CERTIFICATE No 184/03

Revised 24 March 2009

NAME OF PRODUCT

Kerto-S and Kerto-Q
Structural laminated veneer lumber

MANUFACTURER

Metsäliitto Cooperative
Kerto Business Unit
P.O. Box 24
FIN-08101 LOHJA
Finland

PRODUCT DESCRIPTION

The Kerto-S and Kerto-Q products are laminated veneer lumber products for use as structural or non-structural elements in buildings and bridges. The thickness of Kerto-S varies from 21 to 90 mm and that one of Kerto-Q from 21 to 69 mm. The dimensions available vary in great ranges. The products are manufactured from spruce (*Picea abies*) or pine (*Pinus sylvestris*) veneers with a nominal thickness of 3 mm, using an adhesive suitable for exterior conditions. In Kerto-S, all veneers are parallel grained. In Kerto-Q, some of the veneers are cross grained.

CERTIFICATION PROCEDURE

This certificate has been issued by VTT, which is a certification body (S017, EN 45011) accredited by FINAS.

This certificate is based on an initial type assessment of the product, and an initial inspection of the factory and the factory production control. The general certification procedures are based on the certification system of VTT.

The conditions of validity are described in sections 15 - 17.

REGULATIONS, STANDARDS AND INSTRUCTIONS

1. European product requirement standards

1.1 This certificate describes the product in accordance with EN 14374 and other relevant European standards and gives the necessary design information according to the Eurocodes. Since the regulations are not harmonised, the user is recommended to consider separately the relevant national regulations regarding the intended use.

1.2 The Kerto products fulfil the requirements specified in the following European standards:

EN 14374	Timber structures - Structural laminated veneer lumber - Requirements

2. Other standards and instructions

2.1 The following European standards also have relevance for the use of Kerto products (any national determined parameters shall separately be considered):

EN 335-1	Durability of wood and wood-based products - Definition of use classes - Part 1: General
EN 1995-1-1+A1	Eurocode 5, Design of timber structures. Part 1-1: General - Common rules and rules for buildings
EN 1995-1-2	Eurocode 5, Design of timber structures. Part 1-2: General - Structural fire design
EN 1995-2	Eurocode 5, Design of timber structures. Part 2: Bridges
EN 12524	Building materials and products - Hygrothermal properties - Tabulated design values.

PRODUCT INFORMATION

3. Product description, marking and quality control

3.1 Kerto-S and Kerto-Q products are manufactured by Metsäliitto Cooperative, Finnforest at the mills located in Lohja and Punkaharju.

3.2 Kerto products are manufactured from veneers peeled from spruce (*Picea abies*) or pine (*Pinus sylvestris*), which have the nominal thickness of 3 mm after pressing. All veneers are graded with regard to strength and appearance in order to have the desired quality of the product. The minimum number of veneers is 7.

3.3 The lay-up of the cross-section of Kerto-S consists of parallel grained veneers.

3.4 The lay-up of the cross-section of Kerto-Q has some cross grained veneers. The lay-ups are given in Table 1.

Table 1. Lay-up of Kerto-Q-products.

<table>
<tr><th>Nominal thickness mm</th><th>Number of plies</th><th>Lay-up</th></tr>
<tr><td>21</td><td>7</td><td>|—| | |—|</td></tr>
<tr><td>21</td><td>7</td><td>| |—|—| |</td></tr>
<tr><td>24</td><td>8</td><td>| |—| |—| |</td></tr>
<tr><td>27</td><td>9</td><td>| |—| | |—| |</td></tr>
<tr><td>30</td><td>10</td><td>| |—| | | |—| |</td></tr>
<tr><td>33</td><td>11</td><td>| |—| | | | |—| |</td></tr>
<tr><td>39</td><td>13</td><td>| |—| | |—| | |—| |</td></tr>
<tr><td>45</td><td>15</td><td>| |—| | | |—| | | |—| |</td></tr>
<tr><td>51</td><td>17</td><td>| |—| | | | |—| | | | |—| |</td></tr>
<tr><td>57</td><td>19</td><td>| |—| | |—| | | | |—| | |—| |</td></tr>
<tr><td>63</td><td>21</td><td>| |—| | |—| | |—| | |—| | |—| |</td></tr>
<tr><td>69</td><td>23</td><td>| |—| | | |—| | |—| | |—| | | |—| |</td></tr>
</table>

3.5 The veneers are glued together using an adhesive suitable for exterior use. On one side of a veneer, phenol-formaldehyde glue is spread evenly. For surface veneer melamine adhesive may be used. The veneers are scarf jointed using a phenol-formaldehyde or melamine adhesive.

3.6 The products are cut and sawn according to the specification of the customer. The standard sizes of the products are presented in Table 2.

Table 2. The standard sizes of the Kerto products.

Product*	Thickness, mm	Width / height (mm)								
		200	225	260	300	360	400	450	500	600
S/Q	27	X	X							
S/Q	33	X	X	X						
S/Q	39	X	X	X	X					
S/Q	45	X	X	X	X	X				
S/Q	51	X	X	X	X	X	X			
S/Q	57	X	X	X	X	X	X	X		
S/Q	63	X	X	X	X	X	X	X	X	
S/Q	69	X	X	X	X	X	X	X	X	X
S	75	X	X	X	X	X	X	X	X	X
S	81	X	X	X	X	X	X	X	X	X
S	90	X	X	X	X	X	X	X	X	X

*Kerto-Q is also available in widths of 1800/2500 mm or sawn into required width.

Kerto beams and panels are delivered in customer lengths or market area specific standard lengths. The maximum length of a product is 23 m.

3.7 The tolerances of dimensions at the reference moisture content of 10 ± 2% are presented in Table 3.

Table 3. Tolerances of Kerto-products.

Dimension	Size, mm	Tolerance, mm or %
Thickness	All	+ (0,8+0,03 t) mm and – (0,4+0,03 t) mm
Width	< 400 ≥ 400	± 2 mm ± 0,5 %
Length	All	± 5,0 mm

t is the thickness

The angle of the cross section shall not deviate more than 1:50 (about 1,1°) from the right angle.

3.8 Surface veneer quality and classes are given in manufacturer's product manuals.

3.9 The Kerto products covered by this Certificate shall be marked with the oval VTT certificate marking that contains the number of this certificate. In addition, the product type S or Q shall be specified.

Alternatively, the marking is the number of this certificate and the type of the product,

VTT 184/03 Kerto S (or Q)

3.10 The Kerto products are covered by a certified quality system ISO 9001 at the Lohja and Punkaharju mills. The factory production control is regular and comprises the control of equipment, raw and incoming materials, production processes and finished products.

3.11 The manufacturer has an agreement of quality control with VTT. The continuous surveillance, assessment and approval of the factory production control are carried out at least twice a year.

4. Delivery and storage on site

4.1 The Kerto products are delivered in plastic packages. Each delivery package is labelled with the number and dimensions of the Kerto and the delivery address or order number.

4.2 Kerto products should be stored only temporarily on the building site. Any measures to keep the moisture content low and to avoid condensation should be done carefully. Therefore tarpaulins should be used to protect the Kerto products from rain, dirt and excessive solar radiation. The plastic package is only intended to protect the Kerto member during delivery, and does not provide sufficient protection against weather.

Kerto products should be stored on a plane underlay using a sufficient number of supports according to manufacturer's instructions.

4.3 Weather exposure of rain, water flowing as well as water convection from other structures should be avoided. The product may be exposed to the weather for a short time during installation. Products which have become wet shall be dried before use.

DESIGN INFORMATION

5. General

5.1 Kerto products are used for structural or non-structural applications in buildings and bridges.

5.2 Kerto products can be painted or stained. The suitability of the treatment shall be checked with the manufacturer of it.

6. Structural performance

6.1 The structural performance of Kerto products is considered in accordance with the limit state design principles specified in Eurocode 5. Alternatively, national design codes may be used if they are consistent with the Eurocodes system. In design, the methods of glued laminated timber are applied unless otherwise indicated for LVL. In addition, special methods specified in the Annexes of this certificate can be used.

6.2 The characteristic strength and stiffness values for Kerto LVL are given in Table 4. The orientations are clarified in Figure 1. The values are compatible with the design methods mentioned above.

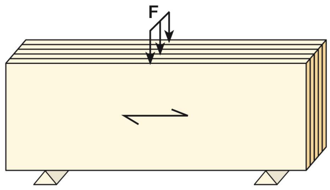
The characteristic strength values are given at an equilibrium moisture content resulting from a temperature of 20 °C and a relative humidity of 65 % exposed to duration of load of 5 minutes.

Furthermore, the reference width (depth of the beam) in edgewise bending is 300 while the reference length in tensile parallel to grain is 3000 mm.

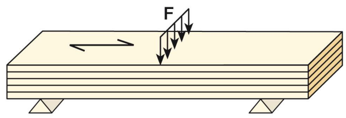
Table 4. The characteristic values of Kerto-S and Kerto-Q.

Property	Symbol	Figure 1	Characteristic value, N/mm^2 or kg/m^3		
			Kerto-S Thickness 21 - 90 mm	Kerto-Q Thickness 21 - 24 mm	Kerto-Q Thickness 27 - 69 mm
Fifth percentile values					
Bending strength:					
Edgewise (depth 300 mm)	$f_{m,0,edge,k}$	A	44.0	28.0	32.0
Size effect parameter	s	-	0.12	0.12	0.12
Flatwise, parallel to grain	$f_{m,0,flat,k}$	B	50.0	32.0	36.0
Flatwise, perpendicular to grain	$f_{m,90,flat,k}$	C	-	8.0*	8.0
Tensile strength:					
Parallel to grain (length 3000 mm)	$f_{t,0,k}$	D	35.0	19.0	26.0
Perpendicular to grain, edgewise	$f_{t,90,edge,k}$	E	0.8	6.0	6.0
Perpendicular to grain, flatwise	$f_{t,90,flat,k}$	F	-	-	-
Compressive strength:					
Parallel to grain	$f_{c,0,k}$	G	35.0	19.0	26.0
Perpendicular to grain, edgewise	$f_{c,90,edge,k}$	H	6.0	9.0	9.0
Perpendicular to grain, flatwise	$f_{c,90,flat,k}$	I	1.8	2.2	2.2
Shear strength					
Edgewise	$f_{v,0,edge,k}$	J	4.1	4.5	4.5
Flatwise, parallel to grain	$f_{v,0,flat,k}$	K	2.3	1.3	1.3
Flatwise, perpendicularl to grain	$f_{v,90,flat,k}$	L	-	0.6	0.6
Modulus of elasticity:					
Parallel to grain, along	$E_{0,k}$	ABDG	11600	8300	8800
Parallel to grain, across	$E_{90,k}$	C	-	1000*	1700
Perpendicular to grain, edgewise	$E_{90,edge,k}$	H	350	2000	2000
Perpendicular to grain, flatwise	$E_{90,flat,k}$	I	100	100	100
Shear modulus:					
Edgewise	$G_{0,edge,k}$	J	400	400	400
Flatwise, parallel to grain	$G_{0,flat,k}$	K	400	60	100
Flatwise, perpendicular to grain	$G_{90,flat,k}$	L	-	16	16
Density	ρ_k		480	480	480
Mean values					
Modulus of elasticity:					
Parallel to grain, along	$E_{0,mean}$	ABDG	13800	10000	10500
Parallel to grain, across	$E_{90,mean}$	C	-	1200*	2000
Perpendicular to grain, edgewise	$E_{90,edge,mean}$	H	430	2400	2400
Perpendicular to grain, flatwise	$E_{90,flat,mean}$	I	130	130	130
Shear modulus:					
Edgewise	$G_{0,edge,mean}$	J	600	600	600
Flatwise, parallel to grain	$G_{0,flat,mean}$	K	600	60	120
Flatwise, perpendicular to grain	$G_{90,flat,mean}$	L	-	22	22
Density	ρ_{mean}	-	510	510	510

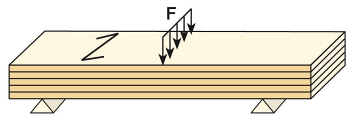
* For the lay up I-III-I the values 14,0; 2900 and 3300 can be used in stead of 8,0; 1000 and 1200.



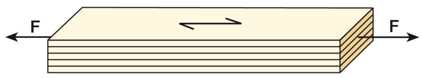
A. Edgewise bending, parallel to grain (m,0,edge)



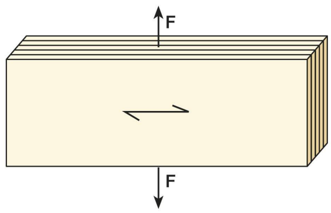
B. Flatwise bending, parallel to grain (m,0,flat)



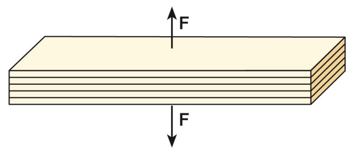
C. Flatwise bending, perpendicular to grain (m,90,flat)



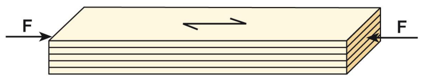
D. Tension, parallel to grain (t,0)



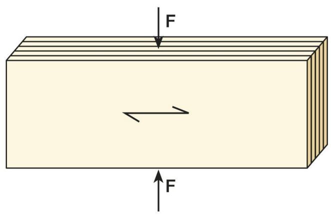
E. Edgewise tension, perpendicular to grain (t,90, edge)



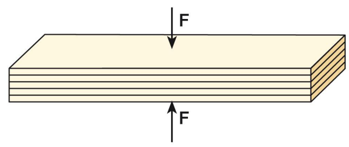
F. Flatwise tension, perpendicular to grain (t,90,flat)



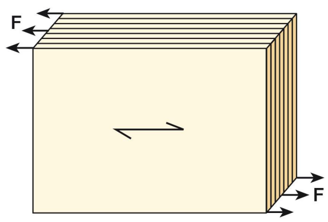
G. Compression, parallel to grain (c,0)



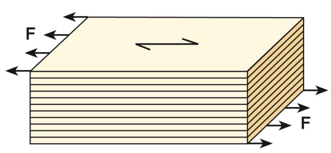
H. Edgewise compression, perpendicular to grain (c,90,edge)



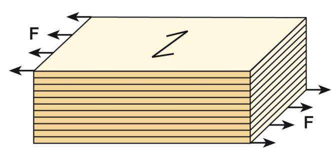
I. Flatwise compression, perpendicular to grain (c,90,flat)



J. Edgewise shear, parallel to grain (v,0,edge)



K. Flatwise shear, parallel to grain (v,0,flat)



L. Flatwise shear, perpendicular to grain (v,90,flat)

Figure 1. Strength and stiffness orientations

6.3 In design, the effect of moisture content and duration of load on strength and deformation shall be taken into account by the modification factor k_{mod} and the deformation factor k_{def} as given in Eurocode 5. For Kerto-Q, flatwise, the k_{mod} and k_{def} values of plywood shall be used. For Kerto-Q, edgewise, the k_{mod} and k_{def} values of LVL shall be used.

6.4 The effect of member size on edgewise bending and tensile strength values shall be taken into account. This is made by the factors k_h and k_l given in Eurocode 5 for which the s-values are given in Table 4.

6.5 The characteristic values given in Table 4 can be used without any modifications for temperatures below or equal to 50 °C for a prolonged period of time.

6.6 Since the dimensions of Kerto products remain quite stable during temperature changes, it is not usually necessary to consider any effects of temperature variations on the structural design.

6.7 For some applications Kerto-Q members are sawn in an angle α to the grain direction of the face veneers. The effect on the strength properties are given in Table 5

Table 5. The reduction factor on strength of Kerto-Q when the member is sawn in an angle α to the grain direction of the face veneers.

	Angle α				
	0	15	30	45 - 60	90
Bending edgewise	1.00	0.40	0.25	0.20	0.20
Bending flatwise	1.00	0.50	0.25	0.20	0.20
Tensile parallel to grain	1.00	0.30	0.20	0.15	0.20
Compressive parallel to grain	1.00	0.50	0.35	0.25	0.35
Modulus of elasticity	1.00	0.40	0.15	0.10	0.10

6.8 In structural applications, any holes and notches to be worked out during the installation shall separately be considered and accepted by the designer. In design of beams with a notch at the support according to Eurocode 5, the following values can be used for factor k_n:

$$k_n = \begin{cases} 6 & \text{for Kerto-S, edgewise} \\ 16 & \text{for Kerto-Q, edgewise} \end{cases}$$

6.9 The design of holes of Kerto structural members is presented in Annex A.

6.10 Kerto members shall be designed in such a way that width and thickness changes due to moisture content variation do not cause harmful stresses in the structures. Special attention shall be paid to the design of joints.

6.11 The design of dowel-type joints of Kerto structural members is presented in the Annexes B and C.

6.12 During installation, the temporary bracing of the Kerto members shall be considered by the designer.

6.13 In design of compression perpendicular to grain, the contact length can be increased as specified in Table 6. Furthermore, the $k_{c,90}$ factor can be used, Table 6.

Table 6. Contact length and $k_{c,90}$ factor.

Compression	Increasing of contact length[1]	$k_{c,90}$[2] (a)	(b)
Kerto-S, edgewise	30 mm along	1,0	1,0
Kerto-S, flatwise	30 mm along 15 mm across	1,4	1,6
Kerto-Q, edgewise	0 mm along	1,3	1,3
Kerto-Q, flatwise	30 mm along 15 mm across	1,4	1,6

[1] The actual contact length is increased at each side by this distance, but not more than *a*, *l* or $l_1/2$ according to Eurocode 5.
Along = contact length parallel to the grain direction of face veneers.
Across = contact length perpendicular to the grain direction of face veneers.
[2] Member on (a) continuous or (b) discrete supports provided that $l_1 \geq 2h$ according to Eurocode 5.

7. Performance in relation to moisture

7.1 On delivery, the moisture content ω of Kerto products is about 8 - 10 %. Due to changes in temperature and relative humidity of the surrounding air, the moisture content will continuously change. In service class 1 the moisture content usually varies between 6 and 10 %, while in service class 2 it usually varies between 10 and 16 %.

Moisture content ω is defined as follows:

$$\omega = \frac{m_\omega - m_0}{m_0}$$

where m_ω is the mass of the product corresponding moisture content ω and m_0 is the dry mass of the product.

7.2 Kerto products swell when the moisture content increases, and shrink when the moisture content decreases. The extent of these dimensional changes depends on the grain direction. Wetting causes permanent deformations, problems with surface veneers and falling of knots.

The formula to calculate the dimensional change ΔL of a Kerto product due to change of moisture content is:

$$\Delta L = \Delta\omega \cdot \alpha_H \cdot L$$

where $\Delta\omega$ is change of moisture content [%], α_H dimensional variation coefficient and L dimension [mm]. The dimensional variation coefficients are presented in Table 7.

Table 7. Dimensional variation coefficients

	Kerto-S	Kerto-Q
Thickness	0.0024	0.0024
Width	0.0032	0.0003
Length	0.0001	0.0001

7.3 Water vapour resistance factor μ of Kerto LVL are given in Table 8.

Table 8. Water vapour resistance factor μ

	Kerto-S	Kerto-Q
In direction of thickness	80	62
In direction of width	82	9.5
Longitudinal	3.9	4.7

8. Performance in case of fire

8.1 The fire resistance of a Kerto product is considered in accordance with Eurocode 5 as follows:

The notional design charring depth $d_{char,0}$ in one-dimensional charring shall be calculated as

$$d_{char,0} = \beta_0 t$$

where t is the relevant time of fire exposure and β_0 is the basic design charring rate for one-dimensional charring at standard fire exposure. β_0 for LVL is 0.65 mm/min.

The notional design charring depth $d_{char,n}$, including the effect of corner roundings and fissures, shall be calculated as

$$d_{char,n} = \beta_n t$$

where t is the relevant time of fire exposure and β_n is the notional design charring rate, including the effect of corner rounding and fissures. β_n for LVL is 0.70 mm/min.

In addition to the fire resistance of the Kerto members, the designer shall consider the fire resistance of the joints.

8.2 Kerto members without surface treatment have Euroclass

D-s1, d0

with regard to reaction to fire.

8.3 The heat of combustion of a Kerto product is 17 MJ/kg.

8.4 Kerto products treated against fire are not covered by this certificate.

9. Hygiene, health and environmental performance

9.1 Outdoor use or use in high relative humidity conditions may cause mould growth on the surface of Kerto. If these kinds of conditions are expected during erection, a brushable or sprayable surface treatment should be used. This kind of treatment has no adverse effects to the structural properties of Kerto.

9.2 If, due to excessive wetting, there is mould growth on the surface of Kerto, this shall be removed by sanding before the structure is enclosed.

9.3 The formaldehyde class of Kerto LVL is E1.

10. Thermal insulation performance

10.1 The thermal conductivity of a Kerto product is 0.13 W/(m K).

11. Durability

11.1 The adhesive and glue bond used for Kerto products is suitable for service classes 1, 2 and 3. Kerto products can be used in service classes 1 and 2 as defined in Eurocode 5, which correspond to the use classes 1 and 2 as defined in EN 335-1. The product should not be used in service class 3 / use class 3 without additional protective treatment. The designer shall pay attention to the details of the construction and to ensure that no water pockets will be formed.

During the erection of the building, Kerto products and structures resist well temporary exposure to water without decay, provided that they are allowed to dry afterwards.

11.2 When necessary and required by the local authorities at the building site, Kerto products can be preservative impregnated against biological attack according to the rules valid on the place. However, Kerto products preservative impregnated against biological attack are excluded from this certificate. Any adverse effects of the preservative impregnation on other properties shall be taken into account according to a separate clarification.

INSTALLATION AND USE

12. Manufacturer's instructions

12.1 Kerto products shall be handled carefully to protect them from damage and dirt.

12.2 Kerto products can be processed using conventional woodworking tools, e.g. sawing, planing, drilling, nailing and screwing.

12.3 General guidelines of wooden constructions shall be followed in installations and use of Kerto products.

12.4 After use, Kerto products shall be disposed of in accordance with national regulations and directives. In general, the products can be reused, composted or burned.

TECHNICAL SURVEY

13. Initial assessment

13.1 The initial assessment of Kerto products is based on requirements specified in the European product standards, and on VTT's experience with the performance of Kerto products as well as other timber products for use in structural applications.

13.2 The characteristic values to be used in structural performance considerations rely for most properties on the methods given in EN 14374.

13.3 The moisture behaviour assessment is based on VTT's experience and test results made by Helsinki University of Technology.

13.4 The charring rate to be used in fire safety considerations is based on the tabulated values specified in Eurocode 5. The reaction to fire performance is based on testing according to Euroclasses system. The heat of combustion performance is based on the tabulated values specified by the Ministry of Environment.

13.5 Release of formaldehyde has been determined by testing.

13.6 The thermal conductivity to be used in thermal behaviour considerations is based on the tabulated values specified in EN 12524.

13.7 The assessment of durability against biological attack is in accordance with EN 350.

14. Initial inspection

14.1 The initial inspections of the factory production control and the factories are based on requirements specified in European product standards, and on VTT´s experience with production processes and control of Kerto products as well as other timber products for use in structural applications.

14.2 In the initial inspection of the factory production control system, VTT was assured that the manufacturer had established, documented and maintained a factory production control system that with regard to the control of production process is in accordance with EN 14374. In addition, tests are made by the manufacturer as required in EN 14374.

14.3 In the initial inspection of the factory the production process, equipment used and factory production control, VTT was assured that the factory production control is in accordance with the documented factory production control system.

VALIDITY OF THE CERTIFICATE

15. Validity period of the certificate

This certificate is valid for a maximum of five years from the date of revision.

16. Conditions of validity

The certificate is valid assuming that no fundamental changes are made to the product, and that the manufacturer has a valid quality control contract. A list of valid certificates is available from VTT.

17. Other conditions

The references made in this certificate to standards and instructions are valid in the format used at the time the certificate was awarded.

The recommendations in this certificate concerning the safe use of this product are minimum requirements that shall be satisfied when using the product. The certificate does not override current or future requirements imposed by laws and statutes. In addition to the issues presented in this certificate, design, manufacturing and use shall follow appropriate construction methods.

The manufacturer is in charge of the product's quality and factory production control. In awarding this certificate, VTT does not bind itself to indemnification liability concerning personal injury or other damage that may directly or indirectly result from using the product described in this certificate.

The Technical Research Centre of Finland (VTT) finds Kerto LVL to be suitable for use in construction as described in this certificate. This certificate no 184/03 has been awarded as described above to Metsäliitto Cooperative, Finnforest

On behalf of VTT on 24 March, 2009

Liisa Rautiainen
Assessment Manager

Mikael Fonselius
Lead Assessor

ANNEX A: DESIGN OF HOLES OF KERTO

Below is given design rules for round holes with a diameter not less than 50 mm and located at the centre axis of the beam. Tolerance for the location of the hole is ± 5 % in the vertical direction.

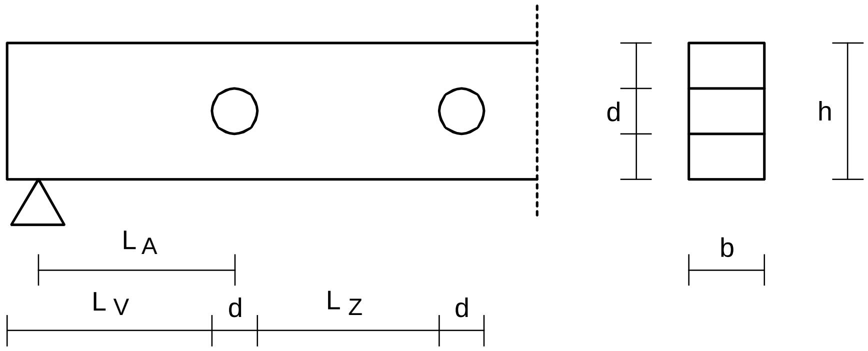


Figure 1. Definition of dimensions and distances.

The following maximum and minimum distances given in mm and defined in Figure 1 shall be fulfilled:

$$L_V \geq h$$

$$L_Z \geq \max\begin{cases} h \\ 300 \end{cases}$$

$$L_A \geq h/2$$

$$d \leq h/2$$

The bending moment resistance of the member shall be verified at the hole as usual. The strength verification for a shear force *V* at the hole shall be carried out as for notched beams subjected to a shear force of *V*/2. It shall be verified that the design shear stress τ_d is less than the design shear strength $f_{v,d}$

$$\tau_d = \frac{3}{2}\frac{V}{b(h-d)} \leq k_v f_{v,d}$$

where for Kerto-S

$$k_v = \min \begin{cases} 1 \\ \dfrac{9\left(1.1+\sqrt{h/2}\right)}{\sqrt{d\left(h-d\right)}} \end{cases}$$

and for Kerto-Q

$$k_v = \min \begin{cases} \text{h/(h - d)} \\ \dfrac{24\left(1.1+\sqrt{h/2}\right)}{\sqrt{d\left(h-d\right)}} \end{cases}$$

The following tables can be used in the design:

Table A1. Kerto-S and Kerto-Q, dimensional requirements for holes.

Beam depth h [mm]	Hole allowed any-where in centre axis d [mm]	Distance from beam end L_V min [mm]	Distance from support L_A min [mm]	Distance between holes L_Z min [mm]	Max hole height [mm]
200	20	200	100	300	100
220	22	220	110	300	110
225	22,5	225	112,5	300	112
260	26	260	130	300	130
300	30	300	150	300	150
360	36	360	180	360	180
400	40	400	200	400	200
450	45	450	225	450	225
500	50	500	250	500	250
540	50	540	270	540	270
600	50	600	300	600	300
750	50	750	375	750	375
900	50	900	450	900	450

Table A2. Kerto-S, shear capacity of the beam with a hole in percentage % of the capacity of a beam without hole

Beam depth	**Hole height [mm]**														
h [mm]	**30**	**40**	**50**	**60**	**80**	**100**	**130**	**150**	**175**	**200**	**225**	**250**	**300**	**350**	**400**
200	85	80	75	70	60	50									
220	86	82	77	73	63	52									
225	87	82	78	73	63	52									
260	88	85	81	77	65	55	43								
300	100	87	83	80	66	57	46	40							
360	100	89	86	81	68	59	48	43	36						
400	100	100	88	82	69	59	49	44	39	34					
450	100	100	89	82	69	60	51	46	40	36	32				
500	100	100	100	82	70	61	51	46	41	37	34	30			
540	100	100	100	83	70	61	52	47	42	38	35	31			
600	100	100	100	83	70	62	53	48	43	39	36	33	28		
750	100	100	100	83	71	63	54	49	45	41	38	35	30	26	
900	100	100	100	83	71	63	54	50	45	42	39	36	32	28	25

Table A3. Kerto-Q, shear capacity of the beam with a hole in percentage % of the capacity of a beam without hole.

Beam depth	**Hole height [mm]**														
h [mm]	**30**	**40**	**50**	**60**	**80**	**100**	**130**	**150**	**175**	**200**	**225**	**250**	**300**	**350**	**400**
200	100	100	100	100	100	100									
220	100	100	100	100	100	100									
225	100	100	100	100	100	100									
260	100	100	100	100	100	100	100								
300	100	100	100	100	100	100	100	100							
360	100	100	100	100	100	100	100	100	100						
400	100	100	100	100	100	100	100	100	100	91					
450	100	100	100	100	100	100	100	100	100	96	86				
500	100	100	100	100	100	100	100	100	100	99	90	81			
540	100	100	100	100	100	100	100	100	100	100	92	84			
600	100	100	100	100	100	100	100	100	100	100	95	87	74		
750	100	100	100	100	100	100	100	100	100	100	100	93	80	70	
900	100	100	100	100	100	100	100	100	100	100	100	96	84	75	67

ANNEX B: DESIGN OF LATERALLY LOADED DOWEL-TYPE CONNECTIONS OF KERTO

General

The principles given for the structural design of laterally loaded dowel-type connections in the EN 1995-1-1+A1:2008 (Eurocode 5) can be applied to Kerto-LVL with the following additional or substitutive design values and criteria concerning the characteristics of Kerto-S and Kerto-Q. This annex concerns the flatwise and edgewise Kerto-LVL joints. In the flatwise connections the direction of fasteners is perpendicular to the surface of veneers, when in the edgewise connections the fasteners are parallel to the veneers and perpendicular to the grain direction of face veneers ("edge joint").

For Kerto-to-Kerto or Kerto-to-steel connections, the partial factor of connection resistance γ_M value of 1,2 may be used in ultimate limit states for the fundamental combinations unless a specified value has not been given in the relevant National annex of EN 1995-1-1.

Equation (8.4) of EN 1995-1-1 is not applied with flatwise connections of Kerto-Q. Due to the cross-veneers, Kerto-Q is not sensitive to splitting with a force perpendicular to the grain.

Nailed connections

The rules given for nailed timber connections in Eurocode 5 may be applied with Kerto-LVL with the following additions.

For edgewise Kerto-Q connections the embedment strength $f_{h,k}$ of clause 8.3.1.1(5) shall be reduced by the factor of $(1-2/d) \geq 1/3$, where d is the nail diameter in mm.

For flatwise Kerto-Q connections, clause 8.3.1.1(8) is disregarded. The nails may be placed to the straight rows in Kerto-Q without any number reduction of fasteners in the calculations of the load-carrying capacity.

For edgewise connections the factor k_{ef} used in equation (8.17) of EN 1995-1-1 should be calculated by the following expression:

$$k_{ef} = 1 - 0{,}03(20d - a_1)$$

The minimum values of nail spacing and distances given in column $\rho_k \leq 420$ kg/m^3 of table 8.2 in Eurocode 5 may be used for flatwise Kerto-S connections without predrilled holes. For edgewise connections the minimum values of nail spacing and distances given for the timber density ρ_k = 480 kg/m^3 in Eurocode 5 should be used.

For flatwise Kerto-Q connections nailed without predrilled holes, the following minimum values of spacing and edge and end distances may be used (clause 8.3.1.2(5)):

$$a_1 = (5 + 2|\cos\alpha|)d$$
$$a_2 = 5d$$
$$a_{3,t} = (4 + 3|\cos\alpha|)d$$
$$a_{3,c} = 4d$$
$$a_{4,t} = (3 + 4|\sin\alpha|)d$$
$$a_{4,c} = 3d$$

Clause 8.3.1.2 (6) or 8.3.1.2 (7) in Eurocode 5 is not need to taken into account with flatwise connections of Kerto-Q. The minimum thickness of Kerto-Q is not limited for nails without predrilled holes. For flatwise Kerto-S connections, clause 8.3.1.2 (6) is applied and clause 8.3.1.2 (7) is disregarded. Clause 8.3.1.2 (7) is applied for the edgewise connections.

Stapled connections

The rules given for stapled connections in Eurocode 5 may be applied with laterally loaded stapled connection of Kerto-LVL. The design load-carrying capacity per staple should be considered as equivalent to that of two nails in corresponding flatwise or edgewise Kerto-LVL connection according to the clause 8.4 (5) of Eurocode 5.

Bolted and dowelled connections

The rules given for bolted and dowelled timber connections in Eurocode 5 may be applied with Kerto-LVL with the following additions and replacements.

For Kerto-Q, clause 8.5.1.1(2) of Eurocode 5 is replaced by the expression:

> For bolts and dowels up to 30 mm diameter, the following characteristic embedment strength values in Kerto-Q should be used, at an angle α to the grain

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \sin^2 \alpha + \cos^2 \alpha} \geq f_{h,45,k}$$

$$f_{h,0,k} = 37\, k_Q (1 - 0{,}01d)$$

where:

$$k_Q = \begin{cases} 1 & \text{for flatwise connections} \\ 1 - \dfrac{2}{d} \leq 0{,}87 & \text{for edgewise connections} \end{cases}$$

$$k_{90} = 1{,}15 + 0{,}015d$$

and:

$f_{\mathrm{h,0,k}}$ is the characteristic embedment strength parallel to the grain of outer veneers, in N/mm^2;

α is the angle of the load to the grain of outer veneers;

d is the fastener diameter, in mm.

Note: $f_{\mathrm{h},\alpha,\mathrm{k}} = f_{\mathrm{h,45,k}}$, when $45° \leq \alpha \leq 90°$.

For bolted and dowelled Kerto-S and edgewise Kerto-Q connections, the following minimum values of spacing parallel to grain a_1 and end distance of loaded end $a_{3,\mathrm{t}}$ should be used (Tables 8.4 and 8.5 in Eurocode 5):

$$a_1 = (4 + 3|\cos\alpha|)d \quad ^{1)}$$

$$a_{3,t} = \max \begin{cases} 7d \\ 105 \text{ mm} \quad ^{2)} \end{cases}$$

1) The minimum spacing may be further reduced to 5d if the embedment strength $f_{\mathrm{h,0,k}}$ is reduced by the factor $\sqrt{\dfrac{a_1}{(4 + 3|\cos\alpha|)d}}$.

2) For d < 15 mm, the minimum end distance may be further reduced to 7d if the embedment strength $f_{\mathrm{h,0,k}}$ is reduced by the factor $\dfrac{a_3}{105\,\mathrm{mm}}$.

For bolted and dowelled flatwise Kerto-Q connections, the following minimum values of spacings and edge and end distances may be used (clauses 8.5.1.1(3) and 8.6(3)):

Spacing and end/edge distances	Bolted Kerto-Q connection	Dowelled Kerto-Q connection
a_1 (parallel to grain)	$4d$	$(3+\|\cos\alpha\|)d$
a_2 (perpendicular to grain)	$4d$	$3d$
$a_{3,t}$ (loaded end)	max($4d$; 60 mm) *)	max($4d$; 60 mm) *)
$a_{3,c}$ (unloaded end)	$4d$	$(3+\|\sin\alpha\|)d$
$a_{4,t}$ (loaded edge)	$\max\{(2+2\|\sin\alpha\|)d; 3d\}$	$\max\{(2+2\|\sin\alpha\|)d; 3d\}$
$a_{4,c}$ (unloaded edge)	$3d$	$3d$
*) For $d < 15$ mm, the minimum end distance may be further reduced to $4d$ if the embedment strength $f_{h,0,k}$ is reduced by the factor $a_{3,t}$/(60 mm)		

For bolted and dowelled moment resisting multi shear Kerto-to-Kerto flatwise connections with circular patterns of fasteners, the following minimum values of distances and spacings may be used:

Spacings and end/edge distances	Kerto-S to Kerto-Q [1)]	Kerto-S to Kerto-S	Kerto-Q to Kerto-Q
End distance	$6d$ in Kerto-S $4d$ in Kerto-Q	$7d$	$4d$
Edge distance	$4d$ in Kerto-S $3d$ in Kerto-Q	$4d$	$3d$
Spacing on a circular	$5d$	$6d$	$4d$
Spacing between circulars [2)]	$5d$	$5d$	$4d$
1) when Kerto-Q is used as outer members 2) between radius of the circulars			

Timber failure capacity of joint area

The following guidelines apply to laterally loaded bolted and dowelled Kerto-LVL connections with a force component parallel to grain and they replace clauses 8.1.2(4)-(5) and 8.5.1.1(4) and Annex A of EN 1995-1-1 (effective number of fasteners and block/plug shear failure). These rules are applied both for timber-to-timber and steel-to-timber joints.

To take account of the possibility of splitting or shear or tension failure of joint area caused by the force component parallel to grain $F_{0,Ed}$, the following should be satisfied

$$F_{0,Ed} \leq F_{0,Rd} = \frac{k_{mod}}{\gamma_M} F_{0,Rk} \qquad \text{(B.1)}$$

where $F_{0,Rk}$ is the characteristic timber failure capacity of joint area calculated according to the following simplified method or by the equation (B.2).

Simplified method

This simplified method may be used instead of the general analysis for flatwise Kerto-LVL connections provided that:

- number of fasteners $n \leq 25$;
- number of fasteners in line parallel to grain $n_1 \leq 5$;
- thickness of all the Kerto lamellas $t_i \geq 3d$ and in steel-to-timber joints the thickness of middle Kerto lamellas $t_2 \geq 5d$;
- dowel spacing perpendicular to grain $a_2 \geq 3{,}5d$;
- tension strength of faster utilized in design $f_{u,k} \leq 800$ N/mm^2;
- load carrying capacities of steel-to-timber connections are calculated by the equations of a thin steel plate;
- the rope effect $F_{ax,Rk}/4$ is not utilized in the design of bolted steel-to-timber connections.

The characteristic timber failure capacity of joint area

$$F_{0,Rk} = n_{1,ef} n_2 F_{v,Rk}$$

where:

n_2 is the maximum number of fasteners in the fastener rows perpendicular to grain (see figure B.1);

$F_{v,Rk}$ is the characteristic load-carrying capacity of each fastener in loading parallel to grain.

The effective number of fasteners in rows parallel to grain

$$n_{1,ef} = \min\begin{cases} n_1 \\ n_1^{0,9}\sqrt[4]{\dfrac{a \cdot t}{50 \cdot d^2}} \end{cases}$$

with:

$a = \min(a_1; a_3)$

$$t = \begin{cases} \min(t_1; t_2) & \text{for single shear connections} \\ \min(2t_1; t_2) & \text{for double/multiple shear timber-to-timber joints} \\ \min(t_{1,ef}; t_2) & \text{for double/multiple shear steel-to-timber joints} \end{cases}$$

$$t_{1,ef} = \min\left\{ t_1; 2 \cdot \sqrt{\frac{M_{y,Rk}}{f_{h,0,k} \cdot d}} \right\}$$

where:

- n_1 is the mean number of fasteners in the rows parallel to grain ($n_1 = n/n_2$) ;
- d is the fastener diameter ;
- a_1 is the spacing between fasteners in grain direction ;
- a_3 is the end distance ;
- t_1, t_2 is the timber thickness according to Fig 8.2 and 8.3 of EC5
  Note: in multiple shear connections t_1 is the minimum thickness of side lamellas and t_2 is the minimum thickness of middle lamellas ;
- $M_{y,Rk}$ is the characteristic fastener yield moment ;
- $f_{h,0,k}$ is the characteristic embedment strength parallel to grain in the timber member t_1.

General analysis

The characteristic timber failure capacity of joint area

$$F_{0,Rk} = \sum_{i=1}^{m} F_{i,0,Rk} \tag{B.2}$$

when $F_{i,0,Rk}$ is the timber failure capacity for lamella i of the Kerto-LVL member calculated according to equation (B.3) and m is the number of joint lamellas in the Kerto-LVL member.

Timber failure capacity for the lamella i should be taken as

$$F_{i,0,Rk} = F_{ip,Rk} + F_{ep,Rk} \tag{B.3}$$

The capacity of **inner parts of lamellas**

$$F_{ip,Rk} = \begin{cases} \min\{A_{h,ip} f_{h,0,k}; F_{tv,k}\} & \text{in tension joints} \\ \min\{A_{h,ip} f_{h,0,k}; F_{cv,k}\} & \text{in compression joints} \end{cases} \quad (B.4)$$

where:

$f_{h,0,k}$ is the embedment strength of Kerto-LVL parallel to grain;

$$A_{h,ip} = (n - n_1) d t_i \quad (B.5)$$

$$F_{cv,k} = F_{v,k} + (n_2 - 1) d t_{ef,i} f_{h,0,k} \quad (B.6)$$

$$F_{tv,k} = \begin{cases} F_{t,k}\left(1 - 0{,}3\dfrac{F_{t,k}}{F_{v,k}}\right) & \text{when } F_{t,k} \le F_{v,k} \\ F_{v,k}\left(1 - 0{,}3\dfrac{F_{v,k}}{F_{t,k}}\right) & \text{when } F_{v,k} < F_{t,k} \end{cases} \quad (B.7)$$

when:

$$F_{t,k} = 1{,}7 n_1^{-0{,}1} A_{t,ip} f_{t,0,k} \quad (B.8)$$

$$F_{v,k} = k_v n_1^{-0{,}1} A_{v,ip} f_{v,k} \quad (B.9)$$

n is the number of fasteners ;

n_1 is the mean number of fasteners in the rows parallel to grain ($n_1 = n/n_2$) ;

d is the fastener diameter ;

t_i is the lamella thickness ≤ penetration of the fastener ;

n_2 is the maximum number of fasteners in the fastener rows perpendicular to grain (see figure B.1) ;

$f_{t,0,k}$ is tension strength of Kerto-LVL without length factor ;

$f_{v,k}$ is shear strength of Kerto-LVL; for flatwise connections $f_{v,k} = f_{v,0,edge,k}$ and for edgewise connections $f_{v,k} = f_{v,0,flat,k}$;

$$k_v = \begin{cases} 0{,}7 & \text{for Kerto - S and edgewise Kerto - Q} \\ 1{,}0 & \text{for flatwise Kerto - Q connections} \end{cases}$$

$$t_{ef,i} = \begin{cases} 0{,}68\, d\sqrt{\dfrac{f_y}{f_{h,0,k}}} \le t_i & \text{for side lamellas} \\ 1{,}63\, d\sqrt{\dfrac{f_y}{f_{h,0,k}}} \le t_i & \text{for middle lamellas} \end{cases} \tag{B.10}$$

$$A_{t,ip} = (n_2 - 1)(a_2 - d)t_i \tag{B.11}$$

$$A_{v,ip} = 2(n_2 - 1)((n_1 - 1)a_1 + a_{3,t})t_{ef,i} \tag{B.12}$$

where:

f_y is yield strength of the fastener ;

a_1 is fastener spacing parallel to grain ;

a_2 is fastener spacing perpendicular to grain ;

a_3 is end distance.

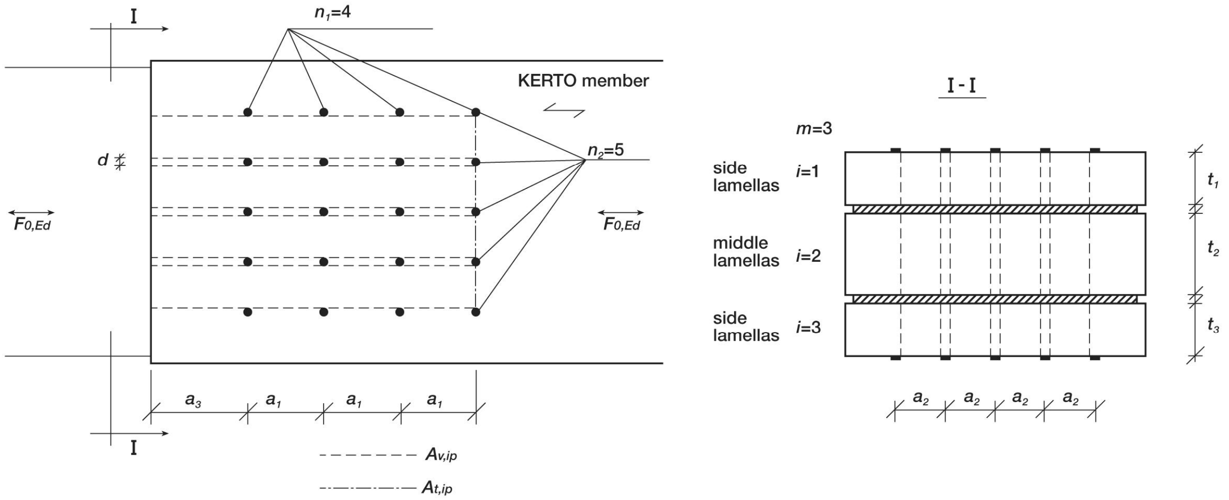


Figure B.1. Definition of symbols for the inner parts of lamellas.

The capacity of **edge parts of lamellas**

$$F_{ep,Rk} = \begin{cases} \min\{A_{h,ep} f_{h,0,k};\, F_{tv,k};\, F_{sv,k};\, F_{se,k}\} & \text{in tension joints} \\ \min\{A_{h,ep} f_{h,0,k};\, F_{cv,k}\} & \text{in compression joints} \end{cases} \tag{B.13}$$

where:

$$A_{h,ep} = n_1 d t_i \tag{B.14}$$

$$F_{cv,k} = F_{v,k} + d t_{ef,i} f_{h,0,k} \tag{B.15}$$

$$F_{sv,k} = \begin{cases} F_{s,k}\left(1 - 0{,}3\dfrac{F_{s,k}}{F_{v,k}}\right) & \text{when } F_{s,k} \le F_{v,k} \\ F_{v,k}\left(1 - 0{,}3\dfrac{F_{v,k}}{F_{s,k}}\right) & \text{when } F_{v,k} < F_{s,k} \end{cases} \tag{B.16}$$

and $F_{tv,k}$ is calculated according to equations (B.7) - (B.9) with substitutions $A_{t,ip} = k_{t,ep}A_{t,ep}$ and $A_{v,ip} = A_{v,ep}$:

$$A_{t,ep} = (2a_4 - d)t_i \qquad \text{(see figure B.2)} \tag{B.17}$$

$$A_{v,ep} = 2\big((n_1 - 1)a_1 + a_3\big)t_{ef,i} \tag{B.18}$$

$$k_{t,ep} = \frac{1}{1 + \dfrac{A_{t,ep}}{A_{v,ep}}} \tag{B.19}$$

when a_4 is edge distance.

In equations (B.13) and (B.16), the splitting capacities

$$F_{s,k} = \frac{14n_1^{0,9}}{s_{hole}} t_{\mathrm{ef,i}}\,(a_3 - 0.5d)\,f_{t,90,k} \tag{B.20}$$

$$F_{se,k} = \frac{14n_1^{0,9}}{s_{end}} t_{\mathrm{ef,i}}\,(a_3 - 0{,}5d)\,f_{t,90,k} \tag{B.21}$$

where:

$f_{t,90,k}$ is tension strength of Kerto-LVL perpendicular to grain; for flatwise connections $f_{t,90,k} = f_{t,90,edge,k}$; for edgewise connections value $f_{t,90,k} = 0{,}4$ N/mm^2 may be used;

$$s_{hole} = \max\begin{cases} 1 \\ 0{,}65\dfrac{a_3}{a_4} \end{cases} \tag{B.22}$$

$$s_{end} = \frac{2{,}7}{\cosh\left(\dfrac{a_3}{a_4} - 1{,}4\right)} \tag{B.23}$$

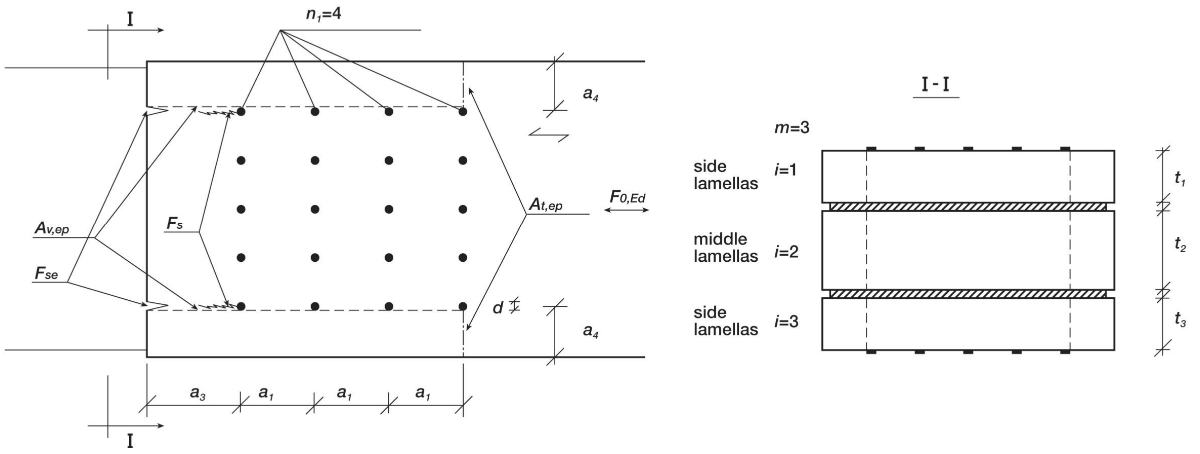


Figure B.2. Definition of symbols for the edge parts of lamellas.

Screwed connections

The rules given for laterally loaded screws in Eurocode 5 may be applied with Kerto-LVL. For smooth shank screws with a diameter d > 6 mm, the additions and replacements given in this certificate for laterally loaded bolted connections, should be applied.

For smooth shank screws ($d_s = d$) with a diameter $d \leq 6$ mm and for self-drilling screws with thread root diameter $d_1 \leq 0{,}7d$ and smooth shank diameter $d_s \leq 0{,}8d$, the rules of nailed connections of Eurocode 5 may be applied with the additional rules given in this certificate for laterally loaded nails. For these self-drilling screws the following general effective diameters may be used in design with rules of nailed connections:

$d_{ef} = 0{,}66d$ in calculation of the load carrying capacity and

$d_{ef} = 0{,}8d$ in determination of minimum spacings and distances,

when d is the nominal diameter of screw (= outer diameter of threads).

ANNEX C: DESIGN OF AXIALLY LOADED DOWEL-TYPE CONNECTIONS OF KERTO

General

The principles given for the structural design of axially loaded dowel-type connections in the EN 1995-1-1+A1:2008 (Eurocode 5) may be applied to Kerto-LVL with the following additional or substitutive design values and criteria concerning the characteristics of Kerto-S and Kerto-Q.

For axially loaded Kerto-LVL connections (figure C.1), the partial factor of connection resistance γ_M value of 1,2 may be used in ultimate limit states for the fundamental combinations unless a specified value has not been given in the relevant National annex of EN 1995-1-1.

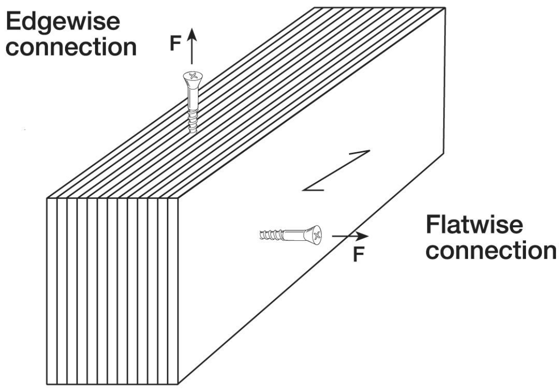


Figure C.1. Definition of axially loaded fasteners.

Axially loaded nails

The rules of clauses 8.3.2 and 8.3.3 in Eurocode 5 may be applied with flatwise connections of Kerto-LVL, where the nails are perpendicular to the plane of the veneers. For edgewise connections, where the pointside of nails are attached to the edge of Kerto-S or Kerto-Q without pre-drilled holes, the following additions should be taken account.

Clause 8.3.2(6):

For smooth nails with a penetration of at least 12*d* in the edge of Kerto-S or Kerto-Q, the characteristic value of the withdrawal strength parameter may be calculated from the following equation

$$f_{ax,k} = 0{,}32d + 0{,}8 \quad \text{N/mm}^2 \qquad \text{(C.1)}$$

In edge connections of Kerto-Q, the minimum nail diameter *d* is 3,1 mm for round nails and 2,8 mm for square nails.

Clause 8.3.2(9):

The minimum values of nail spacings and distances given in column $420 \leq \rho_k \leq 500$ kg/m^3 of Table 8.2 for laterally loaded nails apply to axially loaded nails in the edge of Kerto-S and Kerto-Q.

Axially loaded screws

The rules of clauses 8.7.2 and 8.7.3 in EN 1995-1-1+A1:2008 may be applied with flatwise Kerto-S and Kerto-Q connections, where the screws are placed perpendicular to the veneer plane. The edgewise and inclined screwed Kerto-LVL connections should be designed by the following additional rules.

Axially loaded screws in edgewise connections

When the screws are parallel to the plane of veneers and perpendicular to the grain direction of face veneers, the rules given for axially loaded screws in EN 1995-1-1:2004/A1:2008 may be applied with edge joints of Kerto-S and Kerto-Q with the following modifications of clause 8.7.2.

Table 8.6 in paragraph (2), following replacements:

– $a_1 = 10d$ minimum screw spacing parallel to the grain,

– $a_{1,CG} = 12d$ minimum end distance and

– $a_{2,CG} = 5d$ minimum edge distance.

Delete paragraphs (4) and (5) and replace with:

For connections with selfdrilling screws in accordance with EN 14592 with

- 4,5 mm $\leq d \leq$ 7 mm
- $d_1 \leq 0{,}7d$
- $d_s \leq 0{,}8d$, if the smooth shank penetrates to the edge of Kerto.

where

d is the outer thread diameter;

d_1 is the inner thread diameter;

d_s is the smooth shank diameter

the characteristic withdrawal capacity should be taken as:

$$F_{\text{ax,Rk}} = n^{0,9} f_{\text{ax,k}} d\, \ell_{\text{ef}} \qquad \text{(C.2)}$$

where:

$f_{\text{ax,k}}$ = 10 N/mm^2;

n is the number of screws acting together in a connection;

ℓ_{ef} is the penetration length of the thread part.

NOTE: Failure modes in the steel or in the timber around the screw are brittle, i.e. with small ultimate deformation and therefore have a limited possibility for stress redistribution.

Inclined screwed connections

These rules concerns the design of single shear joint of figure C.2, where the screw inclination angle is α = 30°..60° both in regard to the connection force and screwing surface. The screws should be selfdrilling and fully threaded or partially threaded, where the smooth part diameter $d_s \leq 0{,}8d$, when d is the outer thread diameter

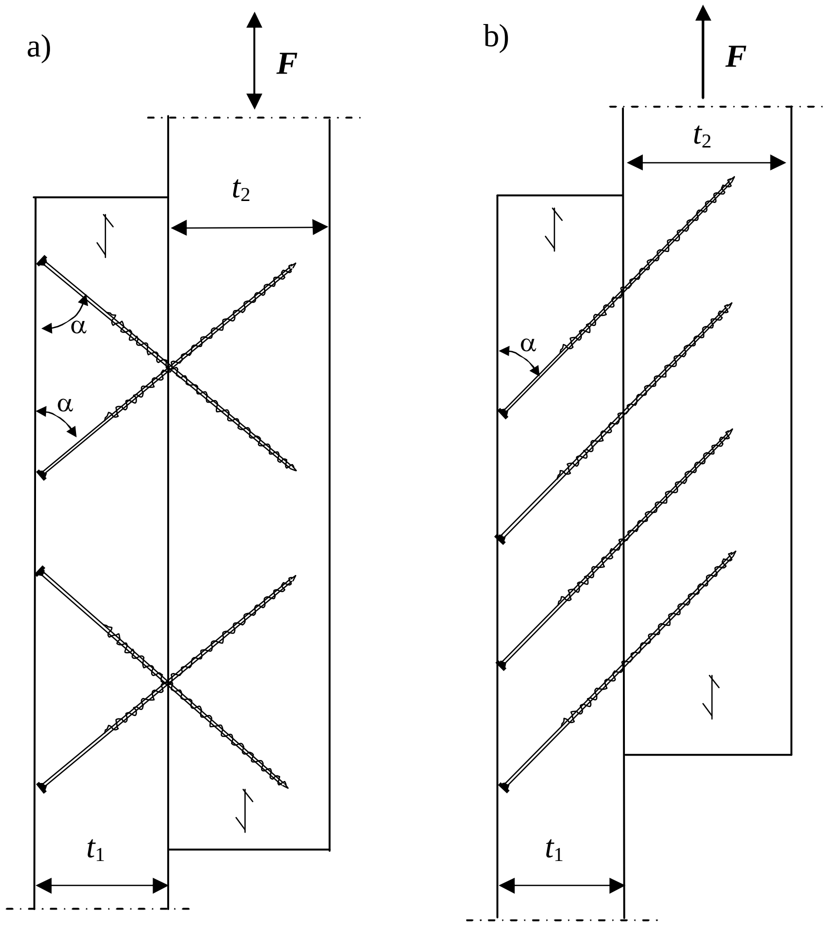


Figure C.2. The inclined screw joint a) cross screw connection b) tension screw connection.

Cross screw connection

The cross screw connection is built up of symmetrical screw pairs, in which one screw is under compression and the other under tension.

The characteristic load-carrying capacity of the cross screw connection

$$F_{\mathrm{Rk}} = n_{\mathrm{p}}^{0,9}\left(F_{\mathrm{C,Rk}} + F_{\mathrm{T,Rk}}\right)\cos\alpha \tag{C.3}$$

where:

- n_{p} is the number of screw pairs in the joint;
- α is the screw angle (see fig. C.2a)

The characteristic compression capacity of the screw

$$F_{\mathrm{C,Rk}} = \min\begin{cases} f_{\mathrm{ax,1,k}}\, d\, s_1 \\ f_{\mathrm{ax,2,k}}\, d\, s_2 \\ 0{,}8\, f_{\mathrm{tens,k}} \end{cases} \tag{C.4}$$

and the characteristic withdrawal capacity of the screw

$$F_{\mathrm{T,Rk}} = \min\begin{cases} f_{\mathrm{ax,1,k}}\, d\, s_1 + f_{\mathrm{head,k}}\, d_{\mathrm{h}}^2 \\ f_{\mathrm{ax,2,k}}\, d\, s_2 \\ f_{\mathrm{tens,k}} \end{cases} \tag{C.5}$$

where:

$$f_{\mathrm{ax,i,k}} = f_{\mathrm{ax,45,k}}\left(\frac{\alpha}{150} + 0{,}7\right)\left(\frac{8d}{s_{\mathrm{i}}}\right)^{0,2} \tag{C.6}$$

- d is the outer diameter of the thread (screw nominal size);
- s_1 is the threaded length of the screw in the head side member;
- s_2 is the threaded length of the screw in the point side member;
- $f_{\mathrm{tens,k}}$ is the characteristic tensile capacity of the screw determined in accordance with EN 14592;
- $f_{\mathrm{ax,45,k}}$ is the characteristic withdrawal strength parameter of the screw, which is determined in angle of 45° and penetration length of $s_2 \geq 8d$ separately for flatwise and edgewise joints of Kerto-S and Kerto-Q in accordance with EN 14592; in table C.1 the withdrawal strength parameters of some screws are given;
- α is the screw angle ($30° \leq \alpha \leq 60°$), see figure C.2;
- d_{h} is the head diameter of the screw;
- $f_{\mathrm{head,k}}$ is the characteristic pull-through parameter of the screw.

The pull through strength of screw head is determined for Kerto-LVL in accordance with EN 14592 or it is calculated by the following:

$$f_{\text{head, k}} = 57\left(\frac{d_h}{d} - 1\right) \quad \text{N/mm}^2 \quad \text{, when } d_\text{h} \leq 2d. \qquad \text{(C.7)}$$

Tension screw connection

A joint consisting of only screws in tension, a contact between the wood members is required. Tension screw connections should not be used in conditions where wood drying could cause a gap of over 0,2d. The gap is determined from the wood shrinkage at a distance of the screw length ($L\sin\alpha$).

The characteristic load-carrying capacity of the tension screw connection

$$F_\text{Rk} = n^{0,9} F_\text{T,Rk} (\cos\alpha + \mu \sin\alpha) \qquad \text{(C.8)}$$

where:

- n is the number of screws in the connection;
- $F_\text{T,Rk}$ is the characteristic withdrawal capacity, using eq. (C.5);
- α is the screw angle (see fig. C.2b);
- μ is the kinetic friction coefficient between the members.

If both surfaces are untreated Kerto-LVL in flatwise (unplanned, unsanded and uncoated), the kinetic friction coefficient in eq. (C.8) may be taken as μ = 0,4. For untreated edgewise connections value μ = 0,26 may be used.

Stiffness of inclined screwed connection

The instantaneous slip of the inclined screw joint is

$$u_\text{inst} = \frac{F}{nK_\text{ser}} \qquad \text{(C.9)}$$

where:

- F is the connection force;
- n is the number of screws (for cross screw joints $n = 2n_\text{p}$);
- K_ser is the slip modulus for an axially loaded screw according to equation (C.10).

In case of tension joints, a term should be added to equation (C.9), which considers the possible drying shrinkage of the members (δ) as a pre-slip: δ/tanα.

For axially loaded screws the slip modulus

$$K_{ser} = \frac{1}{\frac{1}{K_{1,ser}} + \frac{1}{K_{2,ser}}} \tag{C.10}$$

where:

$$K_{i,ser} = k_{i,ser} d\, s_i \tag{C.11}$$

The withdrawal stiffness for the threaded part of the screw

$$k_{i,ser} = k_{ser}\left(1 - \frac{|\alpha - 45|}{75}\right)\left(\frac{8d}{s_i}\right)^{0,3} \tag{C.12}$$

where:

- α is the screw angle (see figure C.2);
- s_i is the length of the threaded part of the screw in member i;
- k_{ser} is the mean withdrawal stiffness of the screw, which is determined by testing according to EN 1382 and EN 26891 in an angle of 45° and penetration length of $s_2 \geq 8d$ separately for flatwise and edgewise joints of Kerto-S and Kerto-Q*;* in table C.2 the withdrawal stiffness of some screws are given.

Structural detailing

In the same joint, different types or sizes of screws may not be combined. All the screws are placed with the same inclination angle α. The screws are placed centrally to the connection force.

Thickness of the Kerto-S member has to be at least (does not concern Kerto-Q):

$$t = \max\begin{cases} 5d \\ 12d - 36\text{ mm} \end{cases} \tag{C.13}$$

where d is the nominal diameter of the screw.

Unless specific values has not been determined for the actual screw by testing, the minimum spacings and end and edge distances should be taken from Table 8.6 of EN 1995-1-1:2004/A1:2008 and in the case of edgewise connection with the following replacements: a_1 = 10d, $a_{1,CG}$ = 12d and $a_{2,CG}$ = 5d.

In three-member flatwise connection, screws may overlap in the central member provided (t_2 - l) is greater than 3*d* (see Figure C.3). For edgewise screws no overlap should be used.

The minimum point side penetration length of the threaded part should be 6*d*. The screws are screwed deep enough so that the screw heads is in full contact with the member surface. The members should be compressed together so that no gaps are present. If pre-drilling is applied, the lead hole diameter shall not be greater than the inner thread diameter d_1.

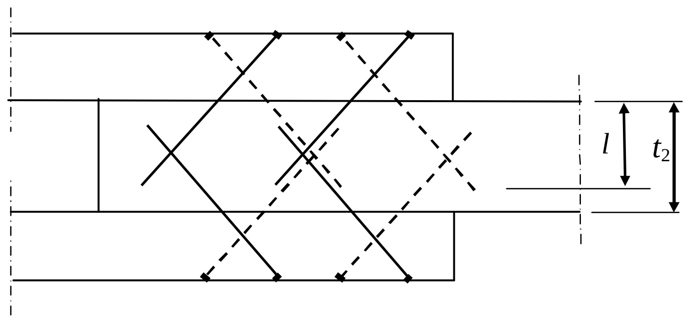


Figure C.3 Overlapping screws.

<u>Withdrawal parameters of some screws</u>

The values of the characteristic withdrawal strength parameter $f_{ax,45,k}$ and the mean withdrawal stiffness k_{ser} has been presented in table C.1 for the general screws, AMO III screws and for SFS-WT-T screws.

Here, the term general screw is defines as selfdrilling screws in accordance with EN 14592 with the inner thread diameter d_1 = 0,6...0,7*d* and the outer thread diameter *d* = 5,0...7,0 mm. The thread advance should be 0,40..0,55*d* per revolution. The values presented in tables C.1 and C.2 concerns sharp tip general screws (screw tip angle 15..40°), where the thread may be wavelike, notched or indented to improve the drilling, but at the point, no chisel or star-shaped drill tip is allowed. The head of the general screw may be countersunk or cylinder form. The tensile strength of general screws $f_{u,k}$ should be at least 500 N/mm^2.

The Würth's AMO III-screws are fully threaded AW-screwhead screws. The values presented in table C.1 and C.2 concerns nominal diameters (thread outer diameter) *d* = 7,5 mm AMO III screws. The screws are manufactured at d_h = 12,0 mm countersunk head (type 1), unheaded d_h = 7,5 mm (type 2, AW25) and d_h = 8,0 mm (type 2, AW30) and d_h = 12,5 mm cylinder head (type 3). For the characteristic tensile capacity of the 7,5 mm AMO III screw, the value $f_{tens,k}$ = 900 N may be used.

The SFS intec's WT-T-screws are bore bit screws, which have been threaded separately both at head and point side and have a smooth shank at the middle of screw. The outer thread diameter (nominal diameter) of the SFS-WT-T screws is 6,5 or 8,2 mm. The head diameter d_h is 8,0 mm for WT-T-6,5 screws and 10,0 mm for WT-T-8,2 screws. For the characteristic tensile capacity of the WT-T-6,5 screw, the value $f_{tens,k}$ = 10000 N may be used and for WT-T-8,2 screws respectively $f_{tens,k}$ = 19000 N. The minimum spacings and end and edge distances of SFS-WT-T screws may be taken both flatwise and edgewise connections from Table 8.6 of EN 1995-1-1:2004/A1:2008 with following reductions: a_2 = 4d and $a_{2,CG}$ = 3d.

Table C.1. Characteristic withdrawal strength parameters $f_{a,45,k}$ for threaded part of general, AMO III and SFS-WT-T screws.

	Screw	General screw, d = 5,0..7,0 mm	AMO III, d = 7,5 mm	SFS-WT-T-6,5 SFS-WT-T-8,2
Material and screwing surface	direction *)	$f_{ax,45,k}$ (N/mm²)	$f_{ax,45,k}$ (N/mm²)	$f_{ax,45,k}$ (N/mm²)
Kerto-S Kerto-Q flatwise Kerto-Q flatwise	0° 0° 90°	14	12	15,5
Kerto-S edge Kerto-S end (point side)	0° 90°, edgewise	12	10,5	13,5

*) direction between connection force and the grain direction of the outer veneers

Table C.2. Mean withdrawal stiffness k_{ser} for threaded part of general, AMO III and SFS-WT-T screws.

	Screw	General screw, d = 5,0..7,0 mm	AMO III, d = 7,5 mm	SFS-WT-T d = 6,5 mm	SFS-WT-T d = 8,2 mm
Material and screwing surface	direction *)	k_{ser} (N/mm³)	k_{ser} (N/mm³)	k_{ser} (N/mm³)	k_{ser} (N/mm³)
Kerto-S	0°	19	17	13	9,5
Kerto-Q flatwise	0°	21	14	13	9,5
Kerto-Q flatwise	90°	16	13	11	9
Kerto-S edge Kerto-S end (point side)	0° 90° edgewise	13	13	12	9,5

*) direction between connection force and the grain direction of the outer veneers