumber can provide the information to both signal the need for adjustment and indicate the type of adjustment required. Examination of failed test specimens reveals the type of characteristics involved in an out-of-control situation that needs correction. This feedback is an important part of a quality control program, and provides the “knobs” for the operator to adjust the grade property statistics and thereby maintain control. Visually observed characteristics including ring count, heart center, density, spike knots, edge knots and early wood - late wood ratios may be adjusted in terms of allowable quantities in the grade as these are known to influence mechanical properties. This is the "failure information" designated in Figure 1 that is used as feedback to correct the process.

A few relatively painless steps are required to put lot-basis quality control into effect for visually graded structural lumber. No rules exist that would prevent immediate adoption of physical QC testing for visual lumber grades.

- MSR quality testing involves testing 10 specimens per grade each shift. This requires the efforts of one person about ¼-time to full time, depending on the number of grades produced.
- Required equipment - bending proof tester for measuring E and proof testing for bending strength
- Optional-- tensile testing equipment
- CUSUM quality control charts with appropriate parameter settings for the visual lumber grades
- For official recognition and possible market benefits, the producer could apply through their grading agency to ALSC for rules changes and appropriate grade stamps

Upon certification by an ALSC accredited agency and conditioned upon maintenance of in-control status, we submit that the ALSC Board of Review could allow issuance of a grade stamp that calls out the controlled design value(s). This proposal has precedence in MSR lumber grades. When quality control in tension is applied, the established practice is for the grading agency to issue grade stamps showing the design tensile strength value included with the E and design bending strength values, both of which are also subjected to quality control testing.

Conclusions

The lumber industry operated for many years on “historical” design values for visually graded structural lumber. With the introduction of machine grading, lumber design values can be and have been verified on a continual basis, assuring the reliability of that sector of the structural lumber supply. Between 2000 and 2009, more than 750,000 specimens have been subjected to off-line testing by mill personnel. This testing has prevented the shipment of lots that failed to meet quality control requirements and verified good lots that were released for shipment. MSR represents less than 15% of the structural lumber used in the United States.

The industry wide In-Grade test program of visually graded lumber helped to address questions about design values in the late 1980s. Since that time little has been done to verify these design values. Except for spot checks, no other major test program has been undertaken to look at visually graded lumber design values in light of significant changes in the timber resource. *This is a glaring disparity between machine graded and visually graded lumber that has been allowed to continue, with unsuspecting users assuming that the stated lumber structural design values are of equal reliability.* It is now time to address this obvious disparity and use proven technology and statistical processes to bring the reliability of visually graded lumber design values into line with the best practices and technology available.

In light of recent events it is evident that some action is advised. **One solution is a second In-Grade program that would be expensive and time consuming and which may result in new design values several years from now reflective of the global resource at the time of sampling. Another solution is that discussed herein with the adoption of an existing protocol that confirms the design values now in use with the added benefit of continuing confirmation on a lot-by-lot basis.**

Upon implementing a QC process for lot-basis statistical control of lumber properties we would expect to see conformance with design values over a good share of the industry as was revealed in the In-Grade program. At the same time, non-compliance with current design values would be readily identified and appropriate action could be taken without an industry wide disruption such as might result from a new In-Grade test program. Verification of In-Grade design values will further enhance the credibility of visually graded lumber in the construction industry.

Appropriate testing equipment is readily available for adoption of quality control through physical testing for visual grades of structural dimension lumber industry-wide. Even for the small producer, the addition of QC testing equipment and a small investment in manpower to run the sample testing can pay big dividends in terms of design value credibility. Reliability in construction is assumed by every owner and is the expected outcome of the grading and quality control process for wood building materials. An appropriate grading process is required to allow use of such a variable and non-uniform material as natural solid wood, so this natural renewable resource can be put to its highest and best use.

The lumber industry can provide material that meets the stated design values by adopting a program of sample testing and quality control. The sampling process and record keeping tools are available at your grading agency and the equipment you need is available now at Metriguard.

<http://www.metriguard.com>

NOW!

Quality Assurance for your
Visually-graded Structural Lumber



Metriguard Model 312 Bending Proof Tester

Protect your design values

- Ensure credibility of design values for all structural lumber grades
- Keep a record of conformance
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- Used for more than 20 billion BF of MSR lumber production over last decade
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- Training is quick and easy
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Lumber Quality Control

| Size: | | Species | | Grade | | Av: | | LP: | |
|--------------------------------------|------|---------|-----|-------|-----|-----|----|-----|-----|
| Cusum Constants | Pfb: | | Pft | | w: | | X: | Y: | Z: |
| Produced in combination with: | | | | | | | | | |
| TEST RESULTS | | | | | | | | | |
| Date | | | | | | | | | |
| Shift | | | | | | | | | |
| | E | Pfb | Pft | E | Pfb | Pft | E | Pfb | Pft |
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| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| CUSUM for AVERAGE E | | | | | | | | | |
| Average | | | | | | | | | |
| Last CUSUM | | | | | | | | | |
| "X" | | | | | | | | | |
| Subtotal | | | | | | | | | |
| Average - | | | | | | | | | |
| SUM | | | | | | | | | |
| CUSUM | | | | | | | | | |
| In Control? | | | | | | | | | |
| CUSUM for MINIMUM (5TH Percentile) E | | | | | | | | | |
| No. below "W" | | | | | | | | | |
| Last CUSUM | | | | | | | | | |
| Subtotal | | | | | | | | | |
| SUM | | | | | | | | | |
| CUSUM | | | | | | | | | |
| In Control? | | | | | | | | | |
| CUSUM for MOR | | | | | | | | | |
| No. of Failures | | | | | | | | | |
| Last CUSUM | | + | + | | + | + | | + | + |
| Subtotal | | | | | | | | | |
| SUM | | | -1 | -1 | | -1 | -1 | | -1 |
| CUSUM | | | | | | | | | |
| In Control? | | | | | | | | | |

Table 1. This MSR quality control chart provides for entry of test results and calculation to perform the CUSUM process and determine in-control status. This chart is set up for a sample of 10 specimens per shift. The operator will prepare the specimens; measure E and proof test for strength for each specimen, then enter the results and determine if the process is currently meeting quality requirements. After a positive result is obtained, the lot is released for shipment.

References

- 1 Voluntary Product Standard PS 20 10 (2010), “American Softwood Lumber Standard”, US Department of Commerce, National Institute of Standards and Technology
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- 7 Kretschmann, David E., James W. Evans and Linda Brown, (1999), Monitoring of Visually Graded Structural Lumber, Research Paper FPL.RP.576, Forest Products Laboratory, Madison Wisconsin
- 8 SPIB, (2010) Notice APPLICATION: Visually Graded Structural Dimension Lumber, 2”- 4” Thick Graded under the Voluntary Product Standard 20 National Grading Rule, Southern Pine Inspection Bureau, <http://www.spib.org/DesignNotice.pdf>