The Future of Structural Round Timber

The Original Mass Timber

By Amelia Baxter and Michaela Harms

As Architecture, Engineering, and Construction (AEC) decision-makers continue to explore new applications for mass timber products. Forest product innovators are applying decades of existing research toward the scaled commercialization of structural round timber (SRT). The authors of this article predict that rising demand for mass timber products is an enormous opportunity for accelerating the use of SRT columns, spanning members, and trusses.

New Markets

A dramatic rise in North American mass timber markets reflects successful public and private initiatives over the last decade to develop new markets for forest products from sustainable forest management. The U.S. alone has over 700 million acres of private and public forests, some ten percent of which are critically under-managed (Bowyer, 2011). The traditional wood products markets that once supported these forests, such as lumber and pulp, are depressed. The long-term decline of the housing and paper industries exacerbates overstocking and requires new diversified markets within the forest products industry.

As government awareness has grown for the role commercial construction markets can play in forest economies and ecologies, building professionals and innovative building owners have amplified this call for new engineered wood products. Private manufacturers have followed suit and invested in manufacturing capacities for high-tech engineered wood solutions such as glued laminated and cross-laminated timber. The results of this 21st century "wood zeitgeist" can be seen in tall wooden buildings such as T3 in Minneapolis, Brock Commons in Vancouver, and HoHo in Vienna.

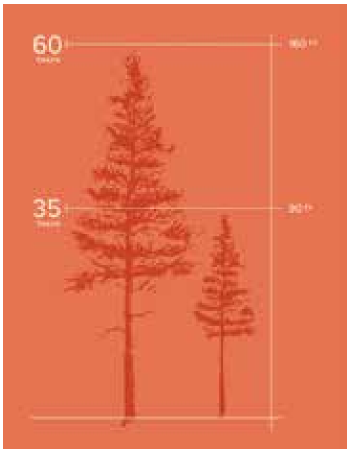

Figure 1. A Douglas Fir's ability to capture carbon from the atmosphere increases exponentially between 35 to 60 years of growth. As a forest matures toward a 60-year planned harvest, it adds considerable mass and carbon storage. (Source: PortBlakely.com)

New markets for mass timber products can also be attributed to the role carbon footprints now play in AEC decision-making and specification. Detailed studies show that well-managed forests result in increased carbon uptake. This first occurs as forest fiber growth patterns speed up when trees are thinned of competition, and then as trees are left in the forest longer while the timber stand reaches a more mature stasis. Forest products can thus achieve higher ratings in data-driven certifications such as Life Cycle Analyses (LCAs) and Environmental Product Declarations (EPDs). New software platforms such as EC3 and One-click LCA then glean carbon sequestration rates from EPD and LCA data, drawing the market's attention to carbon sequestering materials, such as mass timber.

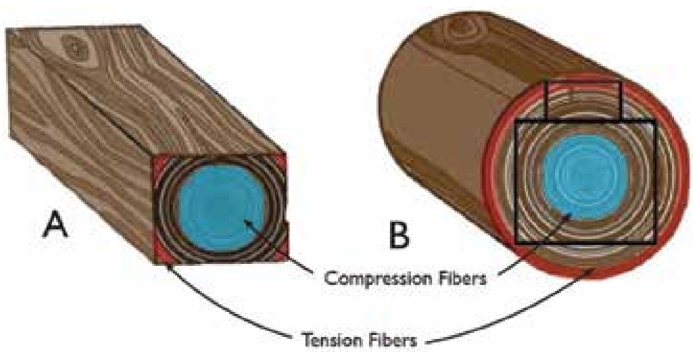

Figure 2. The largest timber (A) that can be milled will be only 17-33% of the strength of the log (B). (Source: Wolfe, 2000, image by author).

New Markets for SRT

Well managed forests are defined here as forests following prescribed plans that successively remove, or thin, low-value trees while the remaining forest grows toward mature high-value harvests. This healthy forest management may cost more during the lifespan of the forest but generally results in more stable ecologies and improved carbon sequestration. If forest owners, both public and private, are expected to manage their forest lands for healthy ecologies and carbon sequestration, then they need new markets for the on-going timber thinning of a forest's first 30 to 60 years (*Figure 1*). The most optimal market value of a timber thinning is when it is used as Structural Round Timber in place of other high-margin mass timber and steel alternatives in commercial construction.

SRT is stronger in bending than an equivalent cross-sectional area of milled lumber due to the wood fiber continuity and preservation of grain orientation (Wolfe, 2000) (*Figure 2*). Comparing SRT strength data (Wood et al. 1960) to dimensional lumber strength data (Green and Evans 1989) has shown that the coefficient of variability (COV) for SRT is about one-half to two-thirds that of conventional lumber. This is because wood fibers in milled lumber are disrupted and discontinuous, creating stress concentrations and fracture initiation, while wood fibers in round timber flow continuously around knots on the surface. This lower variability in strength leads to higher design values for SRT.

Figure 3 illustrates the effects of lower COV on design values. The blue line shows the lower 5th percentile limit for Select Structural Red Pine 2x6 lumber, assuming a normal distribution. Assuming the same mean strength value but half the COV (15%), a distribution and lower 5th percentile for SRT is overlaid with a red line. In this example, the ratio of 5th percentiles is 1.60 for round wood versus

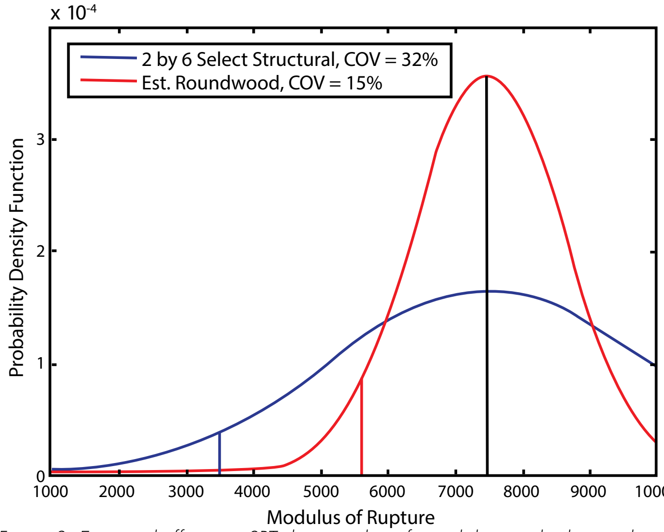

Figure 3. Estimated effects on SRT design values if variability can be lowered through a reliable MSR process.

Figure 4. Red Pine ASTM D198 Flexural Testing at the USDA Forest Products Laboratory, Madison, WI.

milled lumber. The tighter distribution allows for more predictable design values based on fewer outliers.

Grading Methods

Before exploring the future of SRT, an engineer must look to the historical research of this material. SRT is one of the oldest construction materials used by humans, yet there is still no standardized means of deriving optimal design values for SRT in spanning structures. When U.S. builders bring SRT into commercial applications, structural engineers and building code officials often win approval using significant over-designs of members and connections. This over-design is the result of using design values derived from antiquated visual grading techniques meant to be applied to cantilevered poles and piles loaded axially, not in spanning.

Design values for structural round timbers used in pole or log buildings may be determined using the standards published by ASTM International. The ASTM standard D 3200 refers pole designers to ASTM D 2899, the same standard used to derive design stresses for timber piles. Derivation of design stresses for construction logs used in log homes is covered in ASTM D 3957, which provides a method of establishing stress grades for structural members in any of the most common log configurations. These approaches typically assume regular inscribed geometry with an irregular shape. Additional research has been conducted on developing a machine evaluation system for round timber beams (Green and others 2006).

Despite a substantial body of research demonstrating superior design values for SRT, the *International Building Code* (IBC) only accepts design values initially established in the 1930s. Current-state visual grading methodologies build on material properties derived from clear wood one-inch-square samples paired with substantial margins of safety. Visual grading methods to-date are better researched, updated, and practiced for milled lumber where grain patterns can be clearly seen, and do not suit SRT in the same manner.

Machine Stress Rated (MSR) grading, on the other hand, is better able to assign optimal and reliable design values to this geometrically variable natural resource stream, thereby improving consistency and production yields. For this reason, the USDA Forest Products Laboratory in Madison, WI, now recommends MSR grading practices when assisting other countries with assigning new allowable design values to lumber resources or assigning design values to yet-unclassified wood species in the U.S.

The core of MSR grading is the ability to non-destructively measure one or more characteristics from the source material, such as modulus of elasticity (MOE) and specific gravity, to reliably assign member-specific mechanical properties. MSR grading allows manufacturers to sell material with reliable design values without destructive testing, giving architects, builders, and consumers confidence in the specified material.

Research has shown that longitudinal stress tests on standing trees can assist manufacturing decisions by sorting the poles into strength classes earlier in the supply chain (Wang 2001, 2004 and 2007). The authors of this article have built on this body of research. They are working toward the implementation of such nondestructive evaluation (NDE) practices at the log sort yard and in the manufacturing yard to further reduce the downstream variability of SRT members and ensure that components are used in the highest value application for their strength. (*Figure 4*). What is more, pairing NDE data collection with ASTM D198 tests (prescribed flexural bending test) demonstrates that SRT can earn assignable design values 25 to 50% higher than the currently established visual grades, which is allowed when NDE data is cross-correlated with destructive test data by species.

The presence of continuous fibers in SRT, the lack of which diminishes the structural capacity of conventional milled lumber, needs to be considered in an optimized SRT grading system. These benefits are not currently attributed to SRT because existing visual grading and ASTM procedures were developed for the use of poles and piles in an exterior environment, or log buildings. Until methods consider spanning applications in enclosed building structures, grading of SRT will continue to result in over-built structures that inhibit cost competitiveness and market expansion.

Quality and Design Values

Building a broader commercial market for SRT will require a standardized MSR grade procedure for establishing structural design load values. MSR grade methodologies in the milled lumber industry evaluate lumber using a nondestructive machine test, followed by a visual override of certain characteristics that the machine may not properly evaluate. MSR applies measured pressure to each piece of lumber to determine the modulus of elasticity (MOE), and uses the relationship between MOE and bending strength to assign a design value. The general procedure for establishing the mechanical properties of MSR grade systems is covered by ASTM D 6570.

continued on next page

Figure 5. Festival Foods Grocery Store (Madison, WI). The red pine SRT trusses span up to 55 feet and support up to 500lbs/lf. The load-bearing Ash Columns support up to 220kip in live and dead loads. Courtesy of Heartland Photography.

The advantage of using MSR grades for logs is twofold. First, the conventional grading system for logs is based on a conservative, mathematical determination of design values; second, MSR grading allows the identification of select pieces that are superior to the average values based on visual grading alone. For example, a study by Green et al. showed that 64% of the 292 machine-graded lodgepole pine logs studied could be assigned an MSR grade of 1.4E-2250Fb, which is 27% stiffer and 80% stronger than the allowable values for No. 1 lodgepole pine logs. Furthermore, nearly 17% of those 292 logs could be assigned an MSR grade of 1.8E-3350Fb, which is 67% stiffer and 2.7 times stronger than allowable values for No. 1 lodgepole pine logs (Green, 2005). The authors, applying Green's techniques to a study of red pine poles, found similar optimized values at 23% stiffer and 33% stronger than assignable visual grades.

Studies have shown that continuous fibers have a significant benefit to the design value of SRT, but a broad study solely to investigate this would be cost-prohibitive. The authors are instead developing a better approach – a standardized MSR grading procedure that incorporates SRT's unique factors and optimized strength. NDE techniques that include stress wave velocity, transverse vibration, and static mid-point loading can be used to assign an MSR grade to SRT members. Current MSR lumber grade designations could also be utilized for SRT. This relationship and familiarity will enhance the acceptance of the MSR procedures for logs.

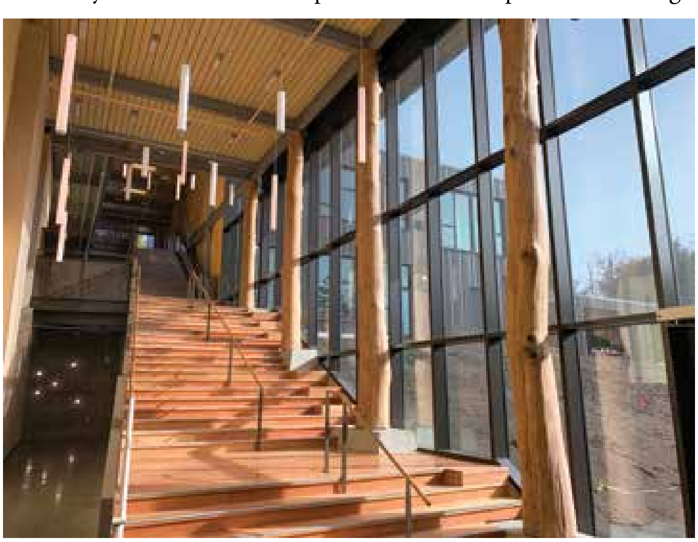

Figure 6. Blakely Elementary School (Bainbridge Island, WA). Fourteen structural White Oak columns interact with a steel superstructure in a Seismic Zone 4.

The Future of SRT

With cost-effective, reliable, scaled grading procedures that allow for 25 to 80% increases in design values for over half of all timber thinnings removed from managed forest plans, SRT of any species becomes a cost-effective mass timber product. Also, SRT thinnings from the on-going management of forest stands are regionally available in nearly all areas of the U.S. This contributes to their carbon-negative footprint, as does the minimal additional processing required to leverage the innate strength of unmilled trees.

The authors predict that rising demand for mass timber products is an enormous opportunity for SRT columns, spanning members, and trusses. Recent projects across the country include the Festival Foods Grocery Store in Madison, WI (*Figure 5*), and the Blakely Elementary School (*Figure 6*) on Bainbridge Island, WA. Both projects include heavy live and dead loads (up to 220 kips on an individual column and 500 lbs/lf on an individual truss) and high seismic conditions in areas of high seismicity. Long spanning trusses are perhaps the earliest and largest potential market for scaling SRT, and examples to-date include 60-foot spans tested at the USDA Forest Products Laboratory. In addition, early adopters of SRT in new commercial settings are specifying load-bearing columns in a wide range of applications, including K-12 education, retail, workspaces, health and recreation, and university facilities.

An approved MSR grade system, in addition to facilitating scale, will promote the development of industry-standard and accepted procedures to disseminate the superior strength, improved environmental impacts, and rural economic development of SRT. The successful scaling of SRT will create markets for a wider variety of low-value trees.▪

The online version of this article has detailed references. Please visit **www.STRUCTUREmag.org**.

Amelia Baxter is co-founder and CEO of WholeTrees Architecture and Structures. She has led project teams in several USDA research grants working toward the commercialization of the tree's natural engineering.

Michaela Harms is a sustainability-focused systems-thinker with an array of research and development experience across the wood construction supply chain. Michaela serves as a Building Products Engineer for PFS TECO.

References

Bowyer, J. (2011). *Green Building Programs – Influencing Positive Change, But Fundamental Flaws Inhibit Effectiveness*. Proceedings: Structural Engineers Association of California Annual Convention. Las Vegas, Sept. 21-24.

Wolfe, R. (2000). Research challenges for structural use of small-diameter round timbers. *Forest Products Journal*. 50(2), 21-29.

Wood L.W, Ecrikson E.C.O, and Dohr, A.W. (1960). *Strength and related properties of wood poles*. Final Report, Wood Pole Research Program, American Soc. of Testing Materials, West Conshohocken, PA.

Green, David W., and Evans, J.W. (1989). *Mechanical properties of visually graded lumber*: Vol. 4 Southern Pine. National Tech. Information Service, Springfield, VA.

Green, David W., Gorman, T.M., Evans, J.W., and Murphy, J.A. (2004). Improved grading system for structural logs for log homes. *Forest Products Journal*. 54(9), 52-62.

Wang, Xiping; Divos, Ferenc; Pilon, Crystal; Brashaw, Brian K.; Ross, Robert J.; Pellerin, Roy F. (2004). *Assessment of decay in standing timber using stress wave timing nondestructive evaluation tools: a guide for use and interpretation*. (Gen. Tech. Rep. FPL–GTR–147). Madison, WI: U.S. Department of Agriculture, Forest Service, *Forest Products Laboratory*. 12.

Wang, Xiping; Carter, Peter; Ross, Robert J.; Brashaw, Brian K. (2007) Acoustic assessment of wood quality of raw forest materials: a path to increased profitability. *Forest Products Journal*. 57(5), 6-14.

Wang, Xiping; Ross, Robert J.; Carter, Peter (2007). *Acoustic evaluation of wood quality in standing trees*. Part I, Acoustic wave behavior. Wood and Fiber Science. 39(1) 28-38.

Wang, Xiping; Ross, Robert J.; Mattson, James A.; Erickson, John R.; Forsman, John W.; Geske, Earl A.; Wehr, Michael A.; (2001) *Several Nondestructive Evaluation Techniques for Assessing Stiffness and MOE of Small Diameter Logs*. USDA FPL Research Paper FPL-RP-600.