Laminated veneer lumber and other structural sections

STEP lecture A9
A. Ranta-Maunus
Technical Research Centre of Finland (VTT)

Objectives

To introduce new high strength wood-based materials not mentioned in EC5, to describe their use and how they can be designed by following the EC5 principles.

Prerequisite

A4 Wood as a building material

Summary

The lecture begins with a brief description of the fabrication technology of the reconstituted wood materials. It presents the material properties for one type of laminated veneer lumber including characteristic values as given by the manufacturer and accepted for European use. Examples are given of how the material is used today in load carrying structures.

The advantage of using reconstituted wood products is that larger dimensions are available and higher characteristic strength values can be achieved than the strength of the raw material used. The dimensions of these products which are, after fabrication, quite dry are more accurate and moisture related distortion of the shape (twisting, warping) is not a problem.

Introduction

The strength of timber is determined more by the weakest cross-sections having defects than by the clear straight grain wood itself, which normally has two to four times higher strength than commercial sawn timber. Large defects can be avoided when logs are first cut into thin sections and then glued to a reconstituted product. Especially the tensile strength is increased. Because the compression strength depends strongly on moisture content, the bending failure in service class 2 may take place also on the compression side.

Glued laminated timber has a higher strength than its raw material. Still more benefit of the redistribution of large defects into several small ones is obtained in the fabrication of plywood, in which logs are peeled to veneers with thicknesses of 1 to 5 *mm*. Plywood veneers are glued usually in right angles to each other.

Laminated veneer lumber (LVL) is a product close to plywood, except that (most) veneers are parallel and larger dimensions are available. The idea of LVL came from the 1960s and the production has expanded in the 1980s. Today, LVL is produced commercially in the USA by seven companies, in Finland, Japan, Australia and New Zealand. The biggest LVL producer in the US markets LVL under the trade mark Micro=Lam LVL. In Finland the product is called Kerto-LVL. The 1993 production of LVL in 440000 m^3 in America, 51000 m^3 in Europe and 40000 m^3 in other parts of the world and showed a rising trend.

Parallel strand lumber (Parallam) is a beam-like product made of long wood strands, which was developed in Canada in the 1970's and 1980's. It is now fabricated also in the USA. Another new American structural wood product is Intrallam, which is made from large parallel chips.

Fabrication

LVL is manufactured in America from Southern Yellow Pine (Micro=Lam) and in Europe from Norway spruce (Kerto). Logs are debarked and heated in hot water for 24 hours. They are rotary peeled into veneers which are clipped into sheets about 2 *m* wide. The veneers, having a typical thickness of 3 to 4 *mm*, are graded according to the density. After drying, phenol formaldehyde adhesive is applied to veneers which are then laid with the grain running parallel to form a continuous mat of the desired thickness. Veneers are scarf-jointed except the middle veneers which are butt-jointed. These joints are staggered vertically in order to minimise the effect of joint on the strength of LVL. The mat is hot pressed at a temperature of about 150 °C. After hot pressing, each finished sheet of LVL is cross-cut and rip-sawn to desired dimensions. Lengths exceeding 20 *m* can be produced. During fabrication the quality control includes regular testing of the quality of the glue bond and the bending strength.

Kerto-LVL is produced as a standard product when all veneers are parallel (Kerto-S) and also as Kerto-Q in which about every fifth veneer is in the perpendicular direction. Standard dimensions of cross-section are given in Table 1.

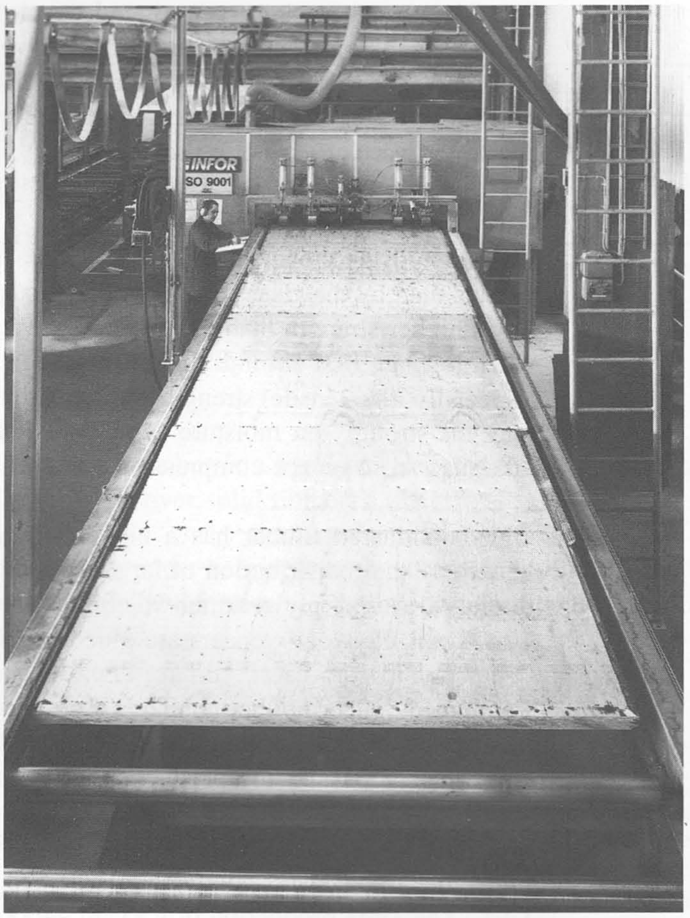

Figure 1 *LVL is produced as a continuous panel with net width of 1800 mm.*

Widths in *mm*	Thicknesses in *mm*						
	27	33	39	45	51	63	75*
200	x	x	x	x	x	x	x
260		x	x	x	x	x	x
300			x	x	x	x	x
360				x	x	x	x
400					x	x	x
450						x	x
500						x	x
600							x
900							x

* Kerto-S only

Table 1 *Standard dimensions of Kerto-LVL. Thicknesses of Micro=Lam LVL comprises from 19 to 89 mm.*

Parallam is made from Douglas fir and Southern yellow pine. As in the manufacture of LVL, logs are peeled into veneers. The sheets of veneer are then clipped into strands up to 2400 *mm* in length and 2-3 *mm* in thickness. The adhesive is applied to the oriented strands which are fed into a rotary belt press and cured under pressure by microwave heating. The process is monitored by programmable logic controllers. Parallam emerges from the process as a continuous billet that can be factory-cut and trimmed to standard sizes up to 20 *m* in length. Maximum depth of beam is 480 *mm* and width 285 *mm*. Square cross-sections up to 180 x 180 *mm* are commonly produced for columns.

Intrallam is made from large chips up to 300 *mm* in length and 30 *mm* in width. After drying, a polyurethane adhesive is applied and the chips are organised to a direction parallel to the panel length. The fabricated product is a large panel (2,44 x 10,6 *m*), which is cut to the required dimensions.

Examples of use

LVL is being used as beams, plates, members of trusses and shells. This is done in new buildings as well as in renovation for beams, joists, truss chords, vehicle decking, concrete formwork, scaffold planking and prefabricated housing. The largest structure made of LVL in Europe is Oulu-dome with a diameter of 115 *m* (Figure 2). In dome structures, high strength to weight ratio, straightness and small fabrication tolerances are important features.

The uses of Intrallam are similar to those of LVL.

Parallam is used for beams, headers and columns. In residential building construction in America it is often used in beams when a material with higher strength is needed. It is suitable also for hall structures and the appearance of material is considered warm and suitable for interior architecture. Both LVL and Parallam are competing with steel in large span structures. The advantages of the wood-based alternatives are good architectural appearance, longer resistance in case of fire and the easy techniques for fastening of the secondary structure.

Beam and post structures can be built in LVL and in Parallam. An example of a three-storey school building is illustrated in Figures 3 and 4. A specific feature of this building is that it is built in an area where seismic loads are effective. LVL panels with screwed joints have been used in shear wall structures in order to achieve the racking strength and energy dissipation needed. Wood-based panels connected by mechanical fasteners to wood frame form a structure with high resistance to earthquakes. High shear strength can be achieved by cross-veneered panels.

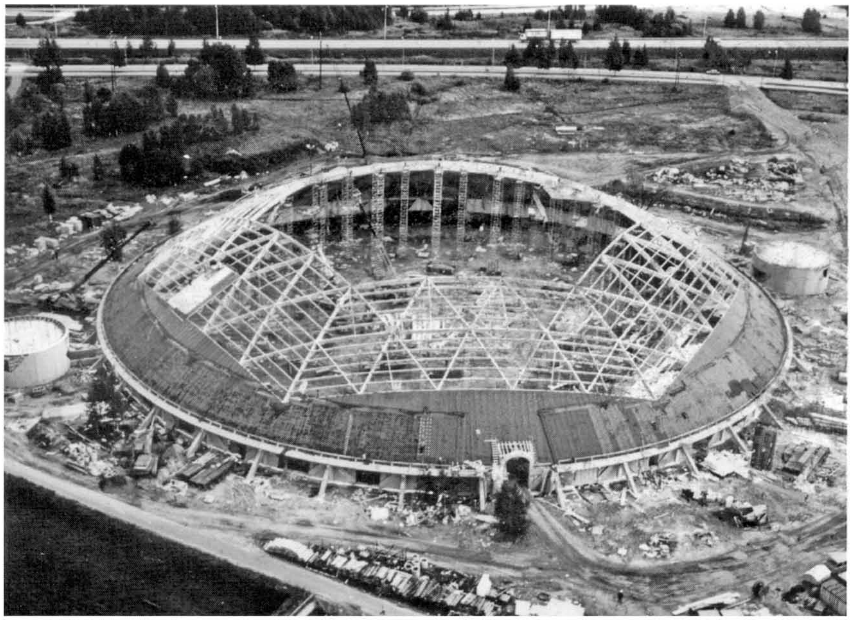

Figure 2 *Oulu-dome under construction, Oulu, Finland made of 560 m^3 LVL. Diameter of dome is 115 m and floor area of building 10700 m^2.*

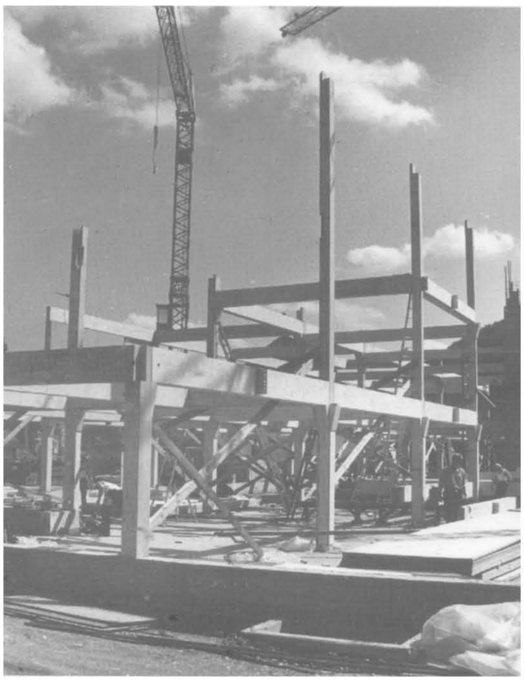

Figure 3 *Albstadt Centre for Technology and Economics, Germany: three storey LVL-frame.*

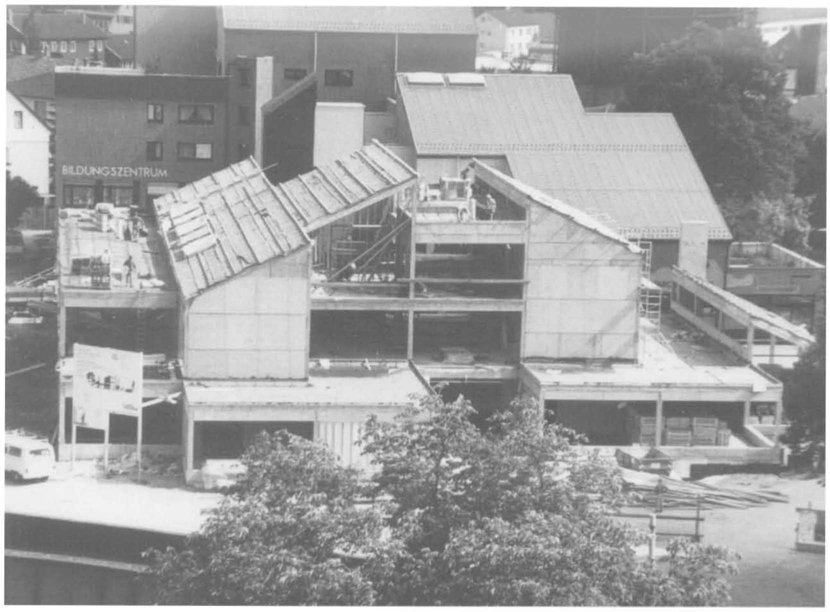

Figure 4 *Albstadt Centre for Technology and Economics, Germany: earthquake resistant shear walls made of cross-veneered LVL panels.*

Figure 5 *LVL frame communal workshop, Sixt-Sur-Aff, France. Span 18 m.*

Material properties

Durability of LVL, Parallam and Intrallam is comparable to natural timber. These products can be impregnated in order to improve durability in moist conditions. Also the charring rate in fire is close to glued laminated timber. For LVL used as panel, the values for plywood can be used.

The moisture content after fabrication is about 10% and in service normally 2% less than the moisture content of solid wood. Moisture expansion coefficients of LVL as change of dimension (%) per one per cent change of moisture content are given in Table 2.

Direction	Kerto-S	Kerto-Q
Length	0,01	0,01
Width	0,32	0,03
Thickness	0,24	0,24

Table 2 *Moisture expansions/shrinkage of Kerto-LVL (%/%).*

Characteristic values are given in Table 3 for Kerto-S-LVL based on information supplied by the manufacturer. These values have been accepted for use in Sweden. A compilation of the research results made in different countries with Kerto-LVL is made by Koponen and Kanerva (1992).

EC5: Part 1-1: 3.1.7
EC5: Part 1-1: 4.1
EC5: Part 1-1: 3.3.2(4)

The modification factors for service class and load duration k_{mod} and deformation factors k_{def} given in EC5 for plywood are also valid for LVL and Parallam. The factor k_h used in glulam design is not necessary for LVL because of the smaller statistical variation in strength. Quality control tests of Kerto-LVL show the coefficient of variation for bending strength to be less than 10%. Thus a depth factor with an exponent of 0,07 would be appropriate based on Weibull's theory.

However, by using the same partial safety coefficient as for other wood materials, γ_M = 1,3, extra safety is already included and further reduction is not necessary.

Strength and stiffness properties in *N/mm²*		
Bending edgewise	$f_{m,k}$	51
Bending flatwise		48
Tension parallel to the grain	$f_{t,0,k}$	42
Tension perpendicular to the grain	$f_{t,90,k}$	0,6
Compression parallel to the grain	$f_{c,0,k}$	42
Compression perpendicular the grain	$f_{c,90,k}$	
- parallel to the glue line		9
- perpendicular to the glue line		6
Shear edgewise	$f_{v,0,k}$	5,1
Shear flatwise	$f_{v,90,k}$	3
Rolling shear	$f_{r,k}$	1,5
5 % modulus of elasticity	$E_{0,05}$	12400
5 % shear modulus	$G_{0,05}$	820
Mean modulus of elasticity	$E_{0,mean}$	14000
Mean shear modulus	$G_{0,mean}$	960
Density in *kg/m³*		
Characteristic Density	ρ_k	500
Average density	ρ_{mean}	520

Table 3 *Characteristic values of Kerto-S-LVL. Density is given at 10% moisture content.*

Design of members and joints

The design of structures made of LVL and Parallam follow the general rules of EC5. Bending strength of LVL and Parallam is about the same. In compression and shear Parallam is stronger. The bending strength of Intrallam is comparable with glulam. Comparison of strength and stiffness of sawn timber (C24), glulam (GL32) and LVL is illustrated in Figure 6. The Figure shows that the stiffness of LVL is somewhat higher but the strength is about twice the strength of average strength graded sawn timber. The bending capacity of the same materials is illustrated in Figure 7 where cross-sections with equivalent bending capacity are shown.

Dowel-type fasteners are used with LVL, and the EC5 design equations are as good for LVL as for sawn timber with the same density. Dowel joints are used also in frame structure with rigid joints as illustrated in Figure 5. Punched metal plate fastener joints are also used and the design principles are the same as for solid wood. Special types of punched metal plates have been developed for LVL (see also STEP lecture E6).

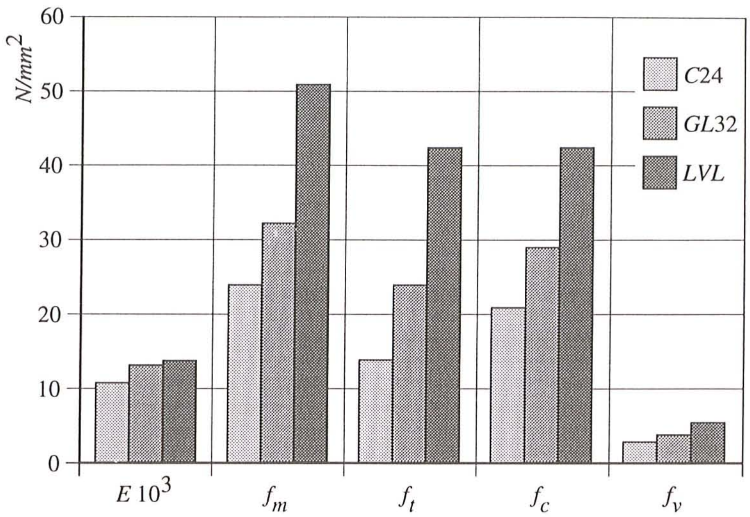

Figure 6 *Comparison of the characteristic values of sawn timber (C24), glulam (GL32) and LVL.*

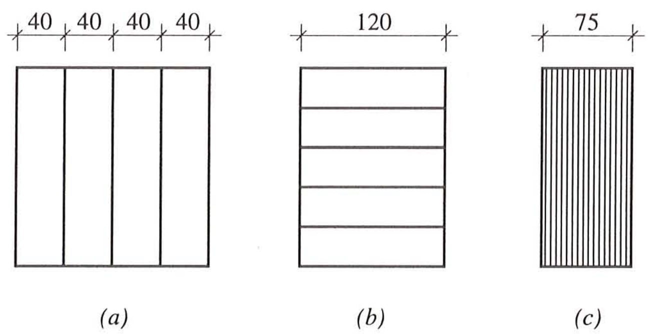

Figure 7 *Three cross-sections with similar bending capacity: sawn timber (C24), glulam (GL32) and LVL.*

Summary

Engineered wood products LVL and Parallam have higher strength and stiffness than traditional wooden products. They are also thoroughly tested because they have entered the market during modern legislation. These industrial products are well suited for use where high strength and dimensional stability is needed.

Reference

Koponen, S., Kanerva, P. (1992). Summary of European Kerto-LVL tests with mechanical fasteners. Report 29. Helsinki University of Technology. Laboratory of Structural Engineering and building Physics. Espoo, Finland.