Manufacturing steps sheet of LVL (micro-laminated wood) of beech (Fagus sylvatica)

The innovation presented in this publication has been selected within the FOREST4EU project. This project has compiled the innovations generated by different operational groups in the forestry sector at European level in recent years. Through different prioritization processes with experts from the sector, 20 innovations have been selected as those of greatest interest to strengthen the transfer of their results in the forestry area. Within this process, the innovation “LVL (Laminated Veneer Lumber) of beech wood”, developed in the context of the GO FAGUS operational group, has been selected as a product of special relevance for its communication in Spain. For further information, please visit the project website https://www.forest4eu.eu/.

LVL is a product consisting of the successive stacking of thin layers of wood, veneers (Fig. 1), obtained by unrolling. Obtaining the material in this way has the following implications:

Figure 1 - Beech veneers used for the manufacture of the LVL.

The raw material for the manufacture of this product are high quality logs. Large diameter, straight, with little taper and knots in order to obtain adequate efficiency, volume and quality. For this reason, it is to be expected that the manufacture of structural products with veneer from roundwood offers superior properties than sawn timber of the same species.

What is unrolling and what is its process?

Unrolling consists of, as the name implies, unrolling the log, converting a cylinder into a sheet. The most visual way to understand this is to compare it to a paper roll, where the log is the roll and the piece of paper is the veneer (Fig. 2). To achieve this goal the process goes as follows:

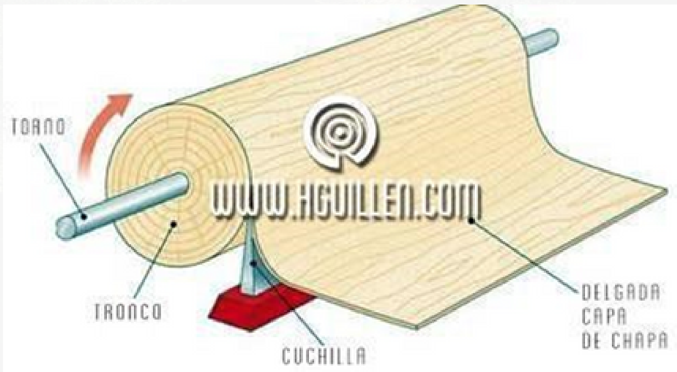

Figure 2. Unrolling scheme. Source: Maderas Hermanos Guilen.

First, the logs are debarked to remove debris or residues from the forest. Next, the logs are scanned with a metal detector, as the presence of metal inside the logs could ruin the machinery used in this process.

The logs are then boiled or steamed to obtain a softer and more flexible consistency. This is intended to achieve several objectives: to prevent the wood from splitting under the tension of unrolling, to reduce resistance to the blade, and to extend the useful life of the cutting tools. Finally the unrolling operation takes place, where, first, the log must be centered on the axis and rolled as shown in Figure 2.

Once this shape is reached, a blade will approach the cylinder and obtain a veneer of the required thickness (Fig. 3) until it reaches the minimum working diameter, thus generating 3 final products: chips from the rolling, the veneer (Fig. 4) and the log from which no more material could be used (Fig. 5). And thus the raw material used to manufacture the specimens tested in this project is obtained.

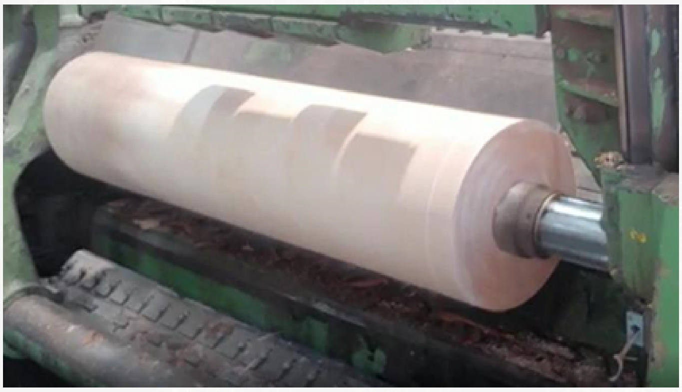

Figure 3. Log ready for unrolling.

Figure 4. Veneer obtained from the log.

Figure 5. Rolls obtained after unrolling.

MANUFACTURING PROCESS

Two types of samples were fabricated for this project:

- 125x30x2500mm beams;
- 500x500mm panels from which small samples were obtained.

Moisture balance

Upon arrival of the veneers at the Cesefor facilities, they were left to acclimatize for a few days to avoid problems with the humidity of the veneers due to the climatic differences between the sawmill and the facilities. Humidity was controlled by means of a xylohygrometer (Fig. 6).

Figure 6. Moisture control of sheets with xylohygrometer.

Attention to the position of the sheet

As the product to be manufactured is LVL, and all sheets must have the same fiber orientation, care was taken to ensure this quality during fabrication, especially in the small 500x500mm specimens where it is much easier to rotate a sheet and manufacture a plywood by mistake (Fig. 7).

Figure 7. Gluing and placement of veneers.

Adhesive considerations

Beech is a complicated species in terms of gluing, as it is difficult for the glue lines to meet the requirements of the regulations, although this could also be due to the high strength of this wood, as some authors comment. In this case, a two-component MUF adhesive with the commercial name GripPro™ Design from Azko novel was used.

The use of the adhesive was determined by the manufacturer's technical data sheet, taking into account the humidity and temperature of the wood and the setting room, the time of the adhesive in the air, the mixture ratio, the pressure during setting and the minimum setting time.

Some of the parameters used for manufacturing are included in Table 1.

Table 1. Some parameters considered for manufacturing.

Glue/hardener ratio	Grammage (g/m²)	Airtime (min)	
		Separately	Mixed
2/1	350	30-40	15-20

Assembly of specimens

After conditioning and preparation of the material and facilities, the manufacturing process began. This process is identical for large and small specimens, the only difference being the size of the resulting specimen and the press used.

Due to the prototyping nature of the facilities and the absence of a system to apply glue and hardener independently with an adjusted ratio, the doses were prepared to mix them just before their application to ensure the air time of the glue. Once mixed, the tank of the hand roller with which the adhesive was applied was filled.

In this way, two different products were obtained: LVL beams of structural size 125x30x2500mm (Fig. 8) and small dimension specimens manufactured from the board press that produces 500x500mm pieces (see Figures 9 and 10) to compare their properties with those of the sawn lumber and structural beams manufactured in the facilities.

Figure 8. Structural size beams.

Figure 9. 500x500 mm panel, used to produce small specimens.

Figure 10. Small specimens for bending tests (upper) and for tensile tests perpendicular to the fiber (lower).

TESTING PHASE

Based on the two products previously developed, 3 different tests will be carried out to evaluate their resistance characteristics:

1. Bending tests with the 10 structural dimension beams manufactured;
2. Bending tests with 50 small dimension specimens;
3. Tensile tests perpendicular to the fiber on 60 small specimens.

Bending test

The bending test (regardless of the size of the specimen) is performed by supporting the piece at its ends (two support points) and by means of a piston exerting a vertical force applied at two points, so that in the section between load points, the beam is only subjected to bending and not to shear. When rupture occurs in this section of the beam, it is due only to bending forces. These tests were carried out according to the methodology of the proposed EN 408 standard for sawn timber and glued laminated timber, as indicated in EN 14374 .

Figure 11 shows a flexural bending test performed on structural dimension beams, and in Figure 12 one performed on small dimension specimens.

Figure 11. Bending test on structural sized specimens.

Figure 12. Bending test on small dimension specimens.

Perpendicular tensile test

This test is performed to determine the behavior of LVL in tensile stress perpendicular to the fibers (the most unfavorable stress to which the wood can be subjected) by means of a metal device specially designed for the test. This device consists of two metal clamps that hold the specimen without damaging it, and then separate one from the other, generating a tensile stress. Figure 13 shows one of these tests in execution.

Figure 13. Perpendicular tensile test on fiber.

These tests must be carried out within the range of time stipulated by the standard, since wood behaves in different ways depending on the time of exposure to a load. In addition, the standard also indicates how the load should be applied, being able to vary its control between force or displacement per unit of time (kg/min or mm/min).

RESULTS

This section will present the results obtained from the different tests performed.

Bending tests on structural sized specimens

The results obtained from the tests carried out on beams of structural size are presented in Table 2. Beams with a cross section of 120x30 mm², with a span of 2160 mm, were tested. Ten tests were carried out, and the characteristic properties desired were obtained, in accordance with EN 14358. The average and characteristic density of the sample, the average and characteristic bending strength, and the local and global modulus of elasticity were determined. The value of the bending strength is adjusted for a reference height of 300 mm according to EN 14358.

Table 2. Structural size LVL beam bending test results.

Bending test	CH (%)	ρ_m (kg/m³)	ρ_k (kg/m³)	$f_{m,m}$ (MPa)	$f_{m,k}$ (MPa)	$E_{m,g}$ (MPa)	$E_{m,l}$ (MPa)
LVL beams	10.7 (9%)	704 (4%)	641	65.4 (10%)	46	10992 (3%)	13425 (7%)

*The values in parenthesis correspond to the coefficient of variation

- CH (%): Moisture Coefficient;
- ρm (kg/m³): Average Density;
- ρk (kg/m³): Characteristic density corresponding to 5%;
- fm,m (MPa): Bending strength, average value;
- fm,k (MPa):Bending strength, characteristic value;
- Em,g (MPa): Global modulus of elasticity (with shear effect);
- Em,l (MPa): Local modulus of elasticity (without shear effect).

Bending tests of small dimension specimens

The results obtained from the tests carried out on small-sized beams are shown in Table 3. Beams with a cross-section of 25x20 mm², with a span of 450 mm, were tested. Fifty tests were carried out, and the characteristic properties desired were obtained, in accordance with EN 14358. In this case, the average and characteristic bending strength and the overall modulus of elasticity were obtained. The value of the bending strength is adjusted for a reference height of 300 mm according to EN 14358.

Table 3. Results of flexural tests of small dimension LVL beams.

Bending test	$f_{m,m}$ (MPa)	$f_{m,k}$ (MPa)	$E_{m,g}$ (MPa)
LVL beams	91.0 (9%)	77	15702 (8%)

*The values in parenthesis correspond to the coefficient of variation.

- fm,m (MPa): Bending strength, average value;
- fm,k (MPa): Bending strength, characteristic value;
- Em,g (MPa): Global modulus of elasticity (with shear effect)

Perpendicular tensile tests

Table 4. Results of perpendicular-to-fiber tensile tests on small LVL specimens.

Perpendicular tensile test	$f_{t,90,m}$ (MPa)	$f_{t,90,k}$ (MPa)
Small LVL Specimen	2.5 (35%)	0.94

*The values in parenthesis correspond to the coefficient of variation.

- $ft,90,m$ (MPa): Perpendicular tensile strength, average value;
- $ft,90,k$ (MPa): Perpendicular traction resistance, 5th percentile.

DISCUSSION OF RESULTS

The results obtained from the bending test on structural size beams could be compared with those declared for the strength classes of sawn timber (EN 338) or glued laminated timber (EN 14080), although the latter is applicable to coniferous species.

If we compare with the sawn timber strength classes, the strength classes D40 and D45 could be taken as a reference. At the same time, the results obtained in this test can be compared with those obtained in the framework of the EGURALT project, where 38 pieces of second quality beech sawn timber of 120x30mm² cross section were tested in bending. Table 5 shows the comparison between the properties of the strength classes obtained for LVL and sawn timber.

Table 5. Comparison of indicator properties of strength classes with properties of LVL and sawn lumber.

Property	D40	D45	LVL	MA
ρ_k (kg/m³)	550	580	641	616
$f_{m,k}$ (MPa)	40	45	46	34
$E_{m,l}$ (MPa)	13.0	13.5	13.4	13.1

*The values in parenthesis correspond to the coefficient of variation.

It can be observed how the bending strength of LVL is higher than that of the tested sawn lumber sample, even having performed only 10 tests of LVL beams (a fact that penalizes the characteristic value).

This is consistent with the fact that engineered wood products such as LVL improve the properties of sawn lumber due to better material utilization and reduction of singularities in structural elements.

If we now analyze the results of the flexural tests performed on small dimension specimens, it is observed, as expected, that these samples are stronger and stiffer than those of structural size. In particular, the ratio between resistances is 1.67, and in the overall modulus of elasticity 1.43. This can be explained by the lower amount of singularities that small-sized wood has compared to structural-sized wood.

On the other hand, the pressing process with the hot plate press, used to produce the panels from which the small dimension specimens were obtained, has a higher degree of control than that performed with the large press used to produce the structural size beams. The latter may also influence the better results obtained with the small specimens.

Finally, with respect to the results of the tensile tests perpendicular to the fiber, it can be commented that the characteristic strength value obtained of 0.94 MPa is higher than that indicated for all hardwood species strength classes D in the EN338 standard, which corresponds to 0.6 MPa.

CONCLUSIONS

Based on the work carried out, it has been possible to produce and evaluate LVL from second quality beech veneers according to the sawmill's aesthetic grading criteria.

Bending tests have been carried out on small dimension and structural size specimens, as well as tensile tests perpendicular to the fiber. The results of the tests are satisfactory and encouraging, achieving good mechanical properties that indicate that the raw material is suitable for the production of this product. Comparing the properties of LVL tested in bending with those of sawn lumber of the same origin, the results have improved both in bending strength and stiffness.

Further information

https://gofagus.es/

Contacts

joseluis.villanueva@cesefor.com

FOREST4EU partners

Funded by the European Union

Funded by the European Union (Grant n. 101086216). Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union or REA. Neither the European Union nor the granting authority can be held responsible for them.

cesefor FORESTRY HEART, research spirit

forest4eu.eu

FOREST4EU Project

FOREST4EU Project

info@forest4eu.eu

FOREST4EU