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BIRCH FOR ENGINEERED TIMBER PRODUCTS :: PART II

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ABSTRACT: Even though birch (*Betula pendula*) is one of the main tree species in the north of Europe, it is currently hardly used for structural products, except plywood. Due to its excellent mechanical properties, the HASSLACHER group decided to see it as a future tree species for their products. In a series of projects, the material was characterised and products like Glued Laminated Timber (GLT) or Cross Laminated Timber (CLT) made from birch were developed and tested. To improve the properties of the material, a new type of lamella was developed and tested, the so-called “Strip Lamella”. By using homogenisation effects, the characteristic values of the mechanical properties were strongly improved compared to birch solid wood lamellas. First tests on GLT beams out of Strip Lamella show, that this effect not only occurs in the lamella, but also in structural timber products using this lamella, leading to higher properties compared to birch solid timber GLT.

KEYWORDS: birch, hardwood, Strip Lamella, homogenization

1 INTRODUCTION

Spruce, by far the main wood species in timber construction in Europe, is under high pressure. Droughts, storm and heavy snowfalls weaken the European spruce forests, followed by enormous bark beetle attacks. In Austria, some mountain areas are already cleared prophylactically from any spruce growing there, because it is just a matter of time until they will be infested.

Meanwhile the demand for structural timber products is constantly increasing. To be able to sustainably meet this demand in the future, new strategies are needed. There are different ways to cope with these challenges:

- **Production efficiency** could be **increased**, by better production techniques or less resource-intensive new products.
- **Old timber elements** from demolished buildings could go into **Reuse** instead of being downcycled to particleboards immediately or even being burned.
- Use of **new timber species** for structural timber products, to increase the resources available for sawmilling industry.

All topics are important to further increase the share of timber buildings while maintaining a sustainable use of forests in Europe. This paper will especially focus on the last one, the use of a new timber species which can create new opportunities in the timber construction industry.

Birch (*Betula pendula*) is one of the main wood species in Russia (11,023 Mio. m³), Scandinavia (817 Mio m³) and the Baltic States (325 Mio. m³) [1]. But birch is not only interesting for the north of Europe, also in Central European countries like Austria, Germany or the Czech Republic this wood species will be more important in the future. Currently for example there just around 6.6 Mio m³ Birch growing in Austria [2], but as the climate changes so does the forest. Especially in areas where spruce is facing more difficulties due to drought, birch-pine-forest could be of interest.

Despite these large amounts available in the north of Europe, birch is currently almost not used for structural applications, except as plywood. In a series of projects, the HASSLACHER group together with the Institute of Timber Engineering and Wood Technology and the Centre of Competence holz.bau forschungs gmbh at Graz University of Technology tried to gain more knowledge on the birch timber. Based on these findings, different products like GLT or CLT made from birch were developed [3].

But when working with new timber species, new challenges can occur. In case of using birch for structural timber products, the more difficult drying of the boards, grading and cutting efficiency due to the smaller log diameters were just some of them. Instead of trying to optimize currently existing standard methods for producing GLT and CLT made from spruce, the HASSLACHER group decided to work on new ways to face these challenges going beyond standard practices.

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2 IDEA

The basic idea of the Strip Lamella, already shown e.g. in [4], is to use thinner boards (with a thickness of about 20 mm) than usually used for GLT production. The advantage of using smaller dimensions is the reduced kiln drying time (~ -65 % compared to 40 mm boards) while maintaining a higher yield in the cutting process.
The boards are then glued together to a so called "mini-GLT", which is then cut again into lamellas. The production steps are shown in Figure 1.

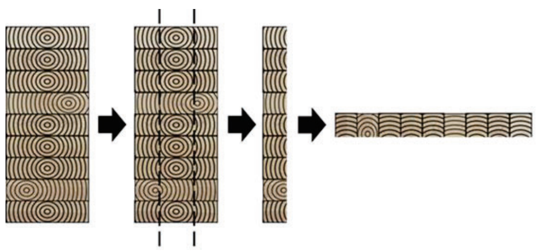

Figure 1: *Process steps of Strip Lamella production*

Despite having higher production effort due to an additional gluing and cutting step, this process is thought to have higher yield. Since production of Strip Lamellas lead to a more homogeneous product, the impact of defects from the original board is reduced. For example, a large knot with a diameter of 50 mm would reduce the strength of the original board dramatically, in the Strip Lamella it is reduced to a maximum width of 20 mm (width of strip), with straight fibres next to it in the adjacent strips.
This leads to fewer rejects when grading and eliminates any cutting of defects in the final Strip Lamella and with that to less loss in the whole production process.

3 STRIP LAMELLA TESTING

3.1 TEST MATERIAL

For production of the test specimen, boards with a dimension of 24 x 150 x 4,000 mm were dried and planed to a thickness of 20 mm. They were then graded following strength class LS7+ [5] and were glued together to a "mini-GLT"-beam with nine boards each using a two component MUF adhesive. The beams were then cut into three lamellas with a dimension of 43 x 169 x 4,000 mm as shown in Figure 1 schematically. A more detailed description of the production process can be found in [4].

As already described in [4], the Strip Lamella was divided into two groups, which were separately tested and analysed:

- **Basic:** middle lamella containing the pith and the pith-near areas, juvenile wood
- **Premium:** outer lamellas without pith, mature wood

Part of the Strip Lamellas produced were cut into shorter sections and finger-jointed together using a two component MUF adhesive.

3.2 TEST METHODS

3.2.1 Tensile Tests

To gain more knowledge on the mechanical properties of the Strip Lamella, tension tests were performed on specimen with and without finger-joints.

<u>*Strip Lamellas without finger-joints*</u>

For this test 159 Strip Lamellas were cut into specimen with a length of 3,000 mm, while the remaining part was used für the flatwise bending tests described in 3.2.2. The tensile tests were performed using a GEZU 850 tensile testing machine according to [6] with a free span length of 2,300 mm. The test setup and measurements are shown in Figure 2.

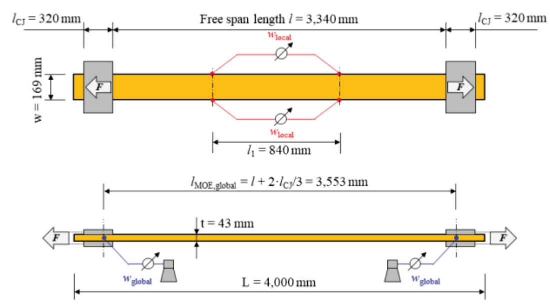

Figure 2: Setup tensile tests | Specimen without finger-joints

<u>*Strip Lamellas with finger-joints*</u>

The tests on Strip Lamellas with finger-joints were performed at Holzforschung Austria in Vienna. The samples were cut and planed to a size of 40 x 160 x 2,200 mm and were tested according to [7] with a free span length of 200 mm. The test setup can be found in Figure 3.

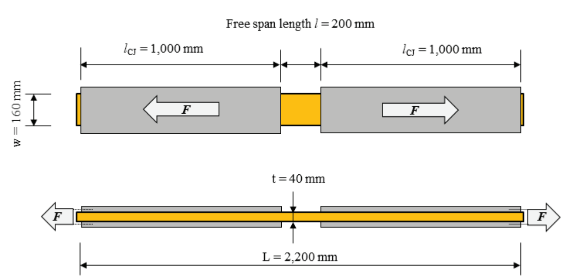

Figure 3: Setup tensile tests | Specimen with finger-joints

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3.2.2 Bending Test

The bending tests were performed according to [6] using a Zwick Universal Testing Machine 275. To gain more insight on the bending behaviour in the two different directions, edgewise and flatwise bending tests were performed on Strip Lamellas with and without finger-joints.

Strip Lamellas without finger-joints

The test setup used for the bending tests on Strip Lamellas without finger-joints is shown in Figure 4.

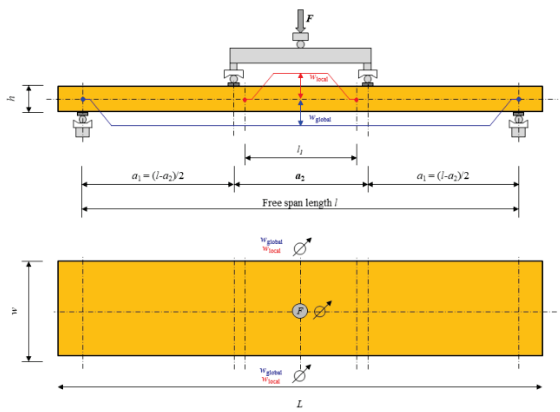

Figure 4: *Bending test setup for lamellas without finger-joint*

Since the test samples were tested flatwise and edgewise, different dimensions had to be used to fulfil the requirements according to [6]. They can be found in Table 1.

Table 1: *Dimensions for test setup of Strip Lamellas without finger-joints in flatwise and edgewise bending in [mm]*

		flatwise	edgewise
Height	h	43	169
Width	w	169	43
Length	L	816	3,211
Free span length	l	774	3,042
Distance force application	a_2	258	1,014
Distance local MOE	l_1	215	845

Strip Lamellas with finger-joints

Since it is not relevant for the characterization of finger-joints, no evaluation of the MOE was performed within these tests. The setup is shown in Figure 5.

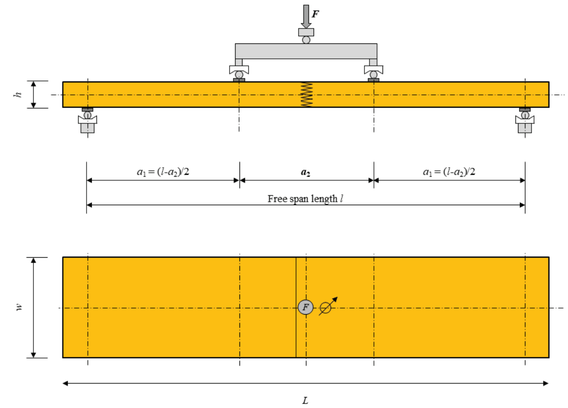

Figure 5: *Bending test setup for lamellas with finger-joint*

The finger-joint was always manufactured horizontally, so the finger-joint profile was visible on the broadside. The dimensions for the tests on Strip Lamellas with finger-joints are shown in Table 2.

Table 2: *Dimensions for test setup of Strip Lamellas with finger-joints in flatwise and edgewise bending in [mm]*

		flatwise	edgewise
Height	h	40	160
Width	w	160	40
Length	L	760	3,040
Free span length	l	720	2,880
Distance force application	a_2	240	960

3.3 Results

3.3.1 Strip Lamella

The mechanical properties of the Strip Lamellas tested are shown in Table 3. Here, the same effect as already discussed in [4] can be observed for all tests: When looking at the “Total” group containing all testes samples, the values are comparable to solid wood boards as shown in Chapter 4. By dividing into the two groups “Basic” and “Premium” according to the position in the log (juvenile vs. mature wood) as shown in Chapter 3.1 and the dynamic MOE as shown in [4], more homogeneous properties can be achieved. This leads to higher characteristic values for bending and tensile strength.

Due to the separation of juvenile and mature wood in the two different groups, also a difference in MOE can be observed, leading to almost 17,000 N/mm² in tensile testing. This shows the high potential birch can have in modern timber construction.

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Table 3: *Results of mechanical tests on Strip Lamellas in [N/mm²]*

Results of Strip Lamella testing width: 169 mm | thickness: 43 mm				
		Total	**Basic**	**Premium**
Tensile strength	$f_{t,mean}$	43.7	35.7	47.7
	$f_{t,k}$	29.4	26.1	35.0
Coefficient of variation	COV	20.7 %	16.4 %	15.9 %
MOE	$E_{t,mean}$	15,682	13,238	16,892
Bending strength flatwise	$f_{m,flat,mean}$	81.6	68,3	88.2
	$f_{m,flat,k}$	62.5	57.5	76.4
Coefficient of variation	COV	14.2 %	9.3 %	7.9 %
MOE	$E_{m,flat,mean}$	15,184	13,422	16,084
Bending strength edgewise	$f_{m,edge,mean}$	55.4*	47.7*	59.2*
	$f_{m,edge,k}$	33.6*	33.7*	34.7*
Coefficient of variation	COV	25.3 %	17.7 %	24.8 %
MOE	$E_{m,edge,mean}$	16,523	14,331	17,591

**Note: Since the gluing of the Strip Lamellas was not sufficient, the strength values in edgewise bending do not represent the full capabilities of this products but are reduced due to failures in the glue line. These insufficiencies were solved after the here presented test samples were produced and tested, further tests determining this property will follow.*

3.3.2 Strip Lamella with finger-joints

The results of testing of finger-joints in Strip Lamellas presented in Table 4 show no significant difference to the values shown for the Strip Lamella itself. This leads to the conclusion, that finger-joints are not reducing the strength of the lamella itself in a critical way, which is essential for developing GLT or CLT using Strip Lamellas.

Table 4: *Results of mechanical tests on Strip Lamellas with finger-joints in [N/mm²]*

Results of Strip Lamella testing width: 160 mm | thickness: 40 mm				
		Total	**Basic**	**Premium**
Tensile strength	$f_{t,j,mean}$	52.8	42.6	58.0
	$f_{t,j,k}$	35.6	30.2	44.9
Coefficient of variation	COV	20.2 %	16.3 %	14.1 %
Bending strength flatwise	$f_{m,j,flat,mean}$	74.1	61.9	80.4
	$f_{m,j,flat,k}$	55.9	49.6	70.7
Coefficient of variation	COV	14.5 %	11.5 %	7.0 %
Bending strength edgewise	$f_{m,j,edge,mean}$	52.5	44.7	56.9
	$f_{m,j,edge,k}$	32.6	28.0	37.3
Coefficient of variation	COV	24.2 %	21.9 %	21.2 %

4 Birch solid wood lamella testing

A randomly selected part of the birch solid wood boards already described in [4] were used for testing using the same methods and dimensions as described in Chapter 3.2. Since they are not in the main focus of this paper, no further discussion will be published here on the preparation of the test samples, but it seems still absolutely relevant to show the results to be able to have a comparison of the newly developed Strip Lamella to more common birch solid wood boards.

Table 5: *Results of mechanical tests on solid wood boards in [N/mm²]*

Results of solid wood board testing width: 165 mm | thickness: 43 mm		
Tensile strength	$f_{t,mean}$	43.9
	$f_{t,k}$	24.2
Coefficient of variation	COV	31.4 %
MOE	$E_{t,mean}$	15,370
Bending strength flatwise	$f_{m,flat,mean}$	89.5
	$f_{m,flat,k}$	64.9
Coefficient of variation	COV	16.8 %
MOE	$E_{m,flat,mean}$	14,851
Bending strength edgewise	$f_{m,edge,mean}$	70.1
	$f_{m,edge,k}$	42.1
Coefficient of variation	COV	24.0 %
MOE	$E_{m,edge,mean}$	16,646

The results of the mechanical tests performed is shown in Table 5 for the solid wood boards and in Table 6 for birch solid wood boards with finger-joints.

Table 6: *Results of mechanical tests on solid wood boards with finger-joints in [N/mm²]*

Results of solid wood board testing with finger-joints width: 160 mm | thickness: 40 mm		
Tensile strength	$f_{t,j,mean}$	53.9
	$f_{t,j,k}$	36.0
Coefficient of variation	COV	21.2 %
Bending strength flatwise	$f_{m,j,flat,mean}$	72.2
	$f_{m,j,flat,k}$	55.8
Coefficient of variation	COV	13.4 %
Bending strength edgewise	$f_{m,j,edge,mean}$	61.4
	$f_{m,j,edge,k}$	36.6
Coefficient of variation	COV	26.2 %

5 GLT FROM STRIP LAMELLA

To further test the mechanical properties, GLT made from Strip Lamellas was produced and tested. The tests were performed at the Institute of Timber Engineering and Wood Technology in Graz.

5.1 TEST MATERIAL AND METHODS

Strip-lamellas with a width of 120 mm (≙ 6 strips) and a thickness of 40 mm were manufactured as described in Chapter 2. Since Basic and Premium lamellas were produced with a ratio of 1:2, a combined beam layup with two Premium lamellas each on top and bottom of the beam and two Basic lamellas in the middle was chosen.

The bending tests were performed according to [6] with a ratio of free span length to height of 1:16. The test setup and measurements are shown in Figure 6.

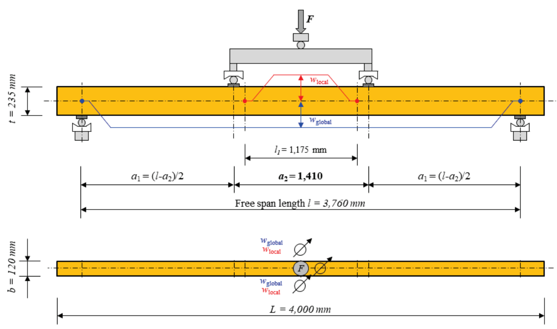

Figure 6: *Test setup for bending tests of GLT made from Strip Lamellas*

5.2 RESULTS

The results of the bending tests in Table 7 show the enormous potential of GLT out of birch Strip Lamellas. With a characteristic bending strength of almost 58 N/mm², this product exceeds the properties of solid birch GLT [8] by 80 % coming close to the values of BauBuche by Pollmeier.

Table 7: *Results of bending tests on GLT made from birch Strip Lamella*

Bending tests on GLT made from Strip Lamella		
width: 120 mm | height: 235 mm		15 specimen
Bending strength	$f_{m,g,mean}$	86.8 N/mm²
	$f_{m,g,k}$	57.8 N/mm²
Coefficient of variation	COV	8.6 %
MOE	$E_{0,g,mean}$	17,813 N/mm²
Coefficient of variation	COV	4.2 %
Density	$\rho_{g,mean}$	616 kg/m³
	$\rho_{g,k}$	557 kg/m³
Coefficient of variation	COV	1.4 %

The MOE on the other hand exceeds not just the solid birch GLT, with 17,800 N/mm² it is the highest value currently available in timber construction products.

6 CONCLUSION AND OUTLOOK

This paper shows the potential modern timber construction products have, when using birch. While current processes are sufficient to achieve very good mechanical properties in the product compared to spruce, new technologies have the chance to further increase them.

To further asses the mechanical properties of the Strip Lamella, more tests will be performed on the lamellas themselves, but also on products like GLT or CLT made from them. There will also be further investigation on connections in these new products to be able to use the in large timber buildings properly.

This will all finally lead to the application for an European Technical Assessment (ETA), to be able to have approved timber construction products.

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