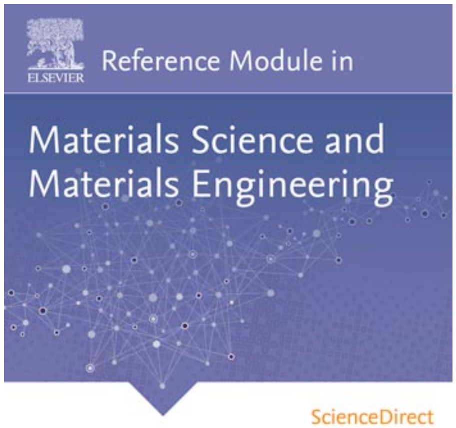

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Lumber: Engineered-Strand ☆

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1 Introduction

Laminated strand lumber (LSL) belongs to a family of engineered wood products generically referred to as structural composite lumber (SCL). These products are manufactured from small wood elements that are bonded together with exterior structural adhesives to form lumber-like structural products (**Figure 1**). They were developed to meet the demand for high-quality lumber from a lower-quality forest resource. According to Milner (2009) Engineered wood products are made from a variety of wood substances which are held together by an adhesive; the aim being to use the wood fiber more efficiently by redistributing and reinforcing natural defects and by forming the products into structurally efficient shapes unachievable by sawing, thereby doing more with less wood fiber. While additional energy resources are required to process engineered wood products they remain largely renewable and thus sustainable compared with competing materials that involve considerable mining.

Figure 1 Lumber-like structural products.

The definition of what constitutes a structural composite lumber product in North America is specified in ASTM D5456 (ASTM, 1999). The only LSL product widely available on the market is trademarked under the name of Timber Strand® LSL. This product using underutilized hardwood species in a proprietary process was first introduced into the structural building market in 1986. Although China possesses abundant Larch (*Larix gmelinii*) resources, which comprise 55% of wooded areas and 75% of forest stocks in the country's frigid temperate zone. Larch, a high-quality wooden structural material that shows excellent mechanical

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performance, can be used quite extensively to fabricate dimension lumber, glued lumber, and wood-based composites (Zhong *et al.*, 2015). A brief discussion on the manufacturing process and structural performance of LSL is important.

The manufacture of LSL is similar in nature to the manufacture of oriented strand panel products and comprises the basic steps of log conditioning, stranding, drying, blending, forming, pressing, and final processing (**Figure 2**). Thin strands in the range of 0.9–1.3 mm thickness and up to 300 mm in length are cut, dried, blended with an isocyanate-based adhesive, longitudinally

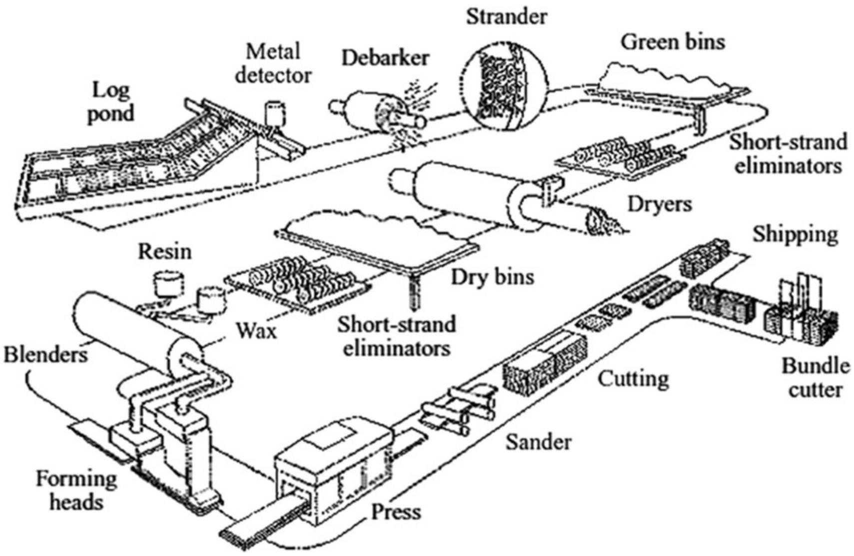

Figure 2 Manufacture of LSL.

aligned to the length of the mat, and bonded under heat and pressure. Steam injection technology may be used to cope with curing of thick sections.

Pressed billets 2.44 m wide, 14.6 m long, and up to 140 mm in thickness are possible with this technology. The wood species used are primarily low-density hardwoods such as aspen and yellow poplar.

The densified nature of the product results in a product density ranging from 625 kg m^{-3} to 690 kg m^{-3}, depending on the product grade.

What makes this technology unique from oriented strand panel products are the longer strands and the greater degree of strand alignment in the longitudinal direction which results in structural properties comparable to solid sawn lumber. The thicker cross-sections and long lengths make it suitable for structural applications.

2 Applications

Typical structural applications include use as beams, headers, lintels, studs, floor and ceiling joists, rafters, columns, I-joist flanges, and rim boards for light framing construction. Industrial applications include use in the manufacture of furniture, windows, and doors.

3 Structural Performance

3.1 Structural Properties

The design stresses for this product can be found in the manufacturer's proprietary code reports and literature. These design stresses can vary between countries due to the different evaluation procedures employed in each country, and reference to their specific evaluation reports is necessary. Common dry-service applications are the 9.0 $MNmm^{-2}$ (1.3 E) and 10.3 $MNmm^{-2}$ (1.5 E) grades.

The LSL manufacturing process produces a highly oriented product resulting in different structural performance with product orientation. For properties such as horizontal shear and compression perpendicular to grain, design stresses are reported for two product orientations: perpendicular to wide strand face (WSF) and parallel to WSF (**Figure 3**).

The perpendicular to WSF orientation (also referred to as the 'joist' orientation) gives significantly higher shear and compression perpendicular to grain strength performance relative to the parallel to WSF orientation (also referred to as the 'plank'

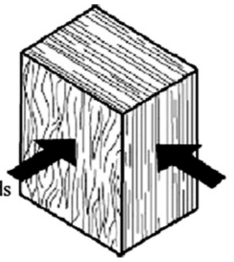

Figure 3 Design stresses for two product orientations.

orientation). Though an increase in impact bending and shear strength, especially in the connection points and load-bearing points were observed in structural applications (Bal, 2014; Kwon *et al.*, 2014).

3.2 Connections

Dowel-type connectors (bolts, lag screws, nails, and screws) are approved for use in LSL. The homogeneous and densified nature of the product results in higher connector capacity relative to the wood species from which it is manufactured.

As with some of the structural properties, connector capacity differs with product orientation. The connector capacity is significantly higher in the perpendicular to WSF orientation relative to the parallel to WSF orientation and most grades of solid sawn timber. Reference should be made to the manufacturer's literature or evaluation reports for the appropriate strength class or wood species grouping.

3.3 Fire Safety

Based on full-scale assembly tests and rate of char tests, the fire resistance of LSL has been demonstrated to be equivalent to similar sizes of solid-sawn lumber. It has been approved for use as a substitute for solid-sawn lumber in US code-approved fire-resistive floor–ceiling, roof–ceiling, and wall assemblies, and as fire blocking. Other countries may have variations for allowable uses.

3.4 Long-Term Load Performance

Given the wide diversity of manufacturing processes available in the manufacture of engineered wood products, the ASTM D5456 SCL standard (ASTM, 1999) recommends that the applicability of the long-term load adjustment factors used for solid-sawn wood products be verified for new SCL products.

An overview of the performance of some proprietary products was given by Sharp and Craig (1996). The observed LSL creep and creep-rupture performance was comparable to that observed for solid-sawn wood products.

3.5 Preservative Treatment

LSL is not currently recommended for use in applications that require preservative or fire-retardant treatment by pressure processes. However, the nature of the manufacturing process does allow for the incorporation of additives such as borate-based antifungal and anti-termitic preservatives during the production process. This preservative has been incorporated into the product for applications in the window/door industry and some structural applications.

3.6 Durability

Products used in dry-service conditions can still be exposed to periods of wetting while in yard storage or on a job site. Use of exterior-type structural adhesives that meet the durability requirements of ASTM D2559, *Standard Specification for Adhesives for Structural Laminated Wood Products for Use Under Exterior (Wet Use) Exposure Conditions*, or an equivalent standard are necessary to ensure good durability performance.

LSL manufactured in the process described in Section 1 exits the press at a moisture content less than 10%. This results in a dimensionally stable product with little in-service shrinkage. However, due to the lower moisture content and densified nature of the product, swelling can be greater than solid-sawn lumber when wetted. Though designed to withstand a reasonable period of wetting, it is best to keep these products dry to maintain good product stability.

4 Quality Assurance

Maintaining product quality is key in the manufacture of structural composite lumber products to maintaining structural performance. Each LSL production facility maintains its own manufacturing standard which specifies all material specifications, key process parameters, quality assurance testing and inspection requirements, and packaging requirements. Quality assurance test requirements include bending tests, tension parallel to grain tests, bond quality tests, and dimensional stability tests. These tests are conducted on a daily basis, and the results used to verify compliance with the code approved values.

An additional requirement is that each production facility be monitored by an independent third-party inspection agency which verifies that the requirements of the manufacturing standard are being met.

5 Summary

LSL belongs to a family of engineered wood products referred to as structural composite lumber. LSL was developed to utilize fast-growing hardwood species to produce structural and industrial grade timber. The manufacturing process produces a long-length, homogeneous laminated strand timber product.

Extensive testing of structural, connection, long-term load, fire, and durability performance of some LSL products has led to approvals in North America, Europe, and Japan.

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