SMALL DIAMETER TIMBER: THE ULTIMATE ENGINEERING SOLUTION

Ibrahim Al-Khattat

ABSTRACT

Common connection methods of small diameter timber (SDT) disrupt the internal growth ring structure of the logs. The result is weak, unpredictable joints that abolish all the strength, cost, and minimal processing energy advantages of SDT. By decisively resolving the connection problem through elementary physics, a sound engineering science framework for SDT structural utilization is established via the LPSA (Light Post-tensioned Segmented Arch) technology. The ends of SDT log members of a structure are slide fitted into pipe sockets on interconnecting units. The resulting assembly is transformed into a load carrying structure in a state of compression by tensioned wire strands. Major processing and testing costs are eliminated and the growth ring structure preserved. This transforms SDT into a low cost, high quality, environmentally sustainable construction material. It also defines a profitable recipe for saving the mature forests, for inhibiting forest fires, and for forest based sustainable development. For the first time, very reliable, aesthetic, reusable, and quantifiable engineering structures for buildings and bridges, of all sizes, shapes and loadings, can be built with SDT at considerable savings. This is in the context of an integrated system involving advanced engineering analysis, design and manufacturing. At no extra cost, LPSA structures have a built-in ability to absorb and dissipate distortion energy, giving them natural resistance to earthquakes, hurricanes and flooding.

Keywords. LPSA, small diameter timber, engineering structures, sustainable development, earthquakes

INTRODUCTION

Small diameter timber (SDT) is by far more energy efficient, and hence more cost effective, than other construction materials. A Weyerhaeuser Company comparative study (Bingham 1975) of energy requirements by three equivalent building shells made of sawn timber, steel, and concrete resulted in figures of 220, 470, and 600 barrels of oil respectively. Other studies of processing energy of major construction materials (Koch 1976) and (Paw et al. 1990) were reported by (Lukindo et al. 1997). They indicate that sawn lumber needs nearly 5 times the processing energy of green SDT. The figures for particle board, plywood, flake board, and glu-lam are approximately 22, 17, 14, and 11 times, respectively.

Thanks to its growth-ring structure, round SDT is nearly one and a half times the strength of an equivalent section in structural grade sawn lumber (Darby 1987). Considering its vast worldwide availability and short growing time, SDT is truly the only environmentally sustainable building material.

These remarkable SDT qualities of strength, low cost, energy conservation, and environmental sustainability are neutralized by two chronic problems in SDT engineering lack of sound connection methods and absence of advanced analysis and design methodologies which have become essential requirements in the design and construction of any important modern structure. Part of the latter problem is due to inadequate methods of testing for engineering properties of SDT. The proprietary LPSA technology provides simple elegant solutions to both problems. In doing so, it opens up a vast new field of research, innovation and very profitable applications. Creating value for such abundant resource could have timeless and global implications for sustainable development.

EXISTING KNOWLEDGE

Unfortunately, all current SDT connection methods belong to one well-entrenched thinking mould: skilled carpentry procedures where intermediate connecting parts are embedded into the ends of SDT members. By damaging the symmetric natural growth-ring structure, these procedures eliminate more than the cost, quality and energy advantages of SDT. They also make it impossible to reliably model and analyze the resulting structures.

Moreover, there is no analytical or practical way to predict joints performance over the service life of the structure. Scope of available literature (e.g., Huybers 1986; Lukindo et al. 1997; Ranta-Maunus 1999; and Stern 2001) is limited to these imbedding methods or similar.

The daunting risks in utilizing SDT as a serious building material have been vividly demonstrated recently. The roof of a large span SDT structure (Fig. 1) of an ice arena in the Minnetonka, MN, developed a leak. No engineer would or could certify the integrity of the structure. It was safer and cheaper for the city to demolish the whole building than to insure it. The connection system used (Fig. 2) consisted of steel plates imbedded into the slotted ends of SDT members and fixed to them by rows of bolts.

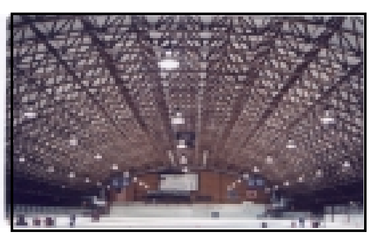

Figure 1.—The Minnetonka Structure.

Figure 2.—The Minnetonka SDT joint.

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The TU Delft connection method (Huybers 1986), adopted by the European Union's multi-state research project (Ranta-Maunus 1999), is a slight variation where bolts are replaced by tube dowels. Lacing wire passes through the dowels and is tightened around the SDT log end.

THE LPSA TECHNOLOGY

Despite the younger and weaker wood fiber of SDT, it is physically stronger and more stable than mature sawn lumber provided the growth-ring structure is not disturbed. This is uniquely achieved in the LPSA regime by slide fitting suitably rounded SDT member ends into pipe sockets located on prefabricated inter-connector units. Typically, a LPSA structural frame is made up of a series of connected single- or multi-member SDT "segments." A system of tensioning wire strands transforms the assembly into a rigid load-carrying structure where all SDT members are in a state of compression. (This imitates the natural state of loading in a tree trunk carrying the weight of the tree).

At the outset, the overall strength of a LPSA structure is several times more than an equivalent conventional timber structure where the joints are the weakest links. Instead of an assumed fraction of a member's strength, the LPSA connector joint is several times the strength of that member. For the first time, strength of the connectors and the overall structure can be determined by analysis. Moreover, there is no more need for expensive joint strength testing (Huybers 1986). In fact, such testing is futile since it can never account for long term or even short-term behavior of actual structures.

Once the connection "black box" is removed, it becomes possible to bridge the gap with the major advances in other fields of engineering science, and to utilize such advances in round timber engineering in particular, and in timber engineering in general. The following examples of LPSA structures demonstrate the endless possibilities with SDT applications. More information and pictures can be found at the Institute's web site (AISST 2002) and in (Al-Khattat 1989) and (Al-Khattat 2001).

LPSA structures have built-in durability and natural resistance to external dynamic forces. This is because small clearances in the slide-fitted connections allow the total structure to absorb and dissipate distortion energy due to earthquakes, hurricanes, soil settlement and flooding.

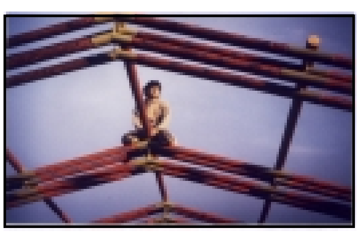

Figure 3.—Building with 4-inch diameter fence posts, United Kingdom.

Figure 4.—Research bridge and geodesic dome, United Kingdom.

Figures 3 and 4 show the first LPSA research and demonstration structures of an 8 m (25 ft) building and a 20 m (60 ft) bridge, respectively. The geodesic dome below the bridge is currently being used as a Woodland Center within the Scolton Heritage Park, near Haverfordwest, U.K. These structures won a U.K. top small business invention award in a national competition organized by the British Design Council and funded by the Toshiba Corporation, Japan. Monitoring these structures over several years produced valuable information about long term behavior of SDT under sustained loading (Al-Khattat 2001).

The pedestrian bridge in Figures 5 and 6 has a span of 10 m (35 ft). It is constructed from five-year old SDT thinnings rounded only along their ends to fit into 63 mm (2.5 inch) pipe sockets. The bridge can be constructed in a few hours by two people, using hand tools. It withstood 130-mile-per-hour hurricane wind without damage although not anchored to any foundations. As with all other LPSA structures, SDT logs are mounted in the green state. An allowance is made for drying and ageing within the design process.

Figure 5.—A 35-ft LPSA bridge built from five-year-old SDT.

Figure 6.—All bridge parts fit on a small trailer.

Figure 7 depicts a LPSA observation tower structure including a spiral staircase around a 1.8 m (6 ft) central well. All connector sockets are 63 mm (2.5 inch) inside diameter. This structure demonstrates that SDT logs can deliver simple, unique solutions unrivalled in cost, aesthetics durability and design flexibility by any other materials or building systems.

THE WAY AHEAD

Creating commercial value and mass use for SDT would transform forest management and forest fire prevention into profitable operations. It would also enable mature sawn lumber consumption to be regulated in a sustainable manner, hence offering long-term insurance for the future of

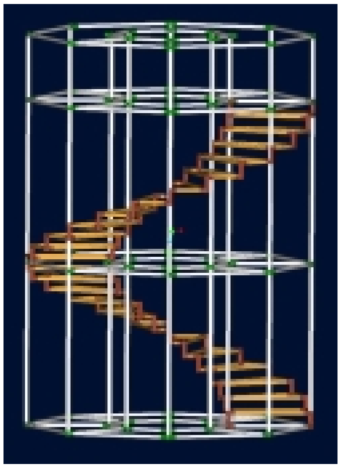

Figure 7.—Observation tower.

current lumber-based forest products industries. In the wake, SDT would become a formidable tool for sustainable rural development. The LPSA technology belongs to an interdisciplinary field of "Sustainable Science and Technology" (SST), being advocated and advanced by this institute. SST is based on a single requisite: conservation and environmental sustainability of natural resources and their optimum recycling. In a world of limited resources on the verge of ecological imbalance, the LPSA is inevitable if what is left of the natural forests is to be spared. At present, this institute is working on LPSA recycling offshoots. These include technologies to utilize discarded shipping pallets and utility poles, scrap tires and the development of composite materials from agricultural waste and other members of the solid waste stream.

The European Union project (Ranta-Maunus 1999) concluded that "the largest quantities" of SDT "are used and can be used in non-structural applications and in small, traditional-type buildings." It predicted, at best, that a smaller volume would be used in "medium-sized leisure industry buildings." It is not surprising, therefore, that for a 10 m project demonstration bridge, dual 120 mm (5 inch) perfectly straight and rounded SDT logs were needed. This is in comparison with the 63 mm socket diameter in the LPSA bridge (Figs. 5 and 6).

Limited only by practical limitations, the LPSA technology would allow "the largest quantities" of SDT to be used in the construction of buildings and bridges of all sizes, shapes and applications.

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REFERENCES

AISST. 2002. American Institute of Sustainable Science and Technology Inc. Web site at: http://www.SustainableScience.org

Al-Khattat, I. 1989. The LPSA: cheap, high-quality building with timber logs. Farm Building and Engineering Journal. (U.K.). 6(2): pp. 42-43.

Al-Khattat, I. 2001. The LPSA: an inevitable sustainable technology. Innovative wooden structures and bridges. Proc. International Association of Bridge and Structural Engineering Conference. Lahti, Finland. pp. 379-384.

Bingham, C.W. 1975. 1975 annual meeting keynote address. Forest Products Journal. 25(9). Madison, WI.

Huybers, P. 1986. Space structures of timber poles. *In:* Shells, membranes and space frames. Proc. IASS symposium. Osaka. 3. pp. 293-300.

Koch, P. 1976. Material balances and energy required for manufacture of ten wood commodities. Proc. Energy and the wood products industry. Forest Products Research Society. Madison, WI. pp. 24-33.

Lukindo, A.R., J.P. Chastain, and K.A. Janni. 1997. Technologies for making connections in small diameter roundwood members. Wood Design Focus, 8(1). pp. 14-22.

Paw, C., J. Rattray, and A. Robertson. 1990. Building with roundwood 1. Farm Buildings Progress Journal. 99: 7-11.

Ranta-Maunus, A. (ed.). 1999. Round small-diameter timber for construction. Final Report of European Union Project FAIR CT 95-0091. Technical Research Center of Finland (VTT).

Stern, E.G. 2001. Construction with small-diameter roundwood. Forest Products Journal. 51(4): pp. 71-82.

Author

Ibrahim Al-Khattat
American Institute of Sustainable Science
and Technology Inc.
211-TIC
Oakdale Research Campus
Iowa City, IA 52242-5000
319-335-4505
ssi@avalon.net