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EXPERT REPORT

“Leneco Vollholzelement”

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1. Introduction

An application has been made for an ETA (European Technical Assessment) for “Leneco Vollholzelement”, which is a prefabricated timber element, consisting of milled rectangular boards made of softwood joined with hardwood dowels.

Leneco elements can consist of all continuous boards or both continuous and non-continuous boards.

Leneco elements are intended to be used as structural or non-structural elements in buildings and timber structures, e.g. as walls, floor or roof elements in service classes 1 and 2 according to EN 1995-1-1.

This Expert Report includes an evaluation of the test data provided in order to assess the relevant characteristics of the structural product.

The following documents are used as a basis for this report:

- Test Report n. 52/01/2018 “Tests to determine some physical and mechanical properties of hard wood dowels”, CNR Ivalsa, Istituto per la Valorizzazione del Legno e delle Specie Arboree, San Michele (TN), 04/03/2019
- Test Report n. 31/01/2018 “Tests to determine some physical and mechanical properties of only-timber panels Leneco Vollholzelement”, CNR Ivalsa, Istituto per la Valorizzazione del Legno e delle Specie Arboree, San Michele (TN), 05/03/2019
- Test Report n. 31/01/2018, Technical Annexes n°1, “Cyclic test on only-timber panels Leneco Vollholzelement”, CNR Ivalsa, Istituto per la Valorizzazione del Legno e delle Specie Arboree, San Michele (TN), 05/03/2019
- Test Report n. 31/02/2018 “Tests to determine some physical and mechanical properties of only-timber panels Leneco Vollholzelement”, CNR Ivalsa, Istituto per la Valorizzazione del Legno e delle Specie Arboree, San Michele (TN), 05/03/2019
- Test Report n. 31/02/2018, Technical Annexes n°1, “Cyclic test on only-timber panels Leneco Vollholzelement”, CNR Ivalsa, Istituto per la Valorizzazione del Legno e delle Specie Arboree, San Michele (TN), 05/03/2019
- Test Report n. 43/01/2018 “Test for the determination of mechanical properties of n° 4 only-wood wall element Leneco Vollholzelement”, CNR Ivalsa, Istituto per la Valorizzazione del Legno e delle Specie Arboree, San Michele (TN), 08/03/2019

- Test Report n. 31/03/2018 “Test for the determination of mechanical properties of n° 4 only-wood wall element Leneco Vollholzelement”, CNR Ivalsa, Istituto per la Valorizzazione del Legno e delle Specie Arboree, San Michele (TN), 06/03/2019
- EAD 130323-00-0304 – “Prüfprogramm für “Leneco Vollholzelement” der Firma LenEco GmbH, Vorgefertigte Holzbauelemente - Elemente aus gefrästen Nadelholzelementen für tragende Bauteile in Gebäuden”

The methods and criteria used for assessing the performance of the solid wood element in relation to the requirements for mechanical resistance and stability are provided in EAD 130323-00-0304.

2. Verification of the essential characteristics of the construction product (Basic Works Requirement 1)

2.1. Mechanical resistance and stiffness regarding mechanical actions perpendicular to the element

2.1.1. Bending (EAD 130323-00-0304 §1.1.2)

4-point bending tests according to EN 408:2012 have been performed on “Leneco Vollholzelement” in flatwise configuration.

Four geometrical configurations were tested:

- 15 samples with thickness 130 mm, width 600 mm, length 2900 mm and span of 2700 mm:
  - all samples were continuous elements
- 15 samples with thickness 200 mm, width 600 mm, length 4900 mm and span of 4100 mm:
  - 8 samples were non-continuous elements
  - 7 samples were continuous elements

The procedure of EN 408 for the determination of the local modulus of elasticity in bending has been applied.

$$E_0 = \frac{a \cdot l_1^2 \cdot (F_2 - F_1)}{16 \cdot I \cdot \left(w_{2,local} - w_{1,local}\right)}$$

Where:

a is the distance between a loading position and the nearest support, in mm

l_1 is the gauge length for the determination of the modulus of elasticity, in mm

I is the second moment of area, in mm^4

The results are given in Table 1. The following values are specified:

h = Depth of the element cross-section, in mm

b = Width of the element cross section, in mm

F_i = Load equal to 0.2 and 0.3 of the maximum load at failure, in kN

$w_{i,\,local}$ = Local deformation corresponding to F_i, in mm

E_0 = Modulus of elasticity parallel to the grain of the boards, in MPa

Configuration 130 x 600 mm, Supports distance: 2700 mm, Continuous elements						
h [mm]	**b [mm]**	**F_1 [kN]**	**F_2 [kN]**	**$W_{1,\ local}$ [mm]**	**$W_{2,\ local}$ [mm]**	**E_0 [MPa]**
131.9	601.7	13.74	20.62	0.32	0.50	8229
131.8	602.3	12.78	19.14	0.33	0.48	9658
130.8	603.7	15.78	23.72	0.35	0.53	9778
131.5	597.7	15.58	23.38	0.35	0.52	9969
131.1	600.3	16.04	24.04	0.46	0.69	7890
131.3	601.7	15.64	23.54	0.39	0.60	8563
131.0	601.0	15.10	22.58	0.39	0.58	8912
130.6	600.7	13.30	19.88	0.37	0.55	8255
130.5	600.7	12.58	18.92	0.32	0.48	8897
131.3	598.3	13.86	20.80	0.42	0.64	7281
131.1	597.7	12.38	18.58	0.35	0.52	8220
131.8	599.0	14.14	21.22	0.40	0.61	7615
130.9	597.7	14.00	21.06	0.42	0.63	7488
131.0	599.0	14.52	21.74	0.39	0.60	7966
131.9	599.7	13.64	20.46	0.44	0.69	6145
Sample mean value					**$E_{0,mean}$ [MPa]**	**8324**
Configuration 200 x 600 mm, Supports distance: 4100 mm, Non-continuous elements						
h [mm]	**b [mm]**	**F_1 [kN]**	**F_2 [kN]**	**$W_{1,\ local}$ [mm]**	**$W_{2,\ local}$ [mm]**	**E_0 [MPa]**
195.4	608.7	21.72	32.62	0.60	0.95	7607
196.0	611.3	18.62	28.00	0.58	0.97	5778
195.5	613.7	23.28	34.92	0.67	1.05	7282
195.8	610.7	23.00	34.50	0.60	0.95	7775
195.9	608.7	18.68	28.08	0.61	0.96	6452
195.1	612.7	18.68	28.02	0.78	1.17	5748
194.8	613.7	16.56	24.84	0.51	0.78	7248
195.4	611.7	20.16	30.22	0.73	1.10	6653
Sample mean value					**$E_{0,mean}$ [MPa]**	**6818**
Configuration 200 x 600 mm, Supports distance: 4100 mm, Continuous elements						
h [mm]	**b [mm]**	**F_1 [kN]**	**F_2 [kN]**	**$W_{1,\ local}$ [mm]**	**$W_{2,\ local}$ [mm]**	**E_0 [MPa]**
195.4	607.3	19.30	28.98	0.67	1.06	6061
195.0	607.7	18.92	28.46	0.65	1.03	6049
194.4	609.3	24.18	36.30	0.69	1.07	7835
192.0	608.7	23.62	35.40	0.70	1.10	7544

195.3	611.3	19.98	29.96	0.87	1.39	4696
194.7	610.0	19.80	29.70	0.68	1.06	6308
194.5	609.7	22.24	33.40	0.66	1.03	7380
Sample mean value					**$E_{0,mean}$ [MPa]**	**6553**

Table 1: Modulus of elasticity, tests results

Proposal for the requirement in the ETA

For the design of the "Leneco Vollholzelement" in flatwise bending according to EN 1995-1-1, the following moduli of elasticity parallel to the grain of the boards may be assumed:

- continuous elements:

  h = 130 mm $E_{0,mean}$ = 8300 MPa

  h = 200 mm $E_{0,mean}$ = 6500 MPa

  linear interpolation between 130 mm ≤ h ≤ 200 mm may be applied;

- non-continuous elements:

  h = 200 mm $E_{0,mean}$ = 6500 MPa

For the design of bending members with the above-proposed moduli of elasticity parallel to the grain, the gross cross-section inertial properties may be used neglecting the presence of the milling and of the holes due to the hardwood dowels.

The bending stress σ_m has been calculated from the ultimate moment by considering the gross area of the Leneco element cross-sections.

The results are given in Table 2. The following values are specified:

F_u = Total load at failure, in kN

M_u = Ultimate bending moment, in kNm

W_{gross} = Elastic gross section modulus, in mm^3

σ_m = Bending normal stress at failure, in MPa

Configuration 130 x 600 mm, Supports distance: 2700 mm, Continuous elements			
F_u [kN]	**M_u [kNm]**	**W_{gross} [mm³]**	**σ_m [MPa]**
68.70	32.98	1743536	18.91
63.78	30.61	1743438	17.56
79.02	37.93	1721582	22.03
77.78	37.33	1723374	21.66
80.34	38.56	1719151	22.43
78.44	37.65	1727792	21.79
75.26	36.12	1718435	21.02
66.38	31.86	1707357	18.66
63.04	30.26	1704046	17.76
69.34	33.28	1719267	19.36
61.90	29.71	1712472	17.35
70.78	33.97	1734141	19.59
70.10	33.65	1706209	19.72
72.52	34.81	1713589	20.31
68.20	32.74	1738882	18.83
Sample mean value (Log-normal dist.)		$\bar{y}$ [MPa]	19.73
Characteristic value (Log-normal dist.)		**$f_{m,k}$ [MPa]**	**16.67**
Configuration 200 x 600 mm, Supports distance: 4100 mm, Non-continuous elements			
F_u [kN]	**M_u [kNm]**	**W_{gross} [mm³]**	**σ_m [MPa]**
108.71	79.63	3871945	20.57
93.30	68.34	3914164	17.46
116.55	85.37	3910415	21.83
114.92	84.18	3900591	21.58
93.47	68.47	3891789	17.59
93.40	68.42	3888087	17.60
82.71	60.59	3882467	15.60
100.70	73.76	3892357	18.95
Sample mean value (Log-normal dist.)		$\bar{y}$ [MPa]	18.78
Characteristic value (Log-normal dist.)		**$f_{m,k}$ [MPa]**	**14.50**
Configuration 200 x 600 mm, Supports distance: 4100 mm, Continuous elements			
F_u [kN]	**M_u [kNm]**	**W_{gross} [mm³]**	**σ_m [MPa]**
96.60	70.76	3863463	18.32
94.83	69.46	3852404	18.03
121.03	88.65	3837923	23.10
117.96	86.41	3738350	23.11
99.98	73.24	3887582	18.84

99.10	72.59	3855309	18.83
111.42	81.62	3844633	21.23
Sample mean value (Log-normal dist.)		$\bar{y}$ [MPa]	20.10
Characteristic value (Log-normal dist.)		**$f_{m,k}$ [MPa]**	**15.75**

Table 2: Bending strength, tests results

Proposal for the requirement in the ETA

For the design of the "Leneco Vollholzelement" in flatwise bending according to EN 1995-1-1, the following characteristic bending strength values parallel to the grain of the boards may be assumed:

- continuous elements:

  h = 130 mm $f_{m,k}$ = 16.50 MPa

  h = 200 mm $f_{m,k}$ = 15.50 MPa

  linear interpolation between 130 mm ≤ h ≤ 200 mm may be applied;

- non-continuous elements:

  h = 200 mm $f_{m,k}$ = 14.50 MPa

For the design of bending members with the above-proposed characteristic strengths, the gross cross-section inertial properties may be used neglecting the presence of the milling and of the holes due to the hardwood dowels.

The k_h factor defined in section 3.2(3) of EN 1955-1-1 and the k_{sys} factor defined in section 6.6 of EN 1955-1-1 shall be always taken equal to 1.0.

2.1.2. Shear (EAD 130323-00-0304 §1.1.4)

Shear tests according to EN 408:2012 have been performed on "Leneco Vollholzelement" in flatwise configuration.

Two geometrical configurations were tested:

- 15 samples with thickness 130 mm, width 600 mm, length 3000 mm and span of 2800 mm;
  - all samples were non-continuous elements
- 15 samples with thickness 200 mm, width 600 mm, length 3000 mm and span of 2800 mm:
  - 8 samples were non-continuous elements
  - 7 samples were continuous elements

The shear stress τ has been calculated from the ultimate shear force by considering the gross area of the "Leneco Vollholzelement" cross-sections.

The results are given in Table 3. The following values are specified:

F_u = Total load at failure, in kN

V_u = Ultimate shear, in kN

A_{gross} = Area of the gross cross section, in mm^2

τ = Shear stress at failure, in MPa

Configuration 130 x 600 mm, Supports distance: 2800 mm, non-continuous elements			
F_u [kN]	**V_u [kN]**	**A_{gross} [mm^2]**	**τ [MPa]**
165.32	82.66	80055	1.55
179.28	89.64	80529	1.67
179.72	89.86	80703	1.67
150.46	75.23	79024	1.43
184.44	92.22	78537	1.76
159.22	79.61	78034	1.53
146.60	73.30	78646	1.40
170.50	85.25	78948	1.62
164.56	82.28	78707	1.57
188.30	94.15	78454	1.80
158.12	79.06	78569	1.51
135.18	67.59	79843	1.27
179.24	89.62	78927	1.70
142.60	71.30	79353	1.35
164.11	82.06	78947	1.56
Sample mean value (Log-normal dist.)		$\bar{y}$ [MPa]	1.55
Characteristic value (Log-normal dist.)		**$f_{v,k}$ [MPa]**	**1.27**
Configuration 200 x 600 mm, Supports distance: 2800 mm, non-continuous elements			
F_u [kN]	**V_u [kN]**	**A_{gross} [mm^2]**	**τ [MPa]**
226.34	113.17	119744	1.42
247.32	123.66	120082	1.54
251.10	125.55	120400	1.56
227.72	113.86	119780	1.43
245.21	122.61	119454	1.54
204.90	102.45	119772	1.28
207.62	103.81	120062	1.30
218.74	109.37	119695	1.37
Sample mean value (Log-normal dist.)		$\bar{y}$ [MPa]	1.43
Characteristic value (Log-normal dist.)		**$f_{v,k}$ [MPa]**	**1.20**
Configuration 200 x 600 mm, Supports distance: 2800 mm, continuous elements			
F_u	**V_u**	**A_{gross}**	**τ**

[kN]	[kN]	[mm²]	[MPa]
225.52	112.76	120082	1.41
234.24	117.12	120013	1.46
245.10	122.55	120257	1.53
232.22	116.11	120137	1.45
234.77	117.39	119938	1.47
238.70	119.35	119715	1.50
254.93	127.47	119938	1.59
Sample mean value (Log-normal dist.)		ȳ [MPa]	1.49
Characteristic value (Log-normal dist.)		**$f_{v,k}$ [MPa]**	**1.33**

Table 3: Shear strength, tests results

Proposal for the requirement in the ETA

For the design of “Leneco Vollholzelement” in flatwise shear according to EN 1995-1-1 a shear strength of 1.20 MPa may be assumed.

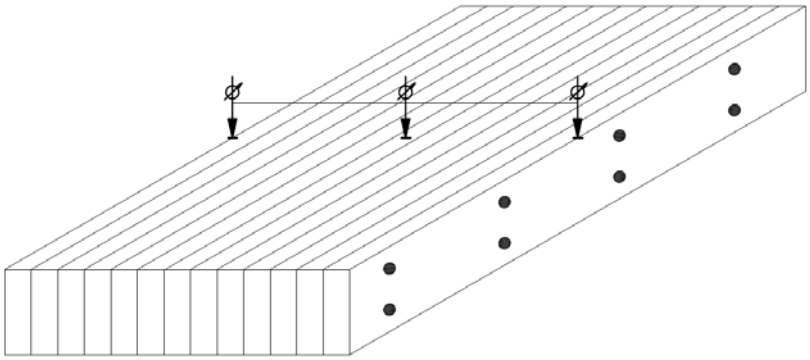
For the design of shear members with the above-proposed characteristic strengths, the gross cross-section areal properties may be used neglecting the presence of the milling and of the holes due to the hardwood dowels.

The k_{cr} factor for solid wood provided in section 6.1.7(2) of EN 1995-1-1 shall be always taken equal to 1.0.

2.1.3. Point loads (EAD 130323-00-0304 §1.1.5)

Bending tests with point load have been performed on “Leneco Vollholzelement” in flatwise configuration, with the milled timber boards arranged upright and with their length parallel to the free span.

The tested configuration consists of a slab-like specimen with thickness 200 mm, width 600 mm, length 5200 mm and span 5000 mm built of timber elements with thickness 50 mm connected with transversal hardwood dowels (20 mm of diameter). 3 samples were tested under a point load applied through a circular steel plate (diameter 50 mm) in the middle of the tested element.



The measurements of reached loads and corresponding deformations in traverse direction are given in Table 4. The following values are specified:

F_i = Load equal to 0.2 and 0.3 of the maximum load at failure, in kN

$W_{i,\ central}$ = Deformation in the central point of the specimen (at mid-span) corresponding to F_i, in mm

$W_{i,\ external}$ = Deformation in the external portion of the specimen (at mid-span) corresponding to F_i, in mm

$W_{i,e} / W_{i,c}$ = Ratio between external and central deformation corresponding to F_i, in %

Configuration 200 x 600 mm, Supports distance: 5000 mm, point load					
F_i [kN]		**$W_{i,\ central}$ [mm]**	**$W_{i,\ external}$ [mm]**		**$W_{i,\ e} / W_{i,\ m}$ [%]**
F_1	10.00	10.39	9.43		90.74
F_2	15.00	15.99	14.51		90.74
F_1	9.48	10.89	9.96		91.48
F_2	14.22	16.31	14.98		91.84
F_1	10.04	12.16	11.08		91.08
F_2	15.06	18.28	16.69		91.33
Mean Ratio $W_{i,e} / W_{i,c}$				**F_1**	**91.10 %**
				F_2	**91.30 %**

Table 4: Point load, tests results

The tests results show that the point load is effectively spread from the directly loaded lamellae to the external ones. The deflection of the external lamellae is, on average, greater than the 90% of the deflection of the lamellae in the middle of the slab specimen.

No failure of the hardwood dowels, meant for transmitting the load through the lamellae, has been reached.

The maximum width of the tested elements was 600 mm and the following proposal relies on this tested configuration.

Proposal for the requirement in the ETA

For the design of the "Leneco Vollholzelement" under concentrated loads, whose minimum dimension is at least 50 mm, the effective width b_{ef} of the element shall be taken as follows: on each side of the loading point, the portion of the effective width (measured perpendicular to the length of the lamellae) shall be equal to the minimum between the distance between the loading point and the edge of a single "Leneco Vollholzelement" (*a*) and 300 mm.

2.1.4. Hardwood dowels (EAD 130323-00-0304 §1.1.1)

3-point bending test have been performed on the hardwood dowels. The load was applied using a properly steel system able to center the load by the use of a cylinder placed exactly at the mid span of the specimen.

A single configuration was tested:

- 30 samples with nominal diameter 20 mm, length 600 mm and a span of 320 mm.

The results are given in Table 5. The following values are specified:

Ø = Diameter of the element cross-section, in mm

F_{max} = Maximum load at failure, in kN

M_{max} = Maximum bending moment at failure, in kNm

Ø20 hardwood dowel, Supports distance: 320 mm		
Ø [mm]	**F_{max} [kN]**	**M_{max} [kNm]**
20.46	1.49	0.119
19.99	1.18	0.094
20.25	1.51	0.121
20.22	1.33	0.106
20.37	1.20	0.096
20.35	1.37	0.110
20.42	1.38	0.110
20.29	1.66	0.133
20.40	1.30	0.104
20.27	1.68	0.134
20.37	1.35	0.108
20.11	1.50	0.120
20.39	1.41	0.113
19.97	1.04	0.083
20.07	1.28	0.102
20.18	1.29	0.103
19.93	1.44	0.115
20.11	1.44	0.115
19.96	1.56	0.125
19.77	1.42	0.114
19.90	1.48	0.118
20.11	1.35	0.108
19.96	1.40	0.112
19.93	1.52	0.122
19.99	1.51	0.121
19.99	1.54	0.123
19.97	1.33	0.106
20.18	1.17	0.094
19.95	1.34	0.107
20.05	1.42	0.114
Sample mean value (Log-normal dist.)	ȳ [kNm]	0.111
Characteristic value (Log-normal dist.)	**M_k [kNm]**	**0.091**

Table 5: Hardwood dowels, tests results

The characteristic value of bending moment capacity of the tested hardwood dowels results to be equal to:

$$M_k = 0.091 \text{ kNm}$$

2.2. Mechanical resistance and stiffness regarding mechanical actions in-plane of the element

2.2.1. Shear (contribution of hardwood dowels - EAD 130323-00-0304 §1.2.2)

4-point bending tests according to EN 408:2012 have been performed on “Leneco Vollholzelement” in edgewise configuration made of layers of boards with their length parallel to the free span. Above and below these elements, centered on the dowels positions, were placed other three outer layers of non-continuous boards.

Two geometrical configurations were tested:

- 15 samples with height 450 mm (internal + outer layers), width 135 mm, length 3000 mm and span of 2800 mm, each layer consists of one continuous board, two dowels in each row, 500 mm spacing;
- 15 samples with height 450 mm (internal + outer layers), width 350 mm, length 3000 and span of 2800 mm, each layer consists of two continuous boards placed side by side, three dowels in each row, 500 mm spacing;

All the specimens were loaded at 300 mm from the supports in order to test the contribution of dowels in shear.

The equivalent bending stiffness of the tested configurations has been calculated according to the data of global deformation and the corresponding loading values. Afterward, the slip modulus of the hardwood dowels has been estimated by applying the mechanically jointed beam method proposed in EN 1995-1-1, Annex B.

The results regarding stiffness are given in Table 6. The following values are specified:

h = Depth of the element cross section, in mm

b = Width of the element cross section, in mm

F_i = Load equal to 0.2 and 0.3 of the maximum load at failure, in kN

$W_{i,\,global}$ = Global deformation corresponding to F_i, in mm

$EJ_{eff,\,global}$ = Stiffness of the element including the shear deformability of the dowels, in MPa

K_{ser} = Slip modulus of the hardwood dowel in the tested configuration, in N/mm

Configuration 135 x 450 mm, Supports distance: 2800 mm, two dowels, one board per layer							
h [mm]	**b [mm]**	**F_1 [kN]**	**F_2 [kN]**	**$W_{1,\,global}$ [mm]**	**$W_{2,\,global}$ [mm]**	**$EJ_{eff,\,global}$ [Nmm²]**	**K_{ser} [N/mm]**
462.3	132.8	11.68	17.52	10.77	18.36	1.19E+11	5745
461.3	132.0	10.98	16.50	11.88	19.83	1.07E+11	4716
456.3	130.8	9.98	14.98	9.60	15.93	1.28E+11	6750
455.3	130.3	11.96	17.96	13.24	21.96	1.10E+11	5016
456.7	131.5	14.26	21.36	15.96	27.03	9.94E+10	4012
453.0	131.0	9.40	14.14	9.59	17.06	1.02E+11	4302
455.3	130.3	9.36	14.00	9.87	16.10	1.19E+11	5918
458.7	131.6	15.51	21.76	16.36	25.66	1.08E+11	4776
458.3	131.5	14.48	21.74	19.19	27.40	1.43E+11	8486
456.3	131.3	11.62	17.42	13.55	22.33	1.05E+11	4557
456.7	131.5	11.08	16.62	12.65	20.63	1.09E+11	4851
456.3	131.3	9.88	14.80	11.75	19.58	1.00E+11	4070
455.3	130.8	10.08	15.12	11.68	19.28	1.08E+11	4767
458.7	131.2	11.01	16.47	7.97	26.11	4.71E+10	128
453.3	130.3	13.81	20.73	17.38	28.22	1.02E+11	4246
Sample mean value						**K_{ser} [N/mm]**	**4823**
Configuration 350 x 450 mm, Supports distance: 2800 mm, three dowels, two boards per layer							
h [mm]	**b [mm]**	**F_1 [kN]**	**F_2 [kN]**	**$W_{1,\,global}$ [mm]**	**$W_{2,\,global}$ [mm]**	**$EJ_{eff,\,global}$ [Nmm²]**	**K_{ser} [N/mm]**
461.0	344.7	24.02	36.06	20.36	30.54	1.89E+11	3196
463.3	342.3	23.56	35.30	22.31	33.78	1.60E+11	1881
464.0	343.0	22.30	33.45	21.98	32.66	1.75E+11	2536
464.7	340.0	23.14	34.58	21.70	32.06	1.71E+11	2405
465.7	339.7	22.60	33.92	20.10	30.66	1.70E+11	2371
464.3	341.7	24.40	36.58	20.36	30.94	1.89E+11	3243
461.7	341.0	29.56	44.46	23.34	34.38	2.15E+11	4564
463.7	340.7	19.12	28.68	17.12	25.74	1.78E+11	2715
463.3	338.3	22.66	34.06	21.54	29.56	2.42E+11	6116
465.7	340.7	23.35	34.95	19.33	29.47	1.86E+11	3104
463.0	337.0	22.22	33.34	18.49	28.93	1.69E+11	2382
464.3	337.7	21.90	32.76	23.10	33.52	1.64E+11	2147
461.3	339.3	22.06	33.10	19.64	29.54	1.85E+11	3120
462.3	338.3	23.36	35.00	19.96	30.43	1.80E+11	2874
466.3	336.3	22.36	33.50	21.20	32.19	1.63E+11	2063
Sample mean value						**K_{ser} [N/mm]**	**2981**

Table 6: Shear (contribution of hardwood dowels), tests results

The calculated values of the slip modulus K_{ser} have to be considered as an equivalent measure of the stiffness of the connection between the layers of the cross-section that may include the contribution of friction and other geometry-correlated factors.

No failure of the dowels has been reached and, consequently, it is not possible to obtain a reliable value of their strength in shear.

Proposal for the requirement in the ETA

With reference to the specific tested configurations, the following overall value of the slip modulus K_{ser} of the hardwood dowels may be assumed equal to K_{ser} = 2900 N/mm.

2.2.2. Shear walls (EAD 130323-00-0304 §1.2.4)

Racking strength and stiffness tests for timber shear walls according to EN 594:2011 have been performed on walls made of “Leneco Vollholzelement” parallel to each other and jointed by means of horizontal or inclined hardwood dowels 20 mm diameter. Further specifications on the materials and fixing of the tested walls may be found in the following Test Reports:

- No. 43/01/2018 “Tests for the determination of mechanical properties of n° 4 only-wood wall element Leneco Vollholzelement”, CNR Ivalsa, Istituto per la Valorizzazione del Legno e delle Specie Arboree, San Michele (TN), 08/03/2019
- No. 31/03/2018 “Tests for the determination of mechanical properties of n° 4 only-wood wall element “Leneco Vollholzelement”, CNR Ivalsa, Istituto per la Valorizzazione del Legno e delle Specie Arboree, San Michele (TN), 06/03/2019

Together with the racking load, a vertical load of 20 kN/m was applied.

Four geometrical configurations were tested:

- 2 samples with thickness 135 mm, width 2400 mm and height of 2430 mm, with horizontal dowels;
- 2 samples with thickness 135 mm, width 2400 mm and height of 2430 mm, with inclined dowels;
- 2 samples with thickness 340 mm, width 2400 mm and height of 2430 mm, with horizontal dowels;
- 2 samples with thickness 340 mm, width 2400 mm and height of 2430 mm, with inclined dowels.

The procedure and the equation of EN 594:2011 for the determination of the racking stiffness has been applied.

$$R = \frac{F_4 - F_2}{v_4 - v_2}$$

The results regarding stiffness are given in Tables 7 and 8. The following values are specified:

F_i = Racking load equal to 0.2 and 0.4 of the maximum load at failure, in kN

v_i = Deformation corresponding to F_i, in mm

R = Racking stiffness of the panel, in N/mm

Configuration 135 x 2400 mm x 2430 mm, horizontal dowels				
F_2 [kN]	**F_4 [kN]**	**v_2 [mm]**	**v_4 [mm]**	**R [N/mm]**
5.72	11.44	0.14	7.67	760
6.01	12.02	0.59	4.06	1730
Sample mean value			**R [N/mm]**	**1245**
Configuration 135 x 2400 mm x 2430 mm, inclined dowels				
F_2 [kN]	**F_4 [kN]**	**v_2 [mm]**	**v_4 [mm]**	**R [N/mm]**
9.01	18.02	1.64	17.58	565
9.12	18.24	0.71	12.00	808
Sample mean value			**R [N/mm]**	**687**

Table 7 - Shear walls, thickness 135 mm, stiffness tests results

Configuration 340 x 2400 mm x 2430 mm, horizontal dowels				
F_2 [kN]	**F_4 [kN]**	**v_2 [mm]**	**v_4 [mm]**	**R [N/mm]**
10.46	20.91	0.84	5.54	2222
11.66	23.31	0.39	3.68	3539
Sample mean value			**R [N/mm]**	**2881**
Configuration 340 x 2400 mm x 2430 mm, inclined dowels				
F_2 [kN]	**F_4 [kN]**	**v_2 [mm]**	**v_4 [mm]**	**R [N/mm]**
10.01	20.02	0.68	4.69	2495
10.21	20.42	1.21	6.28	2015
Sample mean value			**R [N/mm]**	**2255**

Table 8: Shear walls, thickness 340 mm, stiffness tests results

From the racking stiffness calculated above it is possible to define a value of shear stiffness per meter of wall length as follows.

$$(GA)_{ef} = \frac{F_h}{\gamma} = \frac{F_h \cdot h}{\delta} = R \cdot h$$

Where:

$(GA)_{ef}$ is the shear stiffness of the wall;

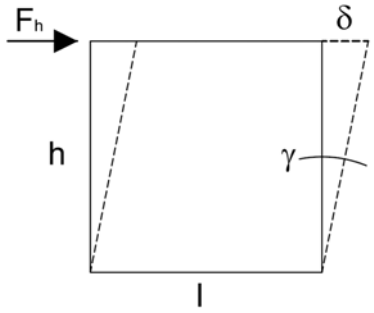
R is the racking stiffness;

l is the length of the wall;

h is the height of the wall;

γ is the shear strain;

δ is the horizont al displacement.



Proposal for the requirement in the ETA

With reference to the specific tested configurations and according to the mean value of the racking stiffness defined above, the following effective shear stiffness value per meter of wall length may be assumed.

Shear stiffness of the wall element, $(GA)_{ef}$ [N/m]		
Wall thickness [mm]	Horizontal dowels	Inclined dowels
135	$1200 \cdot 10^3$	$650 \cdot 10^3$
340	$2800 \cdot 10^3$	$2200 \cdot 10^3$

The racking force has been increased until F_{max} is reached, where F_{max} is either the racking load at failure or the racking load that generates a deformation of 100 mm, whichever occurs first.

The results regarding strength are given in Table 9. The following values are specified:

$v_{h,t}$ = Horizontal deformation at the top of the panel, in mm

$v_{h,b}$ = Horizontal deformation at the base of the panel, in mm

v_v = Uplift of the panel, in mm

F = Racking strength of the panel, in kN

Configuration 135 x 2400 mm x 2430 mm, horizontal dowels			
$v_{h,t}$ [mm]	**$v_{h,b}$ [mm]**		**F [kN]**
100.03	0.54		28.60
100.22	0.19		30.30
Sample mean value (Log-normal dist.)		$\bar{y}$ [kN]	29.32
Minimum value		**$F_{,min}$ [kN]**	**28.60**
Configuration 135 x 2400 mm x 2430 mm, inclined dowels			
$v_{h,t}$ [mm]	**$v_{h,b}$ [mm]**		**F [kN]**
99.90	1.47		45.06
100.63	2.57		45.60
Sample mean value (Log-normal dist.)		$\bar{y}$ [kN]	45.33
Minimum value		**$F_{,min}$ [kN]**	**45.06**
Configuration 340 x 2400 mm x 2430 mm, horizontal dowels			
$v_{h,t}$ [mm]	**$v_{h,b}$ [mm]**		**F [kN]**
97.93	2.16		52.28
100.04	1.81		58.28
Sample mean value (Log-normal dist.)		$\bar{y}$ [kN]	55.20
Minimum value		**$F_{,min}$ [kN]**	**52.28**
Configuration 340 x 2400 mm x 2430 mm, inclined dowels			
$v_{h,t}$ [mm]	**$v_{h,b}$ [mm]**		**F [kN]**
99.69	1.55		50.06
99.89	1.51		51.06
Sample mean value (Log-normal dist.)		$\bar{y}$ [kN]	50.06
Minimum value		**$F_{,min}$ [kN]**	**50.56**

Table 9: Shear walls, strength test results

Proposal for the requirement in the ETA

With reference to the specific tested configurations, the following characteristic load bearing capacity under horizontal loads per m wall length may be assumed.

Load bearing capacity for horizontal loads of the wall element, $F_{H,Rk}$ [kN/m]		
Wall thickness [mm]	Horizontal dowels	Inclined dowels
135	28	45
340	50	50

3. Product characteristics of the "Leneco Vollholzelement"

BWR[1)]	***Essential Characteristic***	***Assessment method***	***Level / Class / Description***		
1	**Mechanical resistance and stability**				
	1. Load bearing capacity and stiffness regarding mechanical actions perpendicular to the "Leneco Vollholzelement"				
	Modulus of elasticity		Continuous elements		Non-continuous elements
			h = 130 mm	h = 200 mm	h = 200 mm
	- parallel to the grain of the boards $E_{0,mean}$	EAD 130323-00-0304 1.1.2 I_{gross}	8300 MPa[2)]	6500 MPa[2)]	6500 MPa
	Bending strength		Continuous elements		Non-continuous elements
			h = 130 mm	h = 200 mm	h = 200 mm
	- parallel to the grain of the boards $f_{m,k}$	EAD 130323-00-0304 1.1.2 W_{gross}	16.5 MPa[2,3,4)]	15.5 MPa[2,3,4)]	14.5 MPa[3,4)]
	Shear strength - parallel to the grain of the boards $f_{v,090,k}$	EAD 130323-00-0304 1.1.4 A_{gross}	1.2 MPa[5)]		

Table 10: Product characteristics of the "Leneco Vollholzelement"

1) BWR: Basic Work Requirements
2) linear interpolation between 130 mm ≤ h ≤ 200 mm may be applied
3) k_h (3.2(3) EN 1955-1-1) shall be always taken equal to 1
4) k_{sys} (6.6 EN 1955-1-1) shall be always taken equal to 1
5) k_{cr} for solid wood (6.1.7(2) EN 1995-1-1) shall be always taken equal to 1

BWR [1)]	***Essential Characteristic***	***Assessment method***	***Level / Class / Description***			
1	**Mechanical resistance and stability**					
	2. Load bearing capacity and stiffness regarding mechanical actions in plane of the "Leneco Vollholzelement"					
	Racking stiffness (per meter of wall length)		Horizontal dowels		Inclined dowels	
			Thickness 135 mm	Thickness 340 mm	Thickness 135 mm	Thickness 340 mm
	- $(GA)_{ef}$	EAD 130323-00-0304 1.2.4	$1200 \cdot 10^3$ N/m [2)]	$2800 \cdot 10^3$ N/m [2)]	$650 \cdot 10^3$ N/m [2)]	$2200 \cdot 10^3$ N/m [2)]
	Racking strength (per meter of wall length)		Horizontal dowels		Inclined dowels	
			Thickness 135 mm	Thickness 340 mm	Thickness 135 mm	Thickness 340 mm
	- $F_{H,Rk}$	EAD 130323-00-0304 1.2.4	28 kN/m [2)]	50 kN/m [2)]	45 kN/m [2)]	50 kN/m [2)]

Table 11: Product characteristics of the "Leneco Vollholzelement"

1) BWR: Basic Work Requirements

2) According to the tested configurations

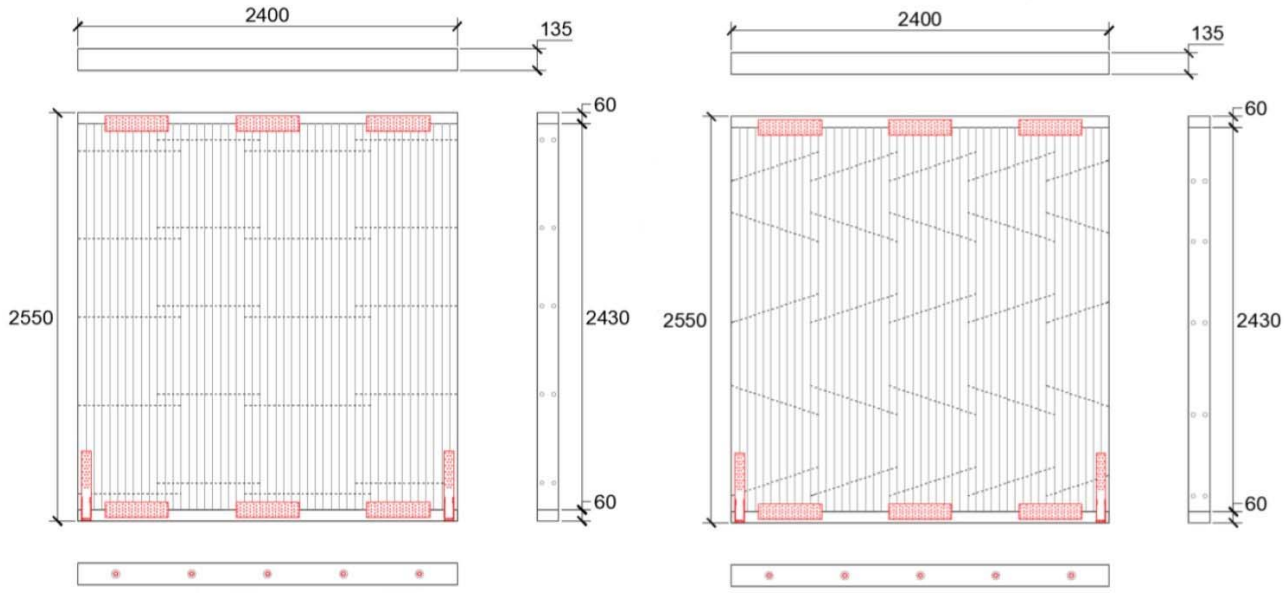


Figure 1 - Tested wall configurations, thickness 135 mm

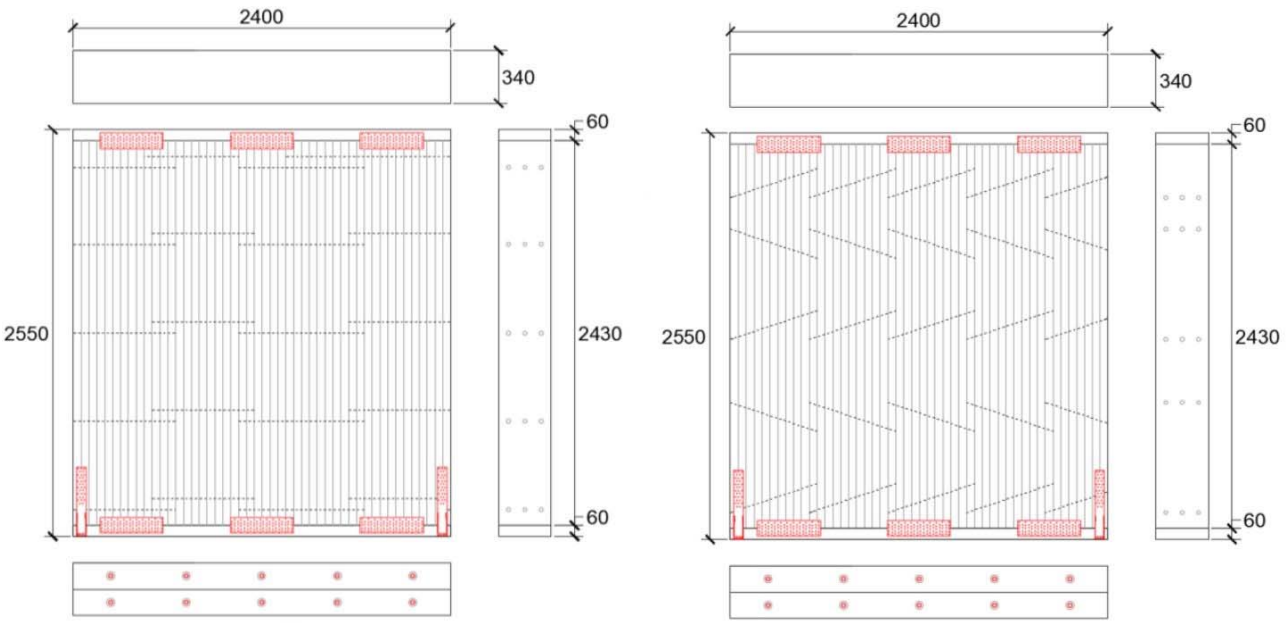


Figure 2 - Tested wall configurations, thickness 340 mm

4. Summary

This expert report assesses the load-carrying capacity of “Leneco Vollholzelement” (prefabricated softwood element joined with hardwood dowels) with a view to a European Technical Assessment on the basis of EAD 130323-00-0304 “Prüfprogramm für “Leneco Vollholzelement” der Firma LenEco GmbH, Vorgefertigte Holzbauelemente - Elemente aus gefrästen Nadelholzelementen für tragende Bauteile in Gebäuden”.

In this expert report test results from CNR Ivalsa, Istituto per la Valorizzazione del Legno e delle Specie Arboree, were used to assess the load-carrying-capacity as well as the stiffness of “Leneco Vollholzelement”.

Trento, 18/04/2019

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