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The 5 Percents of Lumber

by Jim Vogt, P.E.

Lumber design values and lumber grading regulations are defined by 5's.

The framing lumber used in metal plate connected wood trusses is made from wood that is a very complex and variable biological material. Over the last several months a few recurring questions and issues have arisen pertaining to "5% rules" associated with lumber properties and grades. This article will discuss these "rules."

Fifth Percentile & Development of Allowable Strength Properties for Lumber

Wood, like other structural materials, exhibits an inherent variability in strength properties from piece to piece. In order to account for this variability, strength properties such as bending, shear, tension parallel to grain and compression parallel to grain are based not on average values, but instead on a "near minimum" value. Using a near minimum value ensures that the vast majority of the pieces used will exhibit a higher strength property than what has been assigned. For bending, shear, tension and compression parallel to grain, this near minimum value is derived by determining the fifth percentile tolerance limit (with 75 percent confidence). Refer to ASTM D2915 - *Standard Practice for Evaluating Allowable Properties for Grades of Structural Lumber* for a more detailed discussion on determining allowable properties for lumber.

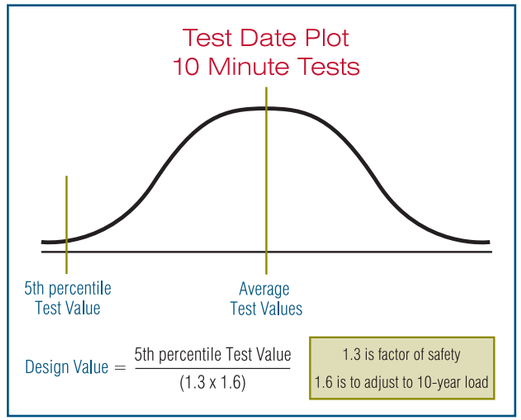

Figure 1. Illustration of a distribution of test values and the location of the 5th percentile test result.

Figure 1 provides a very simple illustration of this concept where the bell curve represents a distribution of test values (such as bending strength), the y-axis represents the frequency of occurrence and the x-axis represents ultimate strength. The fifth percentile tolerance limit is located near the left-hand tail of this distribution. From this illustration it is easy to see that the vast majority of the pieces tested have ultimate strengths that are greater than the value at the fifth percentile tolerance limit.

It is interesting to note that the decision to use the fifth percentile is based on the consequences of failure in a conventional wood building constructed with many closely spaced members such as trusses, floor joists and wall studs, where load sharing will occur in the event of a single member failure.[1] For products that are typically designed to be used in widely spaced applications, a much lower tolerance limit should typically be used.

The property value at the fifth percentile tolerance limit is not the value used for design. The design value is obtained by further reducing the fifth percentile test result by a "property reduction factor," which consists of factors that adjust for:

1. The test duration so that the design value is based on a "Normal" duration (i.e., 10-year) of load, and
2. Several miscellaneous effects typically associated with manufacture and use (often referred to as factor of safety).

The magnitudes of the "duration" adjustment factor and the manufacture and use factor vary by strength property. For bending and tension parallel, the duration adjustment factor and manufacture and use factor are 1.6 and 1.3, respectively, yielding a property reduction factor of 1.6 times 1.3 or 2.1. For compression parallel, the duration adjustment factor and manufacture and use factor are 1.5 and 1.25, respectively, yielding a property reduction factor of 1.9. The value at the fifth percentile tolerance limit, therefore, is divided by the appropriate property reduction factor to yield the reference design value published by the American Forest & Paper Association in the Supplement to the National Design Specification® (NDS®), *Design Values for Wood Construction.* Similar procedures are also followed to derive the reference design values for other wood structural building components such as laminated veneer lumber, structural composite lumber and I-joists.

Basic Principles Concerning Lumber Grading & the 5% Off-Grade

Softwood lumber used in metal plate connected wood trusses must be stress-graded lumber (i.e., lumber that has been assigned design values in accordance with accepted basic principles of strength grading). Stress-graded lumber can be produced by visual inspection or by mechanical procedures. No matter which method is used, each piece of lumber is inspected to determine its grade.

With visual grading, the grade of each piece is assigned by trained and certified lumber graders based on visual observation of growth characteristics (e.g., knots, grain deviation, shake, etc.) and manufacturing characteristics (e.g., wane, seasoning checks, ends splits, etc.). The grading rules used to assess each piece establish the relationship between the observed growth and manufacturing characteristics and the corresponding strength reducing effects of these characteristics. The grading rules are developed in accordance with appropriate ASTM standards and are based on test results of either small, clear specimens, or full-size, commercially graded lumber.

Mechanically graded lumber—either machine stress rated (MSR) or machine evaluated lumber (MEL)—is evaluated via nondestructive analysis of a characteristic such as stiffness or density, which correlates well with structural properties. As each piece of lumber passes through the machine the "predictor" characteristic is measured and used to calculate strength based on algorithms established from previous destructive test-

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at a glance

- Wood, like other structural materials, exhibits an inherent variability in strength properties from piece to piece.
- The design value is obtained by reducing the fifth percentile test result by a property reduction factor.
- The grading of lumber is not an exact science; a reasonable amount of discrepancy is to be expected between individual pieces graded by different graders.
- Cross-cutting stress-graded lumber into pieces shorter than the original piece is a common practice wherever lumber is used in construction.

[1] Hoyle, R. J. 1972. *Wood Technology in the Design of Structures.* 4th Edition. Mountain Press Publishing Company. Missoula, Montana.

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ing. The machine then assigns a grade indicator based on the calculated strength and stiffness. A visual inspection is also made to evaluate growth and manufacturing characteristics that the machine may have missed, and the final grade applied.

Stress-graded softwood lumber used in the United States today must be produced in accordance with the U.S. Department of Commerce Voluntary Product Standard PS 20-05, American Softwood Lumber Standard (see grading parameters below). The American Lumber Standards Committee (ALSC), comprised of manufacturers, distributors, users and consumers of lumber, serves as the standing committee for PS 20-05 and also administers an accreditation program for the grade marking of lumber produced under the American Lumber Standard (ALS) system. The ALS system provides the basis for acceptance of lumber and design values for lumber by the building codes throughout the United States.

Even with a well established set of rules and procedures, the grading of lumber is not an exact science. Lumber graders are human and, as such, a reasonable amount of discrepancy is to be expected between individual pieces graded by different graders. To account for this variation, the lumber grading agencies permit a maximum of 5% below grade material to be included in a given grade.

PS 20-05 section 6.1.1 Grading parameters--..... The grading of lumber cannot be considered an exact science because it is based on either a visual inspection of each piece and the judgment of the grader or on the results of a method of mechanically determining the strength characteristics of structural lumber [see 6.3.2.2]. Grading rules shall establish a maximum of 5 percent below grade as an allowable variation between agency qualified graders. If any grading rules indicate that a grade qualifies under two use classifications, the grade provisions shall satisfy the requirements for both classifications. *(underline added for emphasis)*

This means that potentially for every 100 pieces of a given grade of lumber used to build trusses, up to five pieces could actually grade out lower than what is designated on the grade stamp. As a result, some lumber used in components may have actual properties that are less than the grade stamp properties. The risks associated with this off-grade material causing serviceability or structural problems with the truss are very small. This is due to several reasons. First, the property (e.g., bending, shear, density, etc.,) that is most critical for the particular piece of lumber in the design of the truss may not be affected if the piece is actually a lower grade. Allowable shear stress, for example, is grade independent for visual grades of lumber, so the same design value is used for Select Structural and Utility. Second, the combined stress indices for most truss designs approach 1.0 at only one or two locations, with the remainder of the indices a reasonable amount below 1.0. Thirdly, the occasional use of an off-grade piece is a random enough occurrence that it should not affect the overall structural performance of the building component that the low strength member is placed within.

Is It Okay to Cut the Lumber?

Cross-cutting stress-graded lumber into pieces shorter than the original piece is a common practice wherever lumber is used in construction. Joists often need to be shortened to accommodate span changes, rafters typically require special bevel cuts at ridge and wall locations, and several different lengths of headers and beams are typically required to span the various window and door openings. Cross-cutting lumber for these types of situations is acceptable and the shortened pieces are typically assumed to maintain the same grade and design properties as was assigned to the original piece.

Remanufacturing stress-graded lumber by ripping (i.e., sawing any width of lumber to develop narrower lumber) or resawing (i.e., sawing any thickness of lumber to develop thinner lumber) does potentially negate the grade or grade mark and the design values of the original product. This is because ripping or resawing changes the location of knots and slope of grain relative to the areas of high stress concentration and therefore changes the grade. Section 7.3.7.1 of PS 20-05 specifically states:

> **7.3.7.1** When grade marked dimension lumber is resawn or remanufactured in such a way as to potentially alter the grade indicated by the grade mark, the original grade mark shall be obliterated.

Component manufacturers are sometimes asked to verify that the lumber used in their trusses meet the grade specified on the Truss Design Drawing. If this question is asked, it is most often because the grade stamps are missing from several pieces of lumber of the truss or trusses in question. Since each piece of stress-graded lumber typically contains a single grade stamp, and considering the myriad of lengths required to build a truss, it is not surprising or uncommon for the grade stamps to be cut off of at least a couple of the pieces of lumber.

The 2007 edition of ANSI/TPI 1, *National Design Standard for Metal Plate Connected Wood Truss Construction,* which is anticipated for publication this month, provides the following provisions specific to lumber grade and the use of cross cut lumber:

> **3.4.1 Lumber Specifications.** Truss lumber shall be the size, species and grade specified on the Truss Design Drawing.
>
> **3.4.3 Lumber Identification.** Prior to cross-cutting, lumber shall be identified by the grade mark or the certificate of inspection issued by a lumber inspection agency accredited by the Board of Review of the American Lumber Standard Committee.
>
> **6.3.1 Design Values for Solid Sawn Lumber.** Design values (E, E_{min}, F_b, F_c, $F_{c\perp}$, F_t, and F_v) for solid-sawn lumber and approved, grade stamped, finger-jointed lumber shall be as defined by the grade stamp **prior to cross cutting** and in accordance with the published values of lumber rules writing agencies approved by the Board of Review of the American Lumber Standards Committee.
>
> Design of lumber chord and web members shall be based on dressed sizes as set forth by the U.S. Department of Commerce, PS-20. If other sizes or materials are used, the net dressed size shall be stated in the design and used in the design calculations. *(underline and bold added for emphasis)*

Therefore, for the component manufacturing industry, the design values allowed to be used in the manufacture of trusses shall be as defined by the grade stamp prior to cross cutting and in accordance with the published values of lumber rules writing agencies/NDS. The only time a re-grade of the lumber is necessary is when it is rip sawed. Component manufacturers are also encouraged to include and implement appropriate procedures in their quality control system that will allow traceability and verification of the grades of lumber used in each truss. SBC

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Truss Publications, Inc.

6300 Enterprise Lane • Suite 200 • Madison, WI 53719
608/310-6706 phone • 608/271-7006 fax
www.sbcmag.info • admgr@sbcmag.info