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European Technical Assessment

ETA-06/0138 of 18.01.2021

General part

Technical Assessment Body issuing the European Technical Assessment	Österreichisches Institut für Bautechnik (OIB) Austrian Institute of Construction Engineering
Trade name of the construction product	KLH® - CLT
Product family to which the construction product belongs	Solid wood slab elements to be used as structural elements in buildings
Manufacturer	KLH Massivholz GmbH Gewerbestraße 4 8842 Teufenbach-Katsch Austria
Manufacturing plants	KLH Massivholz GmbH Gewerbestraße 4 8842 Teufenbach-Katsch Austria KLH Massivholz Wiesenau GmbH Wiesenau 2 9462 Bad St. Leonhard Austria
This European Technical Assessment contains	51 pages including 8 Annexes which form an integral part of this assessment.
This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of	European Assessment Document (EAD) 130005-00-0304 "Solid wood slab element to be used as a structural element in buildings".
This European Technical Assessment replaces	European Technical Assessment ETA-06/0138 of 20.02.2017.

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Remarks

Translations of this European Technical Assessment in other languages shall fully correspond to the original issued document and should be identified as such.

Communication of this European Technical Assessment, including transmission by electronic means, shall be in full. However, partial reproduction may be made with the written consent of Austrian Institute of Construction Engineering. Any partial reproduction has to be identified as such.

Specific parts

1 Technical description of the product

1.1 General

This European Technical Assessment[1] (ETA) applies to the cross laminated timber "KLH® - CLT". KLH® - CLT are made of softwood boards, laminated boards or wood-based panels which are bonded together in order to form cross laminated timber (solid wood slab elements). Generally, adjacent layers of the softwood boards are arranged perpendicular (angle of 90°) to each other, see Annex 1, Figure 1.

The principle structure of the cross laminated timber is shown in Annex 1, Figure 1 to 3. Surfaces are planed.

The solid wood slab elements consist of at least three and up to eighteen adjacent layers which are arranged perpendicular to each other. With regard to the thickness of the solid wood slab element, thickness and orientation of individual layers are symmetrically assembled.

The following extensions are considered.

- Single board layers, maximum 50 % of the cross section, may be replaced by one- and multilayer solid wood panels. The solid wood panels shall be suitable for structural use. Adjacent layers of solid wood panels are permissible.
- No load bearing function is assigned to wood-based panels other than solid wood panels. These are only used for providing the surfaces of the solid wood slabs.
- Multiple consecutive board layers may be arranged in the same direction if their overall thickness does not exceed 90 mm.
- For solid wood slabs with distinctive asymmetric cross sections the effects of asymmetry have to be considered.

KLH® - CLT and the boards for its manufacturing correspond to the specifications given in the Annexes 1 and 2. The material characteristics, dimensions and tolerances of KLH® - CLT, not indicated in these Annexes, are given in the technical file[2] of the European Technical Assessment.

The application of wood preservatives and flame retardants is not subject of the European Technical Assessment.

[1] The ETA-06/0138 was firstly issued in 2006 as European technical approval with validity from 27.07.2006, extended in 2011 with validity from 01.07.2011, amended in 2012 with validity from 10.09.2012, amended and converted in 2017 to the European Technical Assessment ETA-06/0138 of 20.02.2017 and amended in 2020 to the European Technical Assessment ETA-06/0138 of 18.01.2021.

[2] The technical file of the European Technical Assessment is deposited at Österreichisches Institut für Bautechnik and, in so far as is relevant to the tasks of the notified product certification body involved in the assessment and verification of constancy of performance procedure, is handed over to the notified product certification body.

1.2 Components

1.2.1 Boards

The specification of the boards is given in Annex 2, Table 2. Boards are visually or machine strength graded. Only technically dried wood shall be used.

Wood species is European spruce or equivalent softwood.

1.2.2 Adhesive

The adhesive for bonding of the cross laminated timber and the finger joints of the individual boards shall conform to EN 15425.

1.2.3 Wood-based panels

Wood-based panels are in accordance with EN 13986 or a European Technical Assessment.

Single board layers, maximum 50 % of the cross section, may be replaced by one- and multilayer solid wood panels. The solid wood panels shall be suitable for structural use.

Laminated boards are exclusively used in cross layers. They are supplied in supporting quality and CE-marked.

Butt joints within one layer of solid wood panels are to be statically regarded as a joint without transfer of tension or compression forces.

Wood-based panels other than solid wood panels are only used for providing the surfaces of the solid wood slabs without a load bearing function.

2 Specification of the intended use(s) in accordance with the applicable European Assessment Document (thereafter EAD)

2.1 Intended use

The solid wood slab is intended to be used as a structural or non-structural element in buildings and timber structures.

The solid wood slab shall be subjected to static and quasi-static actions (not relevant for fatigue e.g. low cycle alternating stress due to person induced vibrations, wind and seismic loads and less highly frequented heavy traffic) only.

The solid wood slab is intended to be used in service classes 1 and 2 according to EN 1995-1-1[3]. Members which are directly exposed to the weather shall be provided with an effective protection for the solid wood slab element in service.

2.2 General assumptions

The solid wood slab elements are manufactured in accordance with the provisions of the European Technical Assessment using the automated manufacturing process as identified in the inspection of the manufacturing plant by Österreichisches Institut für Bautechnik and laid down in the technical file.

The manufacturer shall ensure that the requirements in accordance with the Clauses 1, 2 and 3 as well as with the Annexes of the European Technical Assessment are made known to those who are concerned with design and execution of the works.

Single and double layers of planed boards shall be bonded together to the required thickness of the cross laminated timber. The individual boards shall be jointed in longitudinal direction by means of finger joints according to EN 14080, there shall be no butt joints.

Adhesive shall be applied on one faces of each board. The edges of the boards need not to be bonded. Pressure shall be at or above 0.6 N/mm².

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[3] Reference documents are listed in Annex 8.

Design

The European Technical Assessment only applies to the manufacture and use of cross laminated timber. Verification of stability of the works including application of loads on the cross laminated timber is not subject to the European Technical Assessment.

The following conditions shall be observed:

- Design of cross laminated timber members is carried out under the responsibility of an engineer experienced in such products.
- Design of the works shall account for the protection of the cross laminated timber in service.
- The cross laminated timber members are installed correctly.

Cross laminated timber members elements may be designed according to EN 1995-1-1 and EN 1995-1-2, taking into account Annexes 2 to 7 of the European Technical Assessment.

Standards and regulations in force at the place of use shall be considered.

Packaging, transport, storage, maintenance, replacement and repair

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product as he considers necessary.

Installation

It is assumed that the product will be installed according to the manufacturer's instructions or (in absence of such instructions) according to the usual practice of the building professionals.

2.3 Assumed working life

The provisions made in the European Technical Assessment (ETA) are based on an assumed intended working life of KLH® - CLT of 50 years, when installed in the works, provided that the cross laminated timber elements are subject to appropriate installation, use and maintenance (see Clause 2.2). These provisions are based upon the current state of the art and the available knowledge and experience. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[4].

The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product manufacturer or his representative nor by EOTA nor by the Technical Assessment Body, but are regarded only as a means for choosing the appropriate products in relation to the expected economically reasonable working life of the works.

[4] The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject, as well as on the particular conditions of the design, execution, use and maintenance of that works. Therefore, it cannot be excluded that in certain cases the real working life of the product can also be shorter than the assumed working life.

3 Performance of the product and reference to the methods used for its assessment

3.1 Essential characteristics of the product

Table 1: Essential characteristics of the product and assessment methods

№	Essential characteristic	Product performance
	Basic requirement for construction works 1: Mechanical resistance and stability [1]	
1	Bending [2]	Annex 3
2	Tension and compression [2]	Annex 3
3	Shear [2]	Annex 3
4	Embedment strength	Annex 3
5	Creep and duration of the load	Annex 3
6	Dimensional stability	Annex 3
7	In-service environment	Annex 3
8	Bond integrity	Annex 3
	Basic requirement for construction works 2: Safety in case of fire	
9	Reaction to fire	Annex 3
10	Resistance to fire	Annex 3
	Basic requirement for construction works 3: Hygiene, health and the environment	
11	Content, emission and/or release of dangerous substances	3.1.1
12	Water vapour permeability – Water vapour transmission	Annex 3
	Basic requirement for construction works 4: Safety and accessibility in use	
13	Impact resistance	Annex 3
	Basic requirement for construction works 5: Protection against noise	
14	Airborne sound insulation	Annex 3
15	Impact sound insulation	Annex 3
16	Sound absorption	No performance assessed.
	Basic requirement for construction works 6: Energy economy and heat retention	
17	Thermal conductivity	Annex 3
18	Air permeability	Annex 3
19	Thermal inertia	Annex 3

[1] These characteristics also relate to basic requirement for construction works 4.

[2] Load bearing capacity and stiffness regarding mechanical actions perpendicular to and in plane of the solid wood slab element.

3.1.1 Hygiene, health and the environment

The release of dangerous substances is determined according to EAD 130005-00-0304, “Solid wood slab element to be used as a structural element in buildings”. No dangerous substances is the performance of the KLH® - CLT in this respect.

NOTE In addition to the specific clauses relating to dangerous substances contained in the European Technical Assessment, there may be other requirements applicable to the products falling within its scope (e.g. transposed European legislation and national laws, regulations and administrative provisions). In order to meet the provisions of the Construction Products Regulation, these requirements need also to be complied with, when and where they apply.

3.2 Assessment methods

3.2.1 General

The assessment of the essential characteristics in Clause 3.1 of KLH® - CLT for the intended use, and in relation to the requirements for mechanical resistance and stability, for safety in case of fire, for hygiene, health and the environment, for safety and accessibility in use, for protection against noise and for energy economy and heat retention in use in the sense of the basic requirements for construction works № 1 to 6 of Regulation (EU) № 305/2011 has been made in accordance with the European Assessment Document EAD 130005-00-0304, Solid wood slab element to be used as a structural element in buildings.

3.2.2 Identification

The European Technical Assessment for KLH® - CLT is issued on the basis of agreed data that identify the assessed product. Changes to materials, to composition, to characteristics of the product, or to the production process could result in these deposited data being incorrect. Österreichisches Institut für Bautechnik should be notified before the changes are implemented, as an amendment of the European Technical Assessment is possibly necessary.

4 Assessment and verification of constancy of performance (thereafter AVCP) system applied, with reference to its legal base

4.1 System of assessment and verification of constancy of performance

According to Commission Decision 97/176/EC the system of assessment and verification of constancy of performance to be applied to KLH® - CLT is System 1. System 1 is detailed in Commission Delegated Regulation (EU) № 568/2014 of 18 February 2014, Annex, 1.2., and provides for the following items

(a) The manufacturer shall carry out

- (i) factory production control;
- (ii) further testing of samples taken at the manufacturing plant by the manufacturer in accordance with a prescribed test plan[5];

(b) The notified product certification body shall decide on the issuing, restriction, suspension or withdrawal of the certificate of constancy of performance of the construction product on the basis of the outcome of the following assessments and verifications carried out by that body:

- (i) an assessment of the performance of the construction product carried out on the basis of testing (including sampling), calculation, tabulated values or descriptive documentation of the product;
- (ii) initial inspection of the manufacturing plant and of factory production control;
- (iii) continuous surveillance, assessment and evaluation of factory production control.

[5] The prescribed test plan has been deposited with Österreichisches Institut für Bautechnik and is handed over only to the notified product certification body involved in the procedure for the assessment and verification of constancy of performance. The prescribed test plan is also referred to as control plan.

4.2 AVCP for construction products for which a European Technical Assessment has been issued

Notified bodies undertaking tasks under System 1 shall consider the European Technical Assessment issued for the construction product in question as the assessment of the performance of that product. Notified bodies shall therefore not undertake the tasks referred to in point 4.1 (b)(i).

5 Technical details necessary for the implementation of the AVCP system, as provided for in the applicable European Assessment Document

5.1 Tasks for the manufacturer

5.1.1 Factory production control

In the manufacturing plant the manufacturer shall establish and continuously maintain a factory production control. All procedures and specification adopted by the manufacturer shall be documented in a systematic manner. The factory production control shall ensure the constancy of performance of KLH® - CLT with regard to the essential characteristics.

The manufacturer shall only use raw materials supplied with the relevant inspection documents as laid down in the control plan. The incoming raw materials shall be subject to controls by the manufacturer before acceptance. Check of incoming materials shall include control of inspection documents presented by the manufacturer of the raw materials.

The frequencies of controls conducted during manufacturing and on the assembled product are defined by taking account of the manufacturing process of the product and are laid down in the control plan.

The results of factory production control are recorded and evaluated. The records include at least the following data:

- Designation of the product, basic materials and components
- Type of control or test
- Date of manufacture of the product and date of testing of the product or basic materials or components
- Results of controls and tests and, if appropriate, comparison with requirements
- Name and signature of person responsible for factory production control

The records shall be kept at least for ten years time after the construction product has been placed on the market and shall be presented to the notified product certification body involved in continuous surveillance. On request they shall be presented to Österreichisches Institut für Bautechnik.

5.1.2 Declaration of performance

The manufacturer is responsible for preparing the declaration of performance. When all the criteria of the assessment and verification of constancy of performance are met, including the certificate of conformity issued by the notified product certification body, the manufacturer shall draw up a declaration of performance.

5.2 Tasks for the notified product certification body

5.2.1 Initial inspection of the manufacturing plant and of factory production control

The notified product certification body shall verify the ability of the manufacturer for a continuous and orderly manufacturing of KLH® - CLT according to the European Technical Assessment. In particular the following items shall be appropriately considered

- Personnel and equipment

- The suitability of the factory production control established by the manufacturer
- Full implementation of the control plan

5.2.2 Continuous surveillance, assessment and evaluation of factory production control

The notified product certification body shall visit the factory at least once a year for routine inspection. In particular the following items shall be appropriately considered

- The manufacturing process including personnel and equipment
- The factory production control
- The implementation of the control plan

The results of continuous surveillance are made available on demand by the notified product certification body to Österreichisches Institut für Bautechnik. When the provisions of the European Technical Assessment and the control plan are no longer fulfilled, the certificate of constancy of performance is withdrawn by the notified product certification body.

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The original document is signed by:

Rainer Mikulits

Managing Director

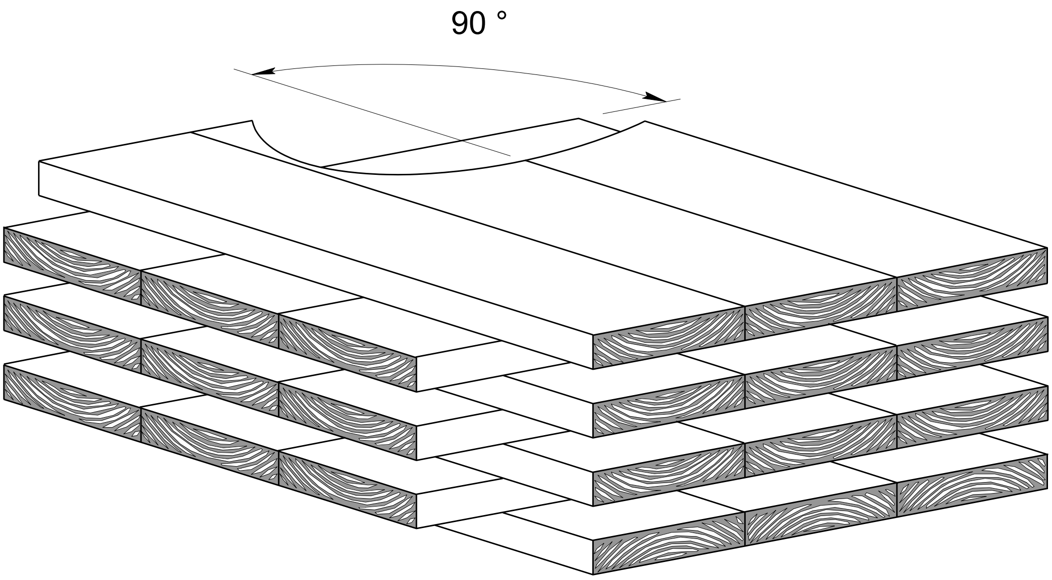

Figure 1: Principle structure of KLH® - CLT

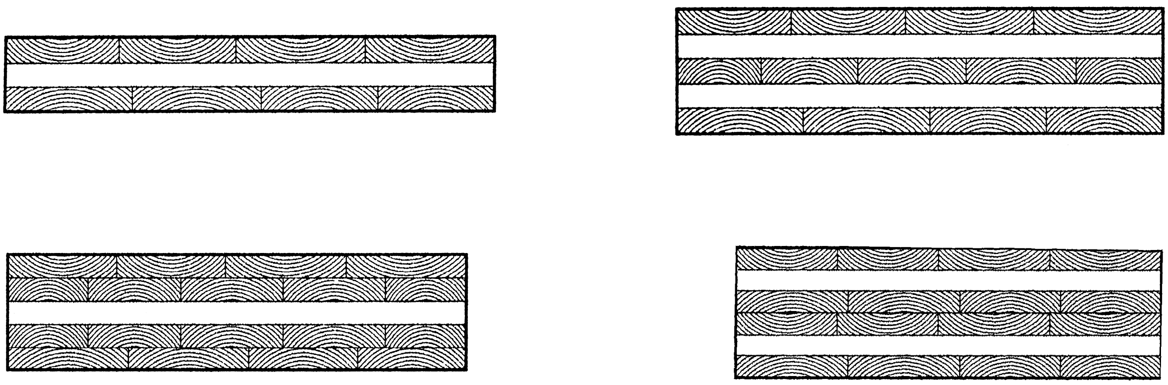

Figure 2: Typical examples of the structure of KLH® - CLT

KLH® - CLT	Annex 1 Page 1 of 2 of European Technical Assessment ETA-06/0138
Structure of KLH® - CLT	

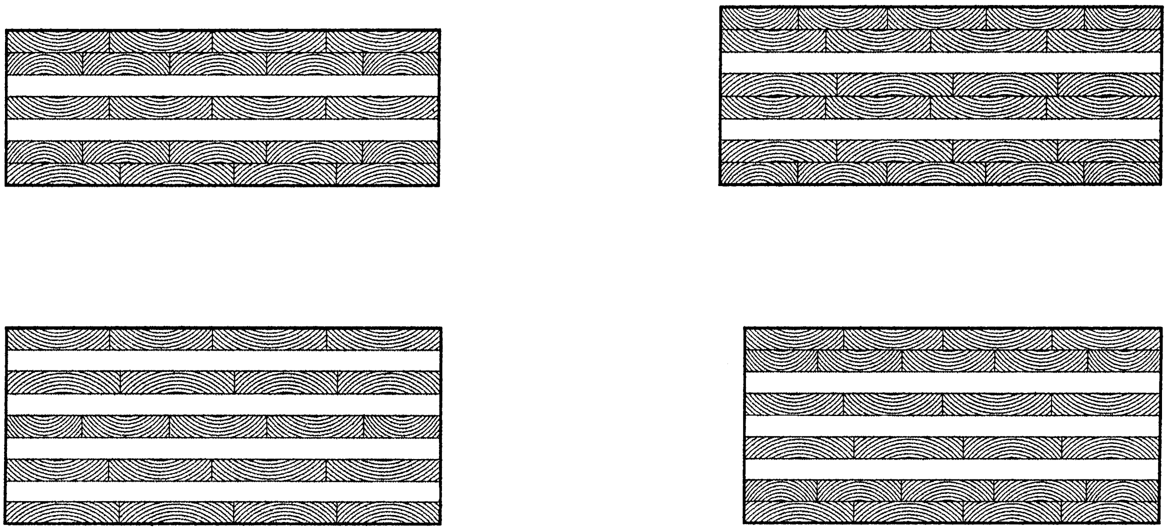

Figure 3: Typical examples of the structure of KLH® - CLT

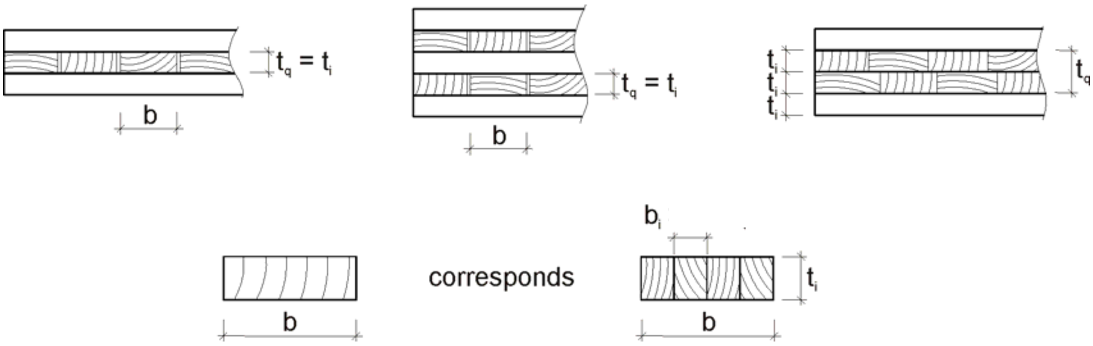

Figure 4: Typical dimensions of cross section of KLH® - CLT lamellas

Where

b .... Width of a single board, solid wood or laminated board

b_i .... Partial cross section of single board or single lamella of laminated boards

t_i .... Thickness of single layer

t_q .... Thickness of single or multiple layer in cross direction, $t_q \leq 90$ mm

Laminated boards are bonded with an adhesive suitable for structural applications.

KLH® - CLT	**Annex 1** Page 2 of 2
Structure of of KLH® - CLT	of European Technical Assessment ETA-06/0138

Table 2: Dimensions and specifications

Item		Dimension / Specification
Solid wood slab element		
Thickness	mm	57 to 360
Width	m	≤ 3.50
Length	m	≤ 16.50
Number of layers	—	3 to 18
Maximum value of joint width between boards within one layer:	mm mm	3 max. 5 % ≤ 6
Density ρ_k	kg/m³	1,1 x $\rho_{l,k}$ = 385
Board [1]		
Surface	—	planed
Thickness, planed dimension	mm	10 to 45
Width [1]	mm	44 to 298
Ratio width to thickness	—	≥ 2.3 : 1 [2] ≥ 4 : 1 [3]
Boards shall be graded with suitable visual and/or machine procedures to be able to assign them to the strength classes according to EN 338.	—	≤ 10 % C16 ≥ 90 % C24 [4]
Moisture of wood according to EN 13183-2	%	Delivery: 12 ± 2 Production: 6 to 15 %, within one member of cross laminated timber the moisture content shall not differ by more than 5 %
Finger joints	—	EN 14080

1) Laminated boards with single lamellas b_i and t_i ≤ 45 mm according to Figure 4, are considered as boards.
2) Minimum ratio for layers oriented in cross direction (stressed on rolling shear).
3) In general
4) For the whole product as well as each single layer.

Table 3: Product characteristics of KLH® - CLT

BWR	Essential characteristic	Assessment method	Level / Class / Description
1	**Mechanical resistance and stability**		
	1. Mechanical actions perpendicular to the solid wood slab		
	Modulus of elasticity [3)]		
	– parallel to the grain of the boards $E_{0,\ mean}$	Annex 4 EAD 130005-00-0304, 2.2.1.1	12 000 MPa
	– perpendicular to the grain of the boards $E_{90,\ mean}$	EN 338, increased	450 MPa
	Shear modulus [3)]		
	– parallel to the grain of the boards $G_{0,mean}$	EN 338	690 MPa
	– perpendicular to the grain of the boards, rolling shear modulus $G_{90,\ mean}$	I_{eff}, γ-method EAD 130005-00-0304, 2.2.1.1	50 MPa
	Bending strength		
	– parallel to the grain of the boards $f_{m,\ k}$	Annex 4 EAD 130005-00-0304, 2.2.1.1	24 MPa
	Tensile strength		
	– perpendicular to the grain of the boards $f_{t,\ 90,\ k}$	EN 338, reduced	0.12 MPa
	Compressive strength		
	– perpendicular to the grain of the boards $f_{c,\ 90,\ k}$	EN 338	2.7 MPa
	Shear strength		
	– parallel to the grain of the boards $f_{v,\ k}$	EN 338	2.7 MPa
	– perpendicular to the grain of the boards (rolling shear strength) $f_{v,\ R,\ k}$	Annex 4 EAD 130005-00-0304, 2.2.1.3	1.2 MPa
	2. Mechanical actions in plane of the solid wood slab		
	Modulus of elasticity [3)]		
	– parallel to the grain of the boards $E_{0,\ mean}$	A_{net}, I_{net}, Annex 4 EAD 130005-00-0304, 2.2.1.1	12 000 MPa
	Shear modulus [3)]		
	– parallel to the grain of the boards $G_{0,mean}$ [1)]	A_{net}, Annex 4 EAD 130005-00-0304, 2.2.1.3	500 MPa [1)]
	Bending strength		
	– parallel to the grain of the boards $f_{m,\ k}$	W_{net}, Annex 4 EAD 130005-00-0304, 2.2.1.1	24 MPa

BWR	Essential characteristic	Assessment method	Level / Class / Description
1	**2. Mechanical actions in plane of the solid wood slab**		
	Tensile strength [2)]		
	– parallel to the grain of the boards $f_{t, 0, k}$	EN 338	16.5 MPa
	Compressive strength		
	– parallel to the grain of the boards $f_{c, 0, k}$	EN 338	24 MPa
	– concentrated, parallel to the grain of the boards $f_{c, 0, k}$	EAD 130005-00-0304, 2.2.1.2	$k_{c,0}$ Annex 4, 3.5
	Shear strength		
	– regardless of loading direction, per glue line $f_{v,K,k}$	Annex 4 – Shear flow	90 N/mm
	– parallel to the grain of the boards $f_{v, k}$	Annex 4 – Shear stress	3.9 to 8.4 MPa
	3. Other mechanical actions		
	Creep and duration of load	k_{mod} and k_{def} according to EN 1995-1-1 for glued laminated timber	
	Dimensional stability Moisture content during service shall not change to such an extend that adverse deformation will occur.		
	– Shrinkage perpendicular to the plane of the solid wood slab	0.24 % in thickness per % moisture variation	
	– Shrinkage in plane of the solid wood slab	0.02 % in length per % moisture variation	
	Fasteners	Annex 7	
	In-service environment		
	Durability of timber Service classes	EN 1995-1-1	1 and 2
	Bond integrity	EAD 130005-00-0304	Pass

1) This value is applicable for 2 dimensional structures, orthotropic plates. For a simplified beam analysis, this value shall be reduced to 50 %.

2) In case of a non-uniform stress distribution, the characteristic bending strength may be applied.

3) For determination of the 5 %-fractile values of the stiffness properties the mean values may be multiplied by $\frac{5}{6}$.

BWR	Essential characteristic	Assessment method	Level / Class / Description
2	**Reaction to fire**		
	Glued laminated timber products	Commission Decision 2005/610/EC	Mean density of wood $\geq$ 380 kg/m^3 Euroclass D-s2, d0
	Resistance to fire		
	Charring rate	EN 1995-1-2	Obtained test data according to Annex 5
3	**Hygiene, health and environment**		
	Vapour permeability, μ, including joints within the layers	EN ISO 12572	300 (dry) to 46 (wet)
4	**Safety and accessibility in use**		
	Impact resistance	Soft body resistance is assumed to be fulfilled for walls with a minimum of 3 layers and minimum thickness of 60 mm.	
5	**Protection against noise**		
	Airborne sound insulation	EN 10140-2	Annex 6
	Impact sound insulation	EN 10140-3	Annex 6
6	**Energy economy and heat retention**		
	Thermal conductivity, λ	EN ISO 10456	0.12 W/(m · K)
	Air permeability	EN 12114	Class 4 acc. to EN 12207
	Thermal inertia, specific heat, c_p	EN ISO 10456	1 600 J/(kg · K)

Design considerations for KLH plate structures

1 General definitions and terminology

1.1 Mechanical actions perpendicular to the solid wood slab

Along the two main directions of the solid wood slab, the two main structural directions are defined. See Figure 5 for mechanical actions perpendicular to the solid wood slab.

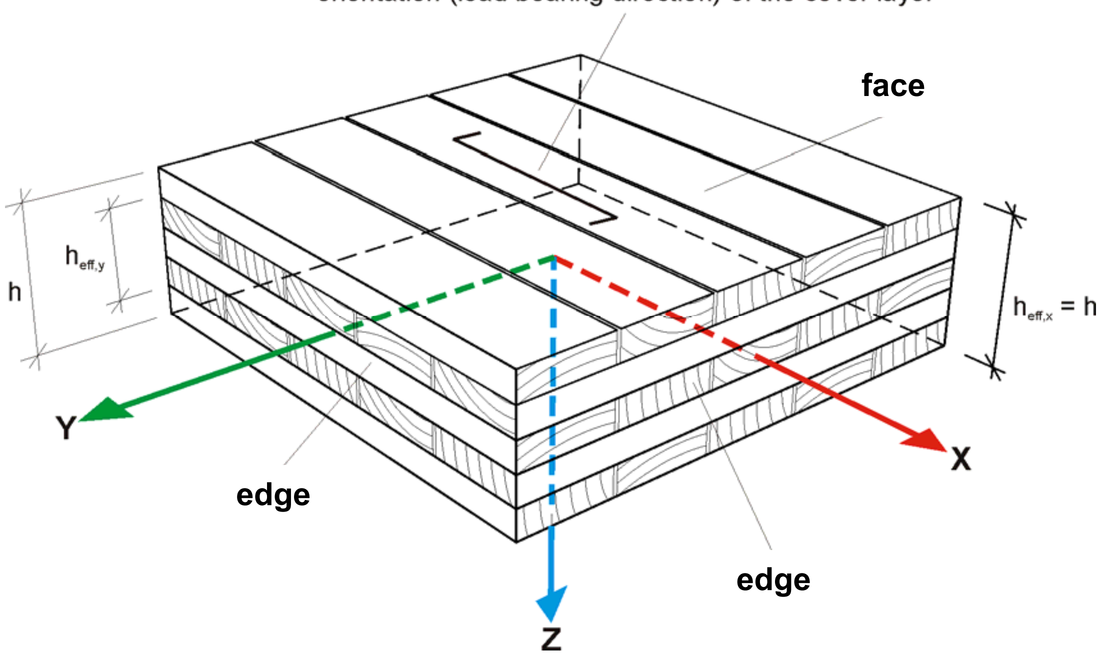

Figure 5: Main directions regarding mechanical actions perpendicular to the solid wood slab

Where

h .... gross thickness of the solid wood slab

$h_{eff,\,x}$, $h_{eff,\,y}$ ...... effective height of the cross section in main structural direction x or y

x.................... direction parallel to the orientation of the cover layer

y.................... direction perpendicular to the orientation of the cover layer

1.2 Mechanical actions in plane of the solid wood slab

Along the two main directions of the solid wood slab, the two main structural directions are defined. See Figure 6 for mechanical actions in plane of the solid wood slab.

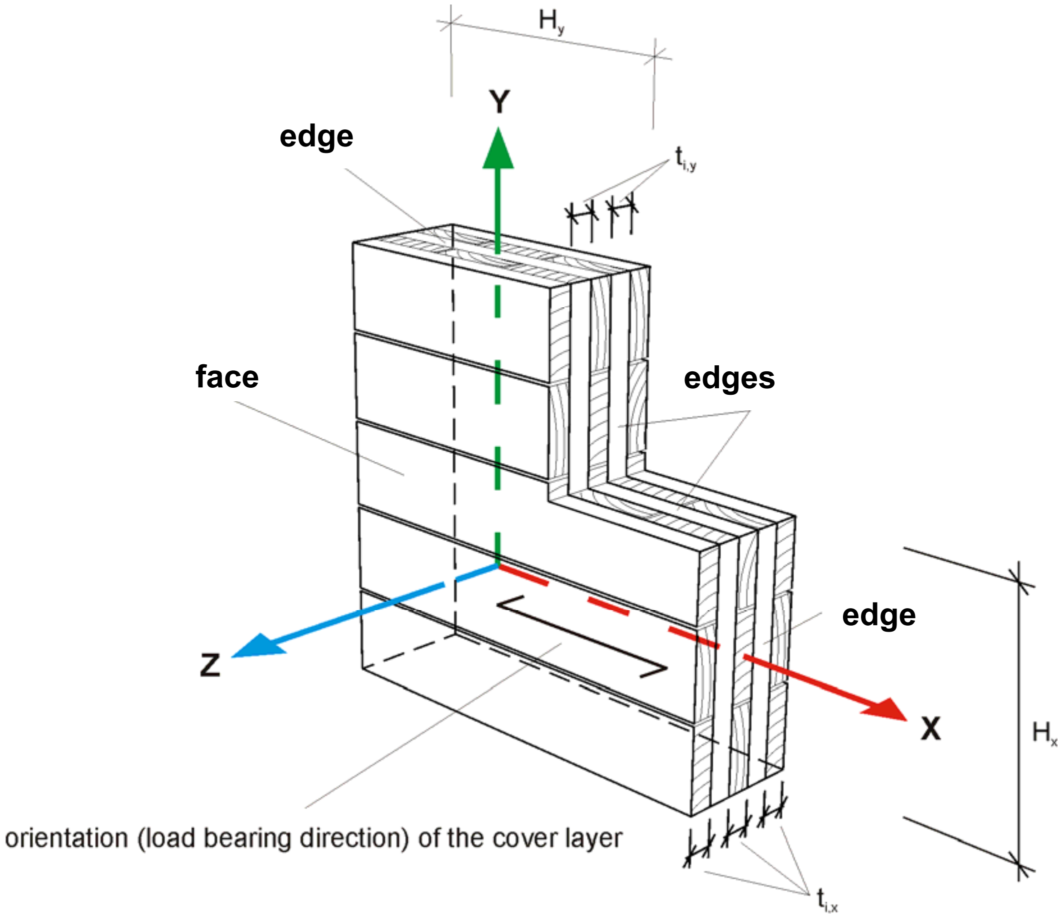

Figure 6: Main directions regarding mechanical actions in plane of the solid wood slab

Where

H_x, H_y............height of the cross section in the respective structural direction without consideration of joints between adjacent boards

$t_{i,x}$, $t_{i,y}$ ....thickness of the single layers in the respective structural direction

1.3 Normal stress and shear stress in the two main directions of the solid wood slab

Normal stresses and shear stresses resulting from mechanical actions perpendicular to the solid wood slab and normal stresses resulting from mechanical actions in plane of the solid wood slab are shown in Figure 7.

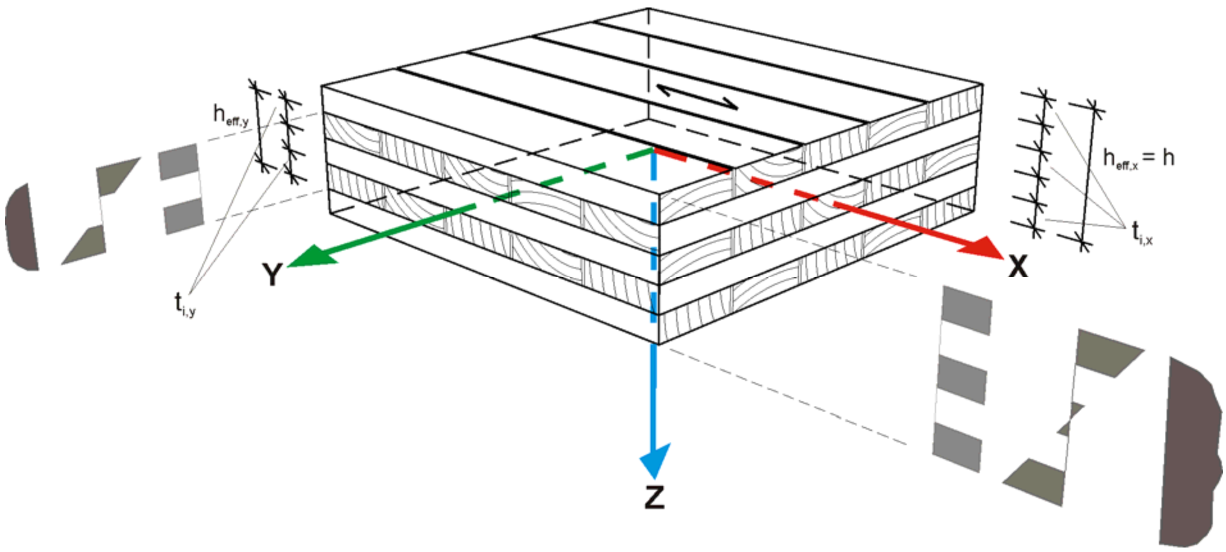

Figure 7: Normal and shear stresses

2 Calculation of stiffness properties

2.1 Short-term deformation

The deformation behaviour of KLH® - CLT members can be considered by applying the following stiffnesses. Member forces and moments based on these stiffnesses shall be used for ultimate limit state design.

For actions perpendicular to the solid wood slab shear deformations of the layers perpendicular to the respective structural direction have to be considered.

Serviceability limit state design may be performed in accordance with EN 1995-1-1.

2.1.1 Bending stiffness

For calculation of the deformation due to pure bending, w_{net}, the net cross section, I_{net}, can be applied without shear deformations. I.e. layers oriented perpendicular to the considered main structural direction shall not be taken into account, i.e. $E_{90,\, mean}$ = 0 MPa and without shear deformation.

Where

I_{net} .... moment of inertia of the net cross section for the structural direction concerned

$E_{0,\ mean}$ .... modulus of elasticity of the layers in the structural direction concerned

$E_{90,\ mean}$ .... modulus of elasticity of the layers perpendicular to the concerned structural direction, normally $E_{90,\ mean} = 0$ MPa

2.1.2 Shear deformations

The shear deformations of the perpendicular layers may be taken into account by application of a global shear modulus. This global shear modulus shall be determined for every cross section either by tests or by calculation. For calculation Annex B of EN 1995-1-1 can be applied, also referred to as γ-method. Therein the expression $\frac{s_i}{k_i}$ shall be substituted by $\frac{t_q}{G_{90,\ mean} \cdot b}$.

Where

t_q .... thickness of the respective cross layers

b .... width of the considered strip of the solid wood slab

$G_{90,\ mean}$ .... rolling shear modulus

The shear deformation results from the equation

$w_v = w_{eff} - w_{net}$

Where

w_{net} .... deformation due to bending by application of I_{net}, pure bending deformation

w_{eff} .... deformation due to bending by application of I_{eff}, bending- and shear deformation

w_v .... shear deformation, thus the global shear modulus can be calculated taking into account a shear factor for the rectangular cross section of 1.2

The global shear modulus is determined with the effective cross section including cross layers according to Figure 7, i.e. $A_{eff,\ x} = b \cdot h_{eff,\ x}$ or $A_{eff,\ y} = b \cdot h_{eff,\ y}$

NOTE For the structural direction perpendicular to the cover layers, the cover layers are disregarded for calculation of the effective cross section.

Where

$A_{eff,\ x}$, $A_{eff,\ y}$...... cross sectional area of the layers in the structural direction concerned, including cross layers

b .... width of the considered strip of the solid wood slab

The global shear modulus, depending on the cross section and on the structural direction, accounting for shear deformation of the cross layers, can be taken to 60 MPa for all types of KLH® - CLT; this simplification is conservative.

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2.1.3 Extensional stiffness

The extensional stiffness to determine deformations in plane of the solid wood slab shall be calculated with the net cross section of the layers in the considered structural direction, $A_{net,\,x}$, $A_{net,\,y}$. I.e. layers oriented perpendicular to the considered structural direction shall not be taken into account, $E_{90,\,mean} = 0$ MPa.

$A_{net,\,x}$, $A_{net,\,y}$ .... net cross sectional area of the layers in the structural direction concerned, without cross layers

2.1.4 Shear stiffness in plane of the solid wood slab

Shear stiffness to determine deformations in plane of the solid wood slab can be calculated with the net cross section of the layers in the considered structural direction, $A_{net,\,x}$, $A_{net,\,y}$.

In a simplified beam analysis, the shear modulus for the layers in the concerned structural direction shall be taken to $G_{LL} = 250$ MPa for all configurations.

2.1.5 Bending stiffness for beams in plane of the solid wood slab

The bending stiffness for beams to determine deformations in plane of the solid wood slab should be applied only for a ratio $\frac{L}{H} \geq 4$

The bending stiffness in the considered structural direction, $E \cdot I_{net,\,z,\,x}$, $E \cdot I_{net,\,z,\,y}$ can be calculated with the net cross section of the layers in the considered main structural direction. I.e. layers oriented perpendicular to the considered main structural direction shall not be taken into account, $E_{90,\,mean} = 0$ MPa.

2.1.6 Recommendations on Finite-Element-Analysis

Finite-Element-Analysis is a suitable means for design of KLH® - CLT if the following items are considered.

Slabs loaded either perpendicular to the plane or in plane of the solid wood slab with a clearly separated structural behaviour, can be considered as orthotropic plate. However, the torsional stiffness shall be limited within the model to 50 % of the total torsional stiffness of the orthotropic plate.

NOTE Suitable means for modelling of orthotropic plates are varying thicknesses or varying moduli of elasticity in the two main structural directions of the solid wood slab.

If combined structural behaviour, perpendicular to the plane and in the plane of the solid wood slab, is to be considered, care should be taken to adequately consider the stiffness according to the Clauses above.

In case the stiffness perpendicular to the structural direction is of unfavourable influence, this effect shall be considered. In all other cases floors and walls may be analysed as uniaxial plate strips.

NOTE Inclined edges above supports shall be carefully considered. Step shaped modelling according to Figure 8 is recommended.

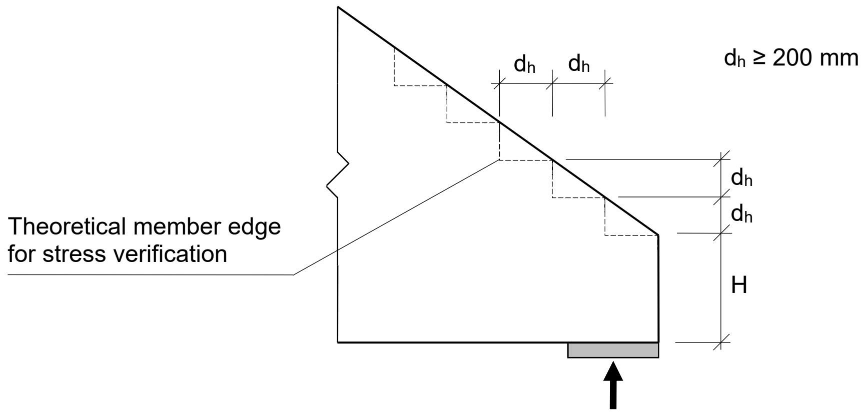

Figure 8: Modelling of an inclined edge by step shaped modelling

2.2 Long-term deformation

All long-term deformations, bending, axial force and shear shall be multiplied by the factors k_{def} given in Annex 3.

3 Ultimate limit state design

3.1 General

Production related constraints, e.g. single boards cut longitudinal in cut outs for openings or the contribution of several layers to the load bearing capacity, should be considered by the system strength factor k_{sys}. Strength characteristics shall be reduced for small members or if only a single layer is loaded in plane of the solid wood slab. They may be increased in case of a larger member or several layers contribute together to the load bearing capacity.

Table 4: System strength factor k_{sys} for KLH® - CLT

Loading perpendicular to the solid wood slab	Loading in plane of the solid wood slab	System strength factor
Member width	Number of layers	
b	n	k_{sys}
b ≤ 20 cm	n = 1	0.90
20 cm < b ≤ 100 cm	2 ≤ n < 5	1.00
100 cm < b ≤ 160 cm	5 ≤ n < 8	1.05
b > 160 cm	n ≥ 8	1.10
n .... number of layers along the concerned structural direction – actions in plane of the solid wood slab		

3.2 Tension along the grain – actions in plane of the solid wood slab

Only layers with a structural direction parallel to the stresses shall be considered. The following expression shall be satisfied:

$$\sigma_{t, 0, d} \leq f_{t, 0, d} \cdot k_{sys}$$

$\sigma_{t, 0, d}$ shall be determined with $A_{net, x}$ or $A_{net, y}$.

For solid wood slabs loaded in plane and with varying tension stresses, the varying parts may be verified against the characteristic bending strength, $f_{m, k}$.

3.3 Tension perpendicular to the grain – actions perpendicular to the plane of the solid wood slab

Tension perpendicular to the grain should be avoided and should be transferred with fasteners.

NOTE Tension perpendicular to the grain for actions in plane of the solid wood slab may be disregarded.

Only short term tension forces, e.g. wind loads, shall be applied perpendicular to the solid wood slab. The following expression shall be satisfied:

$\sigma_{t, 90, d} \leq k_{vol} \cdot f_{t, 90, d}$

The volume factor k_{vol} may be considered in analogy to glued laminated timber according to EN 1995-1-1, taking into account the penetration of the fasteners. Three dimensional effects, spreading of loads, may be taken into account for $\sigma_{t, 90, d}$.

3.4 Compression along the grain – action in plane of the solid wood slab

Only layers with structural direction parallel to the stresses shall be considered. The following expression shall be satisfied:

$\sigma_{c, 0, d} \leq f_{c, 0, d} \cdot k_{sys}$

$\sigma_{c, 0, d}$ shall be determined with $A_{net, x}$ or $A_{net, y}$.

The stability of members may be accounted for with a second order linear elastic analysis. Shear deformation shall be taken into account. The analysis and verification shall be performed using the 5 %-fractile values of the stiffness properties $E_{0.05}$ and $G_{0.05}$. The value for the initial deflection of a member shall be $\frac{L}{400}$ and covers long term deformations.

The stability of columns subjected to compression should be verified in accordance with EN 1995-1-1. Shear deformation shall be taken into account in the calculation of the slenderness ratio. The imperfection factor β_c may be taken to 0.1 and the factor for redistribution of bending stresses k_m should be taken equal to unity.

The stability of at least 300 mm wide solid wood slabs loaded in plane with non-uniform compression stresses, may be verified with the stress value in a distance of 100 mm from the edge of the member. This takes into account the stabilising effect within plate structures.

In addition to stability for members with low slenderness ratio stresses shall be verified.

For members small in width, stability in plane of the solid wood slab shall be taken into consideration.

3.5 Contact compression along the grain – actions in plane of the solid wood slab

The following expression shall be satisfied for contact compression stresses:

$\sigma_{c, 0, d} \leq f_{c, 0, d} \cdot k_{c, 0}$

$\sigma_{c, 0, d}$ shall be determined with $A_{net, x}$ or $A_{net, y}$. For layers of board or wood based panels, except OSB and LVL, the value for $k_{c, 0}$ can be taken to

$k_{c, 0} \leq 1.5$........for support or load introduction in a distance $a \leq \frac{H}{2}$ or $a \leq 500$ mm (the smaller value is decisive)

$k_{c, 0} \leq 1.9$........for support or load introduction in a distance $a > \frac{H}{2}$ or $a > 500$ mm (the smaller value is decisive)

Where

a .... distance from the edge of a concentrated load to the closest end of the member in mm, see Figure 9

H.................... member height in mm

$k_{c,0}$ greater than 1.3 is only applicable for end grain to steel contact. In slabs with more than one cover layers, a maximum thickness of 45 mm of the cover layer shall be considered in calculating $A_{net,x}$ or $A_{net,y}$.

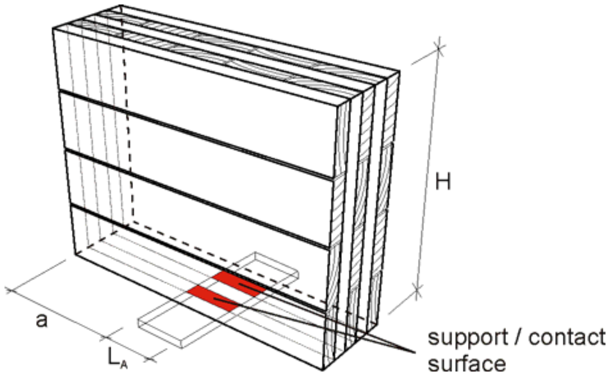

Figure 9: Geometry of load introduction

The capacity of the adjacent members (e.g. timber, concrete, or masonry) shall be verified. The distribution of stresses shall be determined taking into account the slab rotation and the compliance of the adjacent member.

The minimum bearing length L_A shall be 50 mm. For determination of the contact areas only layers with end grain perpendicular to the contact areas shall be considered, t_{normal} according to Figure 10.

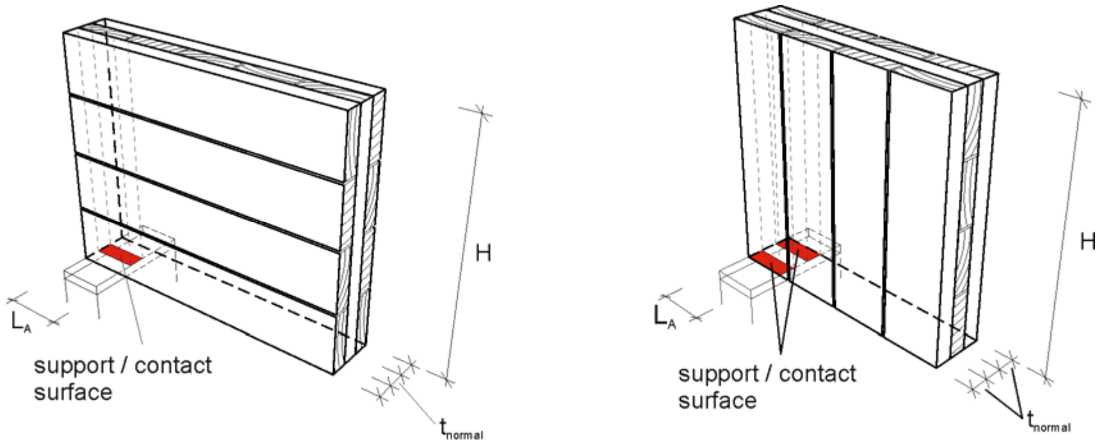

Figure 10: Bearing width and contact area

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The contact areas of two KLH® - CLT members in direct contact at their edges are the end grain to end grain contact areas only. If a rigid load distribution plate is placed between the two solid wood slabs, the full end grain contact areas of both solid wood slabs, i.e. $A_{net,\,x}$ or $A_{net,\,y}$, can be taken.

3.6 Compression perpendicular to the grain

The following expression shall be satisfied:

$\sigma_{c,\,90,\,d} \leq f_{c,\,90,\,d} \cdot k_{c,\,90}$

$\sigma_{c,\,90,\,d}$ may be determined with $A_{c,\,90}$ and $k_{c,\,90}$ should be taken to

$k_{c,\,90} = 2.2$ .... for support or load introduction at the end of the member

$k_{c,\,90} = 3.0$ .... for contact areas with very small rotations, e.g. internal supports of continuous slabs with constant spans

The determination of the contact areas $A_{c,\,90}$ shall take into account:

$A_{c,\,90}$ is the contact surface of KLH® - CLT to timber, steel, or concrete. In the case of contact to the edge of a KLH® - CLT, e.g. contact from wall to floor, $A_{c,\,90}$ should be calculated with the effective width, $b_{eff,\,x}$ or $b_{eff,\,y}$, to $A_{eff,\,x}$ or $A_{eff,\,y}$, see Figure 11. For verification the complete contact area may be taken into account, assuming a uniform stress distribution. Rotations of the members at the contact area may be neglected.

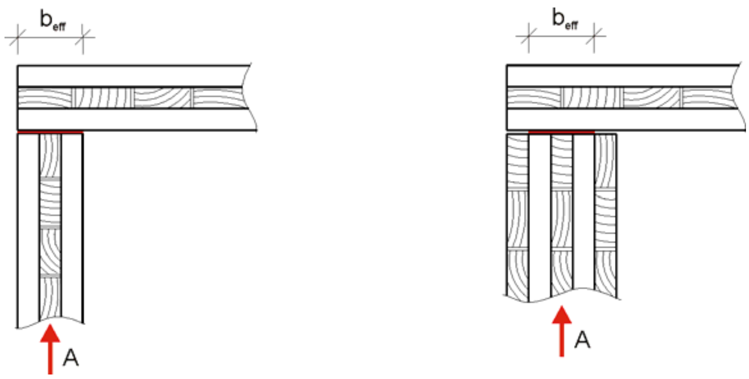

Figure 11: Effective bearing width for determination of contact area

3.7 Compression at an angle to the grain

The design compressive strength $f_{c,\,\alpha,\,d}$ at an angle α to the grain shall be determined in accordance with EN 1995-1-1.

The angle to the grain is to be considered in determining the contact areas. For a wide angle α, the cross layers may be taken into account. Thereby it shall be verified that the load can be uniformly transferred.

3.8 Bending perpendicular to the plane of the solid wood slab

Shear deformation shall be considered in determining bending stresses. The following expression shall be satisfied:

$\sigma_{m,d} \leq f_{m,d} \cdot k_{sys}$

In a simplified stress analysis for members with a slenderness ratio $\frac{L}{h} > 10$, and by neglecting shear deformations, the design stresses shall not exceed a percentage η_M of the design strength.

$\eta_M \leq 90$ % .... within in the span

$\eta_M \leq 70$ % .... close to supports and concentrated loads

More accurate methods for the determination of stresses take into account the shear deformation and are e.g.: Finite-Element-Analysis, the shear-analogy-method, or other specific correction methods.

Superposition of bending stresses resulting from bending in both structural directions is not required, since in both structural directions different layers are stressed. Twisting moments, m_{xy}, resulting from two-dimensional analysis need not to be verified.

3.9 Bending in plane of the solid wood slab

The technical bending theory may be applied to beams with a slenderness ratio of $\frac{L}{h} \geq 4$.

The following expression shall be satisfied:

$\sigma_{m,d} \leq f_{m,d} \cdot k_{sys}$

$\sigma_{m,d}$ may be determined by application of $W_{net,z,x}$ or $W_{net,z,y}$.

$W_{net,z,x}$, $W_{net,z,y}$......... section modulus of the layers in the structural direction parallel to the span

Superposition of bending stresses resulting from bending in both structural directions is not required, since in both structural directions different layers are stressed.

3.10 Superposition of normal stresses

Normal stresses in the same layer and of the same structural direction resulting from different actions shall be added for verification, see Figure 7.

3.11 Shear perpendicular to the plane of the solid wood slab

The crack factor k_{cr} according to EN 1995-1-1 is to be taken equal to unity. The following expression shall be satisfied:

$\tau_{v,d} \leq f_{v,R,d} \cdot k_v$

$f_{v,R,d}$............... design rolling shear strength

k_v .... factor taking into account notches or areas with similar failure modes, see Annex 4, Clause 3.12

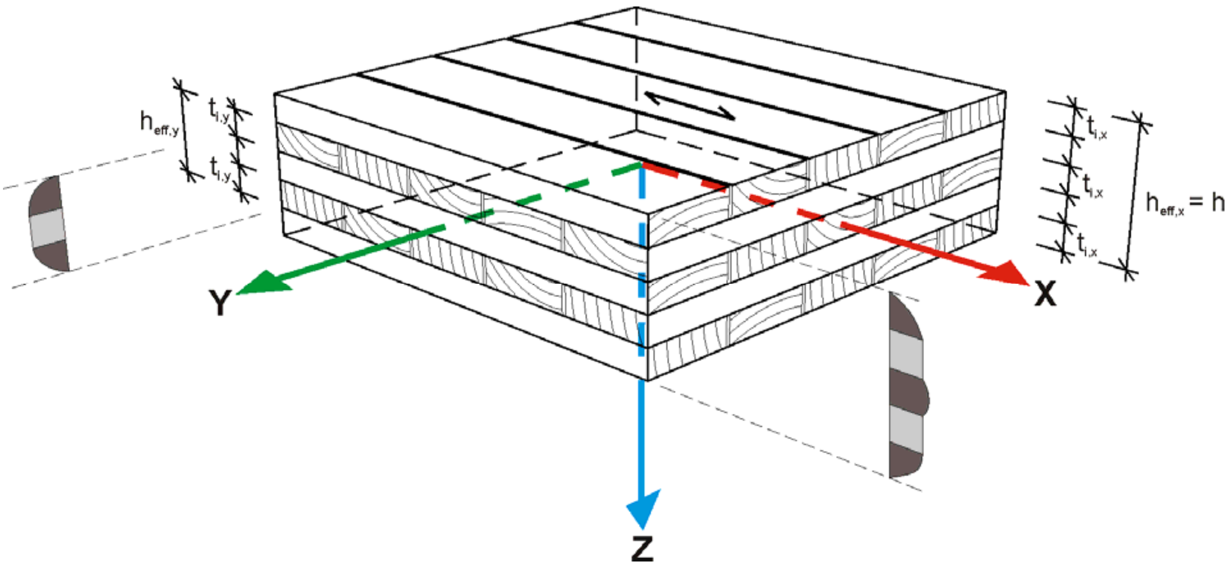

Figure 12: Shear stresses resulting from actions perpendicular to the plane of the solid wood slab

Figure 13: Effective height for calculation of shear stresses

Shear stresses can be determined by application of I_{net} and S_{net}, not taking into account shear deformation. In general, layers with orientation perpendicular to the structural direction concerned, rolling shear strength $f_{v, R}$, are governing.

NOTE If the effective cross section, h_{eff}, comprises only one layer, the shear strength f_v according to Table 3 is applicable.

The design shear stress is calculated with

$$\tau_{v, d} = \frac{V_d \cdot S_{net}}{I_{net} \cdot b}$$

Where

S_{net}................static moment of the respective part of the net cross section

I_{net} ....moment of inertia of the net cross section

S_{net} and I_{net} are calculated by disregarding the layers perpendicular to the structural direction concerned, i.e. $E_{90, mean}$ = 0 MPa

3.12 Shear perpendicular to the plane of the solid wood slab – Notches

To take account for notches or support details similar to notches, e.g. edges subjected to shear forces at a partly unsupported edge, the effective cross section $h_{eff, red}$ shall be determined according to Figure 14 and Figure 15. The notch factor k_v shall be determined according to EN 1995-1-1, with $k_n = 4.7$ for KLH® - CLT. The notch inclination i shall be taken to zero in any case.

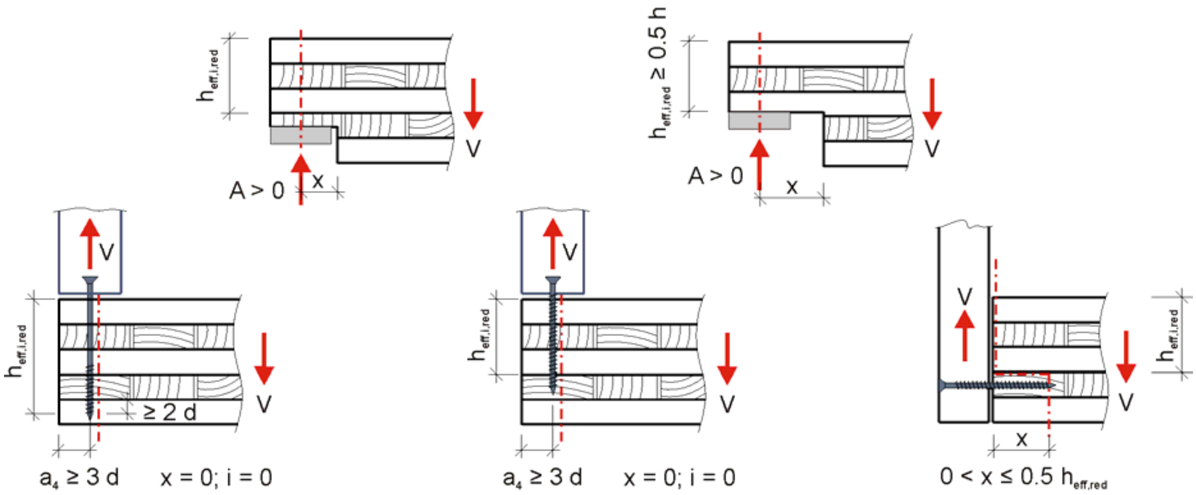

Figure 14: Reduced height, h_{eff}, to account for notches

Examples of typical notches, including notches from connections with fasteners, are given in Figure 14. In connections with wood screws, the width of the cross section shall be taken as the centre spacing of the screws, however not large than $h_{eff, i, red}$.

Edges which are supported only in part shall be considered by a notch.

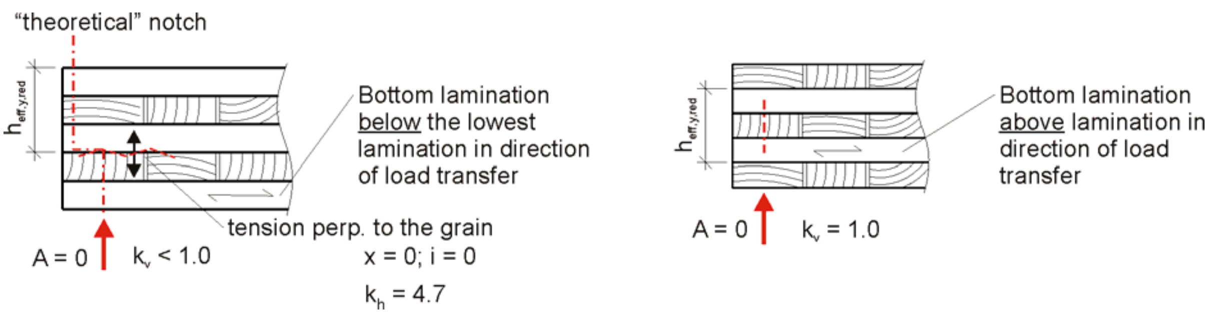

Figure 15: Left – partly supported edge – edge perpendicular to the cover layers
Right – partly supported edge – edge parallel to the cover layers

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Shear forces of unsupported edges close to point supports may be determined in a distance e, see Annex 3, Clause 3.13, away from the support.

In reinforcements perpendicular to the grain, e.g. by fully threaded self tapping screws, the total shear force is to be covered by the reinforcement elements. The screws shall extend down to layers below $h_{eff, red}$, with a minimum pointside penetration in the layer of $2 \cdot d$. The part of the cross section between the point of the screw and the surface of the solid wood slab shall be verified as a notch.

Where

d .... nominal diameter of the wood screw

3.13 Shear perpendicular to the plane of the solid wood slab – Point supports

For solid wood slabs stressed in both structural directions, different stiffness for these two directions shall be considered.

Point supports and linear supports may be modelled as points and lines. This inherent gives close to that point or line distorted results. For shear stress verification the stresses in a distance of $e = 0{,}5 \cdot h$ away from the edge of the supporting member may be applied, see Figure 16. A uniform distribution of shear stresses may be assumed in each cross section. The total reaction force at the support may be distributed proportional to the shear areas in the two structural directions, see Figure 17.

Reductions in the cross sectional area, e.g. holes, or drill holes, shall be taken into account if they are within the distance e, see Figure 16.

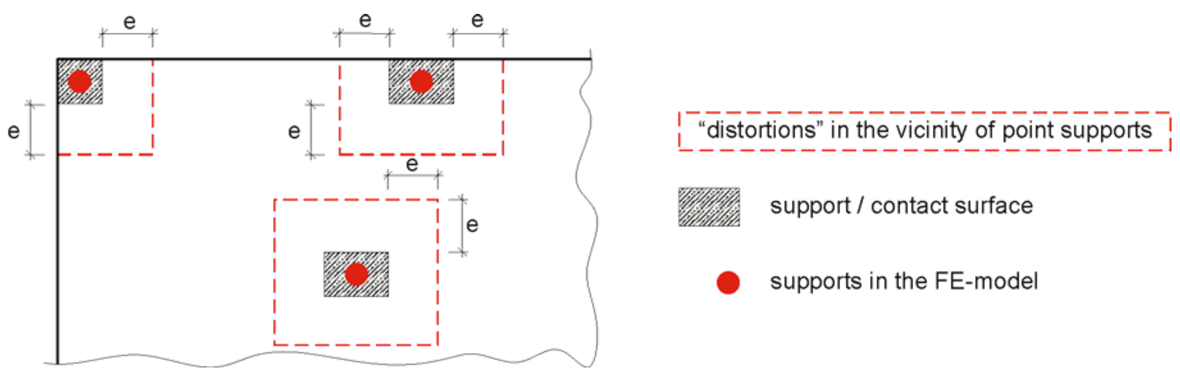


Figure 16: Relevant cross section for calculation of shear stresses close to point supports or concentrated loads

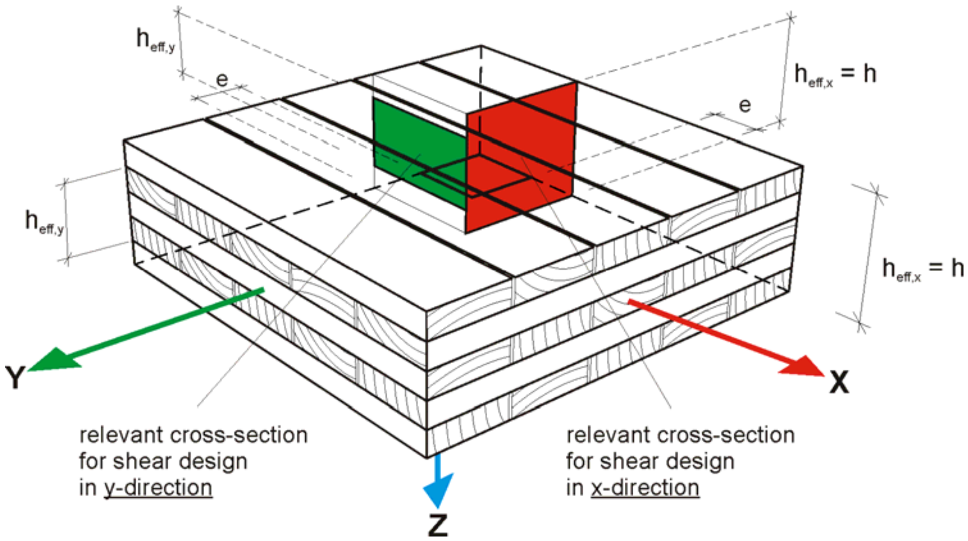


Figure 17: Relevant cross sections for shear stress verification – example of a point support at a corner

3.14 Shear in plane of the solid wood slab

Shear forces in plane of the solid wood slab are to be transferred to a large extent in the contact areas between the crosswise arranged layers. These glue lines are parallel to the direction of the force and hence a reduction of the shear force is not to be applied, i.e. the full shear force has to be taken for verification.

3.14.1 Slabs with general loading situation – verification of shear flow

For in plane shear forces without distinctive loading direction the following expression shall be satisfied:

$t_{v,d} \leq f_{v,K,d}$

The design shear flow $t_{v,d}$ may be determined by application of L_K.

$$t_{v,d} = \frac{n_{xy,d} \cdot 1}{L_K}$$

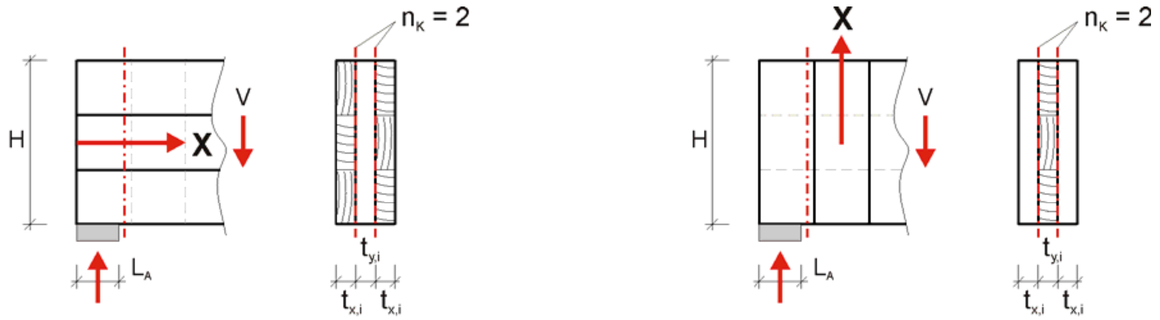
L_K .... total glue line length between adjacent, crosswise arranged layers, where $L_K = n_K \cdot H$

H .... design-relevant member height in mm

$n_{xy,d}$ .... design shear force per unit of length resulting from e.g. an Finite-Element-Analysis

n_K .... number of gluelines between adjacent, crosswise arranged layers in the respective cross section

Normally H is to be taken to unity and $t_{v,d} = \frac{n_{xy,d}}{n_K}$ applies.



Finite Element Analysis:
- Verification in a section at the edge of the support
- In general, results of an FEA refer to 1 m unit length (H = 1.00 m)

Figure 18: Verification of shear forces in plane of the solid wood slab – shear flow

NOTE Design shear forces, as a result of a Finite-Element-Analysis, are related to a specific unit of length, e.g. kN/m, so H shall be in relation to this length.

3.14.2 Solid wood slabs as beam – verification of shear stress

Members or parts of members with a distinctive loading direction, even for $\frac{L}{H} < 4$, may be verified by shear stress analysis. A distinctive loading direction can be assumed, if the layers perpendicular to this direction are nearly unloaded or if their main purpose is the coupling of the adjacent layers. This is applicable for most beam like members, e.g. lintels above doors and windows, or columns between windows.

The following expression shall be satisfied:

$$\tau_{v,d} \leq f_{v,d}$$

The design shear stress $\tau_{v,d}$ may be determined by application of $A_{net,x}$ or $A_{net,y}$.

$$\tau_{v,d} = \begin{cases} \dfrac{n_{xy,d} \cdot 1}{A_{net,x}} \\ \text{or} \\ \dfrac{n_{xy,d} \cdot 1}{A_{net,y}} \end{cases}$$

Where

$A_{net,x}$, $A_{net,y}$ .... cross sectional area of the layers parallel to the concerned structural direction, without cross layers

$f_{v,d}$.................. design value of shear strength parallel to the concerned structural direction, depending on the thickness of the layer

Table 5: Characteristic values of shear strength – shear in plane of the slab

Thickness of layer t	mm	19 [2)]	20	30	40	45
Characteristic value of shear strength $f_{v,k}$ [1)]	MPa	8.4 [2)]	8.2	6.2	4.6	3.9

[1)] Interim values may be calculated by linear interpolation.

[2)] Shear strength values > 8.4 MPa are not applicable, e.g. for laminations with t < 19 mm

The characteristic values of shear strength according to Table 5 may be increased by 25 % for inner layers. When cover layers and inner layers are stressed simultaneously, 25 % higher shear forces shall be assigned to the inner layers. In cover layers with a thickness greater than 45 mm, a maximum thickness of 45 mm shall be taken for stress calculation.

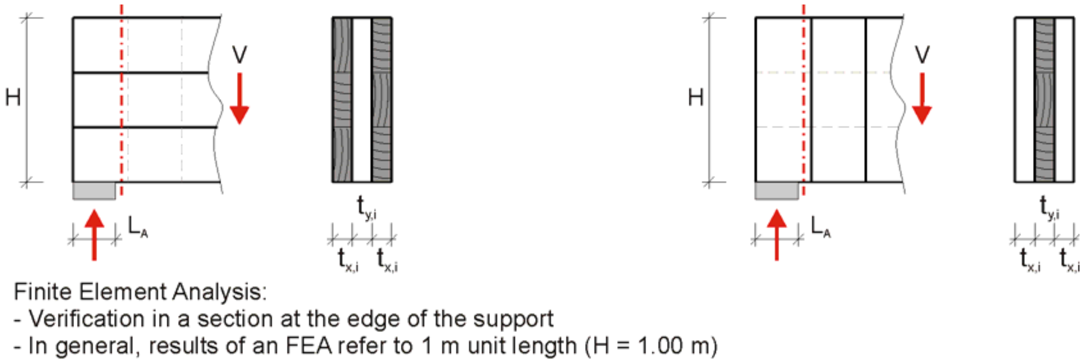


Figure 19: Verification of shear in plane of the slab – shear stress

3.14.3 Simplified verification for beams

Members or parts of members with a distinctive loading direction and with $\frac{L}{H} \geq 4$ and a height of $H \leq 800$ mm may be verified by applying the technical beam theory. The cross section may be calculated with the layers parallel to this direction, disregarding the joints between the single boards and longitudinal cut boards. In the case of a rectangular cross section, the shear stresses may be calculated according to the following equation.

$$\tau_{v,d} = \begin{cases} \dfrac{1.5 \cdot V_d}{A_{net,x}} \\ \text{or} \\ \dfrac{1.5 \cdot V_d}{A_{net,y}} \end{cases}$$

Where

V_d.................. design shear force

$A_{net,x}$, $A_{net,y}$ .... cross sectional area of the layers parallel to the concerned structural direction, without cross layers

3.15 Combined shear stresses

Shear stresses resulting from actions in plane of the solid wood panel and perpendicular to the solid wood slab shall be combined by linear superposition, as these stresses are effective in the glue lines between the layers.

4 Structural fire design

4.1 Performance R – load bearing capacity

Structural fire design of KLH® - CLT shall be by applying the charring depth and the reduced strength and stiffness parameters for the part of the cross section which is influenced by elevated temperatures. For verification, a method with reduced cross sections considering the structure of KLH® - CLT shall be applied according to EN 1995-1-2. Strength and stiffness parameters for the part of the cross section which is influenced by elevated temperatures can be either taken from Annex B of EN 1995-1-2, by application of test results or by analogy to e.g. glued laminated timber.

The temperature profiles, 300 °C isotherm, and depths of elevated temperatures within the cross section are given in Table 6.

NOTE For members or parts of members subjected to compression, a non-linear relationship, elastic-plastic, may be applied. It can be assumed, that tensile stresses in sections with a temperature > 200 °C lead to local failure and the stresses are redistributed to sections with temperatures ≤ 200 °C.

Where

d_{char} .... charring depth; distance between the outer surface of the original member and the 300 °C isotherm

β_i .... charring rate of the considered layer i in mm/min

d_{Start} .... initial value for the determination of the 300 °C isotherm, char line

T_{Start} .... time corresponding to d_{Start}

T_i .... time of fire exposure of the considered layer

T_{ges} .... total time of fire exposure

α .... inclination of the member with respect to the horizontal, $0° \leq \alpha \leq 90°$

$$T_{ges} = T_{Start} + \Sigma\, T_i$$

$$d_{char} = d_{Start} + \Sigma\, (T_i \cdot \beta_i)$$

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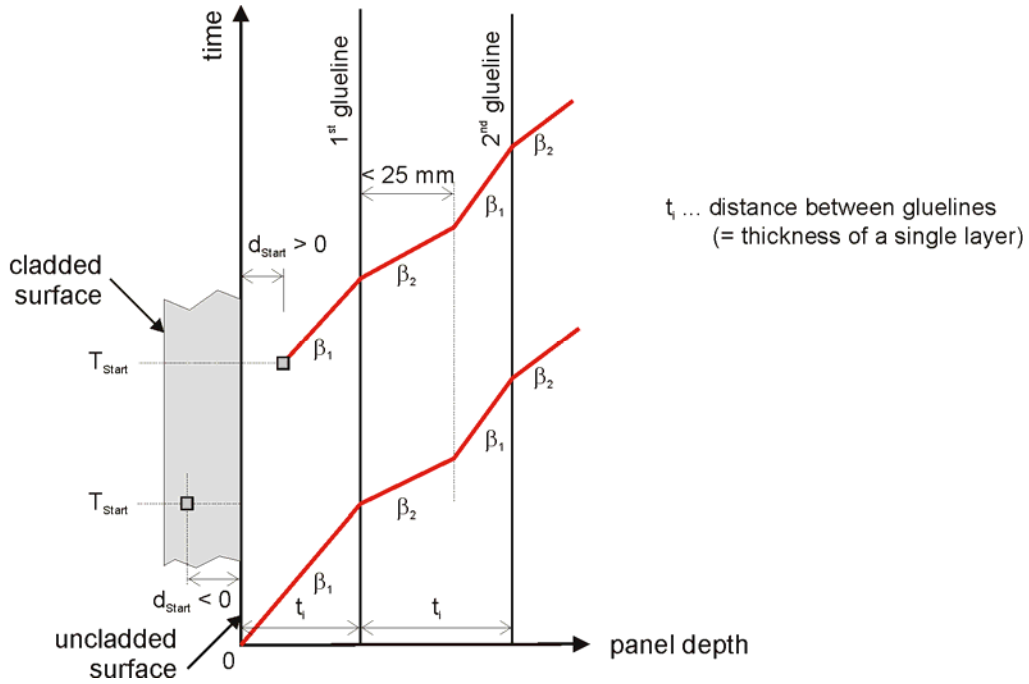

Figure 20: Charring behaviour with and without cladding

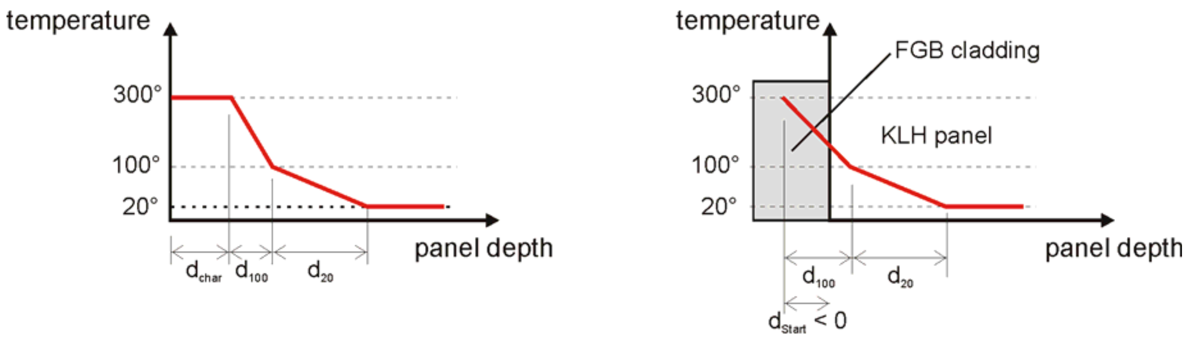

Figure 21: Temperature profiles for non cladded and cladded KLH® - CLT

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4.1.1 Parameters for structural fire design

Table 6 is applicable for fire exposure up of 120 minutes for cladded KLH® - CLT. For non cladded KLH® - CLT the time of fire exposure may exceed 120 minutes.

Table 6: Charring rates and depth of elevated temperatures for KLH® - CLT

Inclination α	Cladding System KLH	d_{Start} 1)		β_1 2), 1)	β_2 3), 1)	d_{100}	d_{20}	T_{Start}	Time of exposure
		mm		mm/min	mm/min	mm	mm	min	min
α > 75 °	none	0		0.55 / 0.65	0.80 / 0.90	15	25	0	T > 0
	1 x 12,5 FGB/GF 4)	-3	4	0.55 / 0.65	0.80 / 0.90	25	25	30	T = 30
		15	22			15	25	60	T ≥ 60
	1 × 15 FGB/GF 4)	-12	-6			25	25	30	T = 30
		11	16			15	25	60	T ≥ 60
	2 × 15 FGB/GF 4)	-35	-25			25	35	30	T = 30
		-15	-10			25	35	60	T = 60
		0	5			25	35	90	T = 90
		8	13			25	35	120	T = 120
	2 × 18 FGB/GF 4)	-30	-25			25	35	30	T = 30
		-20	-15			25	35	60	T = 60
		-10	-5			25	35	90	T = 90
		5	10			25	35	120	T = 120
	VS70 with 1 x 15 FGB/GF 4)	-25	-19			20	35	30	T = 30
		0	6			20	30	60	T = 60
		17	23			15	25	90	T ≥ 90
α ≤ 75 °	none	0		0.65 / 0.75	1.00 / 1.10	15	25	0	T > 0
	1 × 15 FGB/GF 4)	-12	-6	0.65 / 0.75 5)	1.00 / 1.10	25	25	30	T = 30
		30	34			15	25	60	T ≥ 60

1) 1st value = global, mean value – 2nd value = local, increased value for a solid wood slabs with width b < 300 mm
2) regular charring rate within one single layer
3) increased charring rate after the failure / drop off of one layer
4) Fireproof Gypsum Board or gypsum fibre boards with a density ≥ 1 000 kg/m³
5) Following the initial value T_0 the charring rate a_2 shall be applied until the next glue line is reached

For KLH® - CLT with fire exposure on both sides, the temperature profiles may be determined independently for each side. The temperatures shall be added where temperature profiles are overlapping with temperatures above 20 °C.

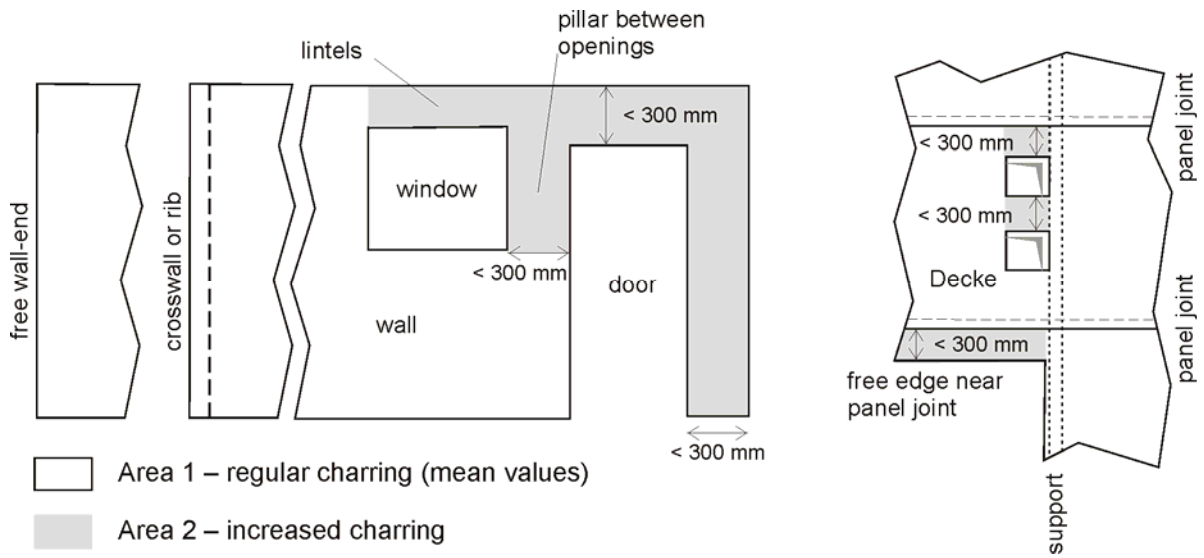

Figure 22: Definition of regions for application of regular and increased charring rates

4.1.2 Local charring at corners, grooves, etc.

The depth of the 300 °C isotherme may be assumed according to Figure 23. Grooves with a cross section ≤ (20 / 20) mm may be disregarded. Grooves smaller than 80 mm shall be considered as shown in Figure 23.

To account for the increased charring at edges, the charring rate at the edges of solid wood slabs shall be taken to 1,5 times the rate at the face.

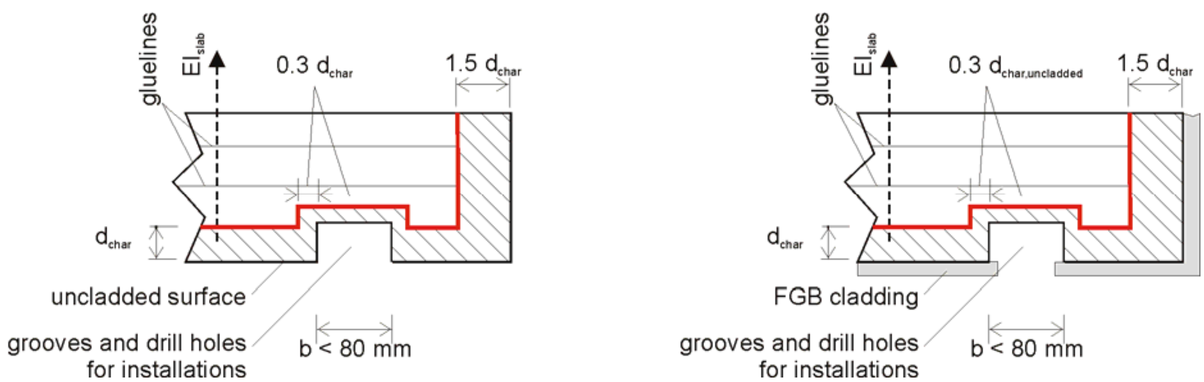

Figure 23: Charring at a groove and at an edge of a wall

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Structural fire design	of European Technical Assessment ETA-06/0138

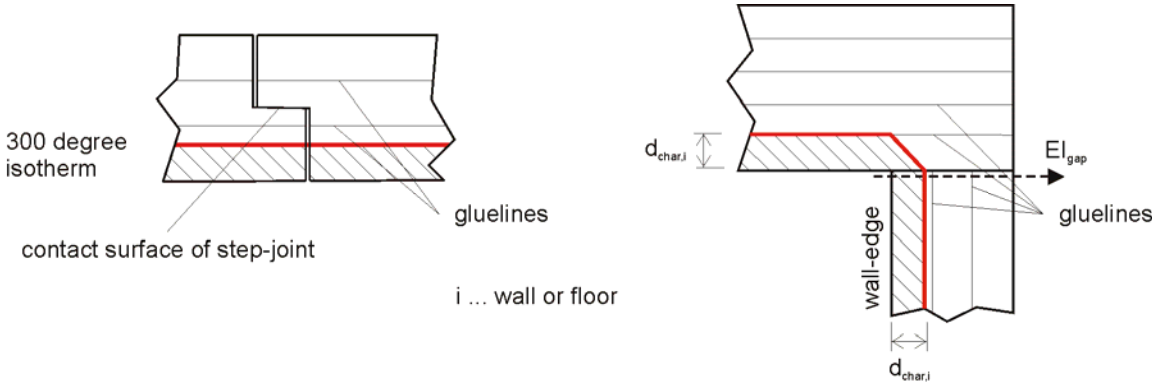


Figure 24: Charring behaviour in the vicinity of a step-joint or an inside corner

4.1.3 Connections

The capacity of connections may be assumed as unchanged if the complete fastener is exposed to temperatures < 200 °C. Edge distances are measured from the char line if the forces are parallel to the char line. Forces perpendicular to the char line relate to the 200 °C isotherm as the edge of the member.

4.2 Performances E and I – integrity and insulation

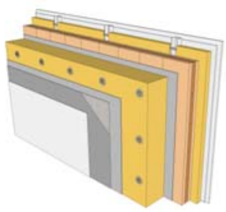
The performances E and I, penetration of hot gases through the member and limited temperatures on the unexposed side, may be regarded as acceptable under the following conditions:

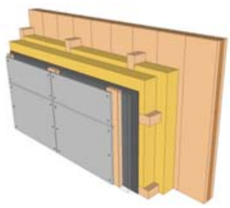
- The residual cross section comprises at least one cover layer and one glue line and
- the distance between glue line and 300 °C isotherm is greater than 15 mm.

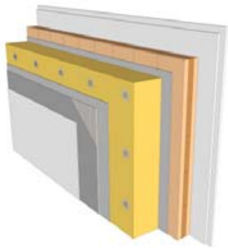
The use of sealing tapes is not required if the following is fulfilled:

- The surface temperature on the unexposed side is determined with the above given temperature profiles and does not exceed 120 °C.
- This is also applicable to butt-joints in corners of two solid wood slabs, if the maximum centre spacing of the screws is 250 mm.
- The temperature in the contact surface of step joints, with the contact surfaces parallel to the face of the solid wood slab, shall be not exceed 150 °C. The step joint shall be connected with wood screws with a maximum centre spacing of 250 mm.

Examples for airborne and impact sound insulation

№	Wall elements		
KLH12.04	158 mm	5s KLH® - CLT, 470 kg/m³	**$R_w(C; C_{tr})$ = 41 (-1; -4) dB** 
KLH12.03	128 mm	5s KLH® - CLT, 470 kg/m³	**$R_w(C; C_{tr})$ = 37 (-1; -3) dB** 
KLH12.02	94 mm	3s KLH® - CLT, 470 kg/m³	**$R_w(C; C_{tr})$ = 36 (-1; -3) dB** 
KLH12.01	72 mm	3s KLH® - CLT, 470 kg/m³	**$R_w(C; C_{tr})$ = 32 (-1; -3) dB** 
AW15.01	12.5 mm 50 mm 94 mm 3 mm 200 mm 6 mm 2 mm	Gypsum plasterboard, 680 kg/m³ Light weight C-profiles mounted on connectors including 40 mm mineral wool, 15 kg/m³ 3s KLH® - CLT, 470 kg/m³ Adhesive mortar / compensation layer Stone wool rendering panel, 110 kg/m³ Rendering including glass fiber reinforcement Finishing coat	**$R_w(C; C_{tr})$ = 46 (-5; -12) dB** 

№	Wall elements		
AW14.07a	6 mm 100 mm 94 mm 120 mm 8 mm	Clay rendering Wood fiber board, 140 kg/m³ 3s KLH® - CLT, 470 kg/m³ Wood fiber board, 140 kg/m³ Rendering system	**$R_w(C; C_{tr})$ = 45 (-3; -8) dB** 
AW14.05	94 mm 100 mm 100 mm 30 mm 12 mm	3s KLH® - CLT, 470 kg/m³ Wooden battens, horizontal, 470 kg/m³ including 100 mm stone wool rendering panel, 115 kg/m³ Wooden battens, vertical, 470 kg/m³ including 100 mm stone wool rendering panel, 115 kg/m³ PE-foil Wooden battens, vertical, 470 kg/m³ Cement bonded particle board, 1350 kg/m³	**$R_w(C; C_{tr})$ = 53 (-2; -7) dB** 
AW14.01	94 mm 3 mm 200 mm 5 mm 2 mm	3s KLH® - CLT, 470 kg/m³ Adhesive mortar / compensation layer Thermal insulation of hemp, 100 kg/m³ Adhesive mortar / compensation layer including glass fiber reinforcement Finishing coat	**$R_w(C; C_{tr})$ = 54 (-2; -7) dB** 
AW13.04	10 mm 94 mm 100 mm 100 mm 30 mm 19 mm	Gypsum plasterboard, 680 kg/m³ 3s KLH® - CLT, 470 kg/m³ Wooden battens, vertical, 470 kg/m³ including 100 mm stone wool clamping plate, 30 kg/m³ Wooden battens, horizontal, 470 kg/m³ including 100 mm stone wool clamping plate, 30 kg/m³ PE-foil Wooden battens, vertical, 470 kg/m³ Shuttering, 500 kg/m³	**$R_w(C; C_{tr})$ = 44 (-1; -5) dB** 
AW12.05	25 mm 50 mm 35 mm 94 mm 280 mm 3 mm 3 mm	2 x Gypsum plasterboard, 680 kg/m³ Acoustical mounting including 50 mm mineral wool, 25 kg/m³ Air layer 3s KLH® - CLT, 470 kg/m³ Adhesive mortar / compensation layer EPS, 25 kg/m³ Adhesive mortar / compensation layer including glass fiber reinforcement Finishing coat	**$R_w(C; C_{tr})$ = 57 (-4; -10) dB** 

№	**Wall elements**		
AW12.01	94 mm 100 mm 100 mm 30 mm 30 mm 30 mm	3s KLH® - CLT, 470 kg/m^3 Wooden battens, vertical, 470 kg/m^3 including 100 mm stone wool clamping plate, 30 kg/m^3 Wooden battens, horizontal, 470 kg/m^3 including 100 mm stone wool clamping plate, 30 kg/m^3 PE-foil Wooden battens, vertical, 470 kg/m^3 Wooden battens, horizontal, 470 kg/m^3 Shuttering, 470 kg/m^3	**$R_w(C; C_{tr})$ = 46 (-1; -5) dB** 
AW11.01	25 mm 94 mm 3 mm 180 mm 4 mm 3.5 mm 1.5 mm	2 x Gypsum plasterboard, 900 kg/m^3 3s KLH® - CLT, 470 kg/m^3 Adhesive mortar / compensation layer Stone wool rendering panel, 110 kg/m^3 Adhesive mortar / compensation layer Rendering including glass fiber reinforcement Finishing coat	**$R_w(C; C_{tr})$ = 43 (-3; -8) dB** 
IW12.03	94 mm 25 mm	3s KLH® - CLT, 470 kg/m^3 2 x Gypsum plasterboard, 680 kg/m^3	**$R_w(C; C_{tr})$ = 39 (-1; -4) dB** 
IW12.02	94 mm 12.5 mm	3s KLH® - CLT, 470 kg/m^3 Gypsum plasterboard, 680 kg/m^3	**$R_w(C; C_{tr})$ = 37 (-1; -3) dB** 
TW15.01	94 mm 50 mm 12.5 mm	3s KLH® - CLT, 470 kg/m^3 Light weight C-profiles mounted on connectors including 40 mm mineral wool, 15 kg/m^3 Gypsum plasterboard, 680 kg/m^3	**$R_w(C; C_{tr})$ = 47 (-3; -8) dB** 

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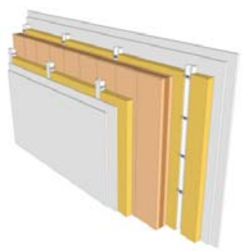
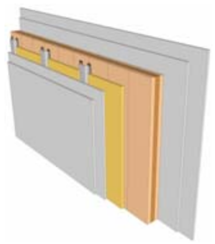
№	**Wall elements**		
TW14.03a	94 mm 20 mm 6 mm	3s KLH® - CLT, 470 kg/m³ Wood fiber board, 110 kg/m³ Clay finish	**$R_w(C; C_{tr})$ = 43 (-3; -8) dB** 
TW14.01	25 mm 50 mm 94 mm 50 mm 25 mm	2 x Gypsum plasterboard, 1000 kg/m³ Acoustical mounting including 40 mm glass wool, 15 kg/m³ 3s KLH® - CLT, 470 kg/m³ Acoustical mounting including 40 mm glass wool, 15 kg/m³ 2 x Gypsum plasterboard, 1000 kg/m³	**$R_w(C; C_{tr})$ = 67 (-7; -15) dB** 
TW13.14	23 mm 27 mm 94 mm 27 mm 23 mm	Quartz sand panel, 1200 kg/m³ Acoustical mounting including 15 mm mineral wool, 110 kg/m³ 3s KLH® - CLT, 470 kg/m³ Acoustical mounting including 15 mm mineral wool, 110 kg/m³ Quartz sand panel, 1200 kg/m³	**$R_w(C; C_{tr})$ = 64 (-8; -17) dB** 
TW13.10	30 mm 94 mm 20 mm 30 mm	2 x Gypsum fiberboard, 1150 kg/m³ 3s KLH® - CLT, 470 kg/m³ Acoustical mounting including 20 mm glass wool, 40 kg/m³ 2 x Gypsum fiberboard, 1150 kg/m³	**$R_w(C; C_{tr})$ = 57 (-3; -9) dB** 
TW13.09	94 mm 20 mm 25 mm	3s KLH® - CLT, 470 kg/m³ Acoustical mounting including 20 mm glass wool, 40 kg/m³ 2 x Gypsum plasterboard, 900 kg/m³	**$R_w(C; C_{tr})$ = 50 (-3; -10) dB** 

KLH® - CLT	**Annex 6** Page 4 of 8
Protection against noise	of European Technical Assessment ETA-06/0138

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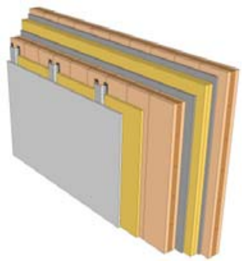
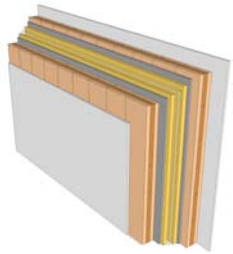
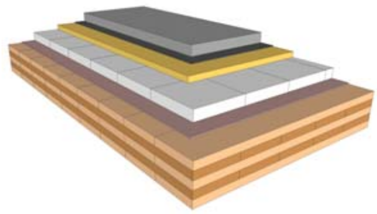
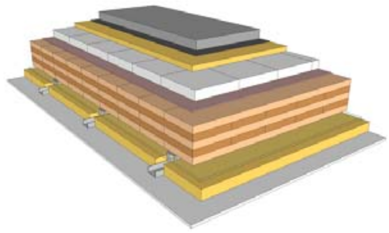
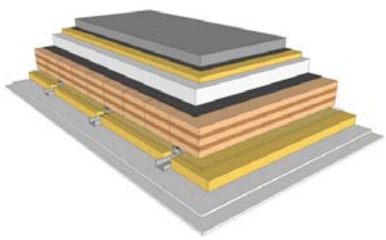
№	Wall elements		
TW12.06	25 mm 50 mm 35 mm 94 mm 35 mm 50 mm 25 mm	2 x Gypsum plasterboard, 680 kg/m³ Lightweight C-profiles including 50 mm stone wool, 22 kg/m³ Air layer 3s KLH® - CLT, 470 kg/m³ Air layer Lightweight C-profiles including 50 mm stone wool, 22 kg/m³ 2 x Gypsum plasterboard, 680 kg/m³	**$R_w(C; C_{tr})$ = 71 (-7; -14) dB** 
TW12.02	94 mm 35 mm 50 mm 25 mm	3s KLH® - CLT, 470 kg/m³ Air layer Lightweight C-profiles including 50 mm stone wool, 22 kg/m³ 2 x Gypsum plasterboard, 680 kg/m³	**$R_w(C; C_{tr})$ = 61 (-3; -9) dB** 
WTW16.05	12.5 mm 20 mm 94 mm 15 mm 30 mm 30 mm 15 mm 94 mm	Gypsum fiberboard, 1150 kg/m³ Acoustical mounting including 15 mm mineral wool, 110 kg/m³ 3s KLH® - CLT, 470 kg/m³ Cement.bonded sandwich panel, 1000 kg/m³ Fleece laminated glass wool, 40 kg/m³ Fleece laminated glass wool, 40 kg/m³ Cement.bonded sandwich panel, 1000 kg/m³ 3s KLH® - CLT, 470 kg/m³	**$R_w(C; C_{tr})$ = 64 (-5; -12) dB** 
WTW16.03	12.5 mm 94 mm 15 mm 30 mm 10 mm 30 mm 15 mm 94 mm 12.5 mm	Gypsum plasterboard, 680 kg/m³ 3s KLH® - CLT, 470 kg/m³ Cement.bonded sandwich panel, 1000 kg/m³ Fleece laminated glass wool, 40 kg/m³ Air layer Fleece laminated glass wool, 40 kg/m³ Cement.bonded sandwich panel, 1000 kg/m³ 3s KLH® - CLT, 470 kg/m³ Gypsum plasterboard, 680 kg/m³	**$R_w(C; C_{tr})$ = 65 (-2; -8) dB** 
WTW16.02	94 mm 15 mm 30 mm 30 mm 30 mm 15 mm 94 mm	3s KLH® - CLT, 470 kg/m³ Cement.bonded sandwich panel, 1000 kg/m³ Fleece laminated glass wool, 40 kg/m³ Air layer Fleece laminated glass wool, 40 kg/m³ Cement.bonded sandwich panel, 1000 kg/m³ 3s KLH® - CLT, 470 kg/m³	**$R_w(C; C_{tr})$ = 66 (-4; -8) dB** 

№	Wall elements		
TW12.01	94 mm 50 mm 10 mm 94 mm	3s KLH® - CLT, 470 kg/m³ Mineral wool, 25 kg/m³ Air layer 3s KLH® - CLT, 470 kg/m³	**$R_w(C; C_{tr})$ = 60 (-4; -8) dB** 

№	Floor elements		
GD15.02	60 mm 30 mm 50 mm 5 mm 145 mm	Cement screed, 2200 kg/m³ Separating layer Impact sound insulation board, 110 kg/m3, s' ≤ 7 MN/m³ Concrete layer, 2000 kg/m³ Acoustic layer, s' ≤ 115 MN/m³ 5s KLH® - CLT, 470 kg/m³	**$R_w(C; C_{tr})$ = 60 (-1; -3) dB** **$L_{n,w}(C_I)$ = 43 (1) dB** 
GD15.01	60 mm 30 mm 50 mm 5 mm 145 mm 60 mm 12.5 mm	Cement screed, 2200 kg/m³ Separating layer Impact sound insulation board, 110 kg/m3, s' ≤ 7 MN/m³ Concrete layer, 2000 kg/m³ Acoustic layer, s' ≤ 115 MN/m³ 5s KLH® - CLT, 470 kg/m³ Acoustical mounting including 50 mm glass wool, 15 kg/m³ Gypsum plasterboard, 1000 kg/m³	**$R_w(C; C_{tr})$ = 75 (-2; -6) dB** **$L_{n,w}(C_I)$ = 36 (5) dB** 
GD14.08	60 mm 30 mm 80 mm 145 mm 60 mm 25 mm	Cement screed, 2200 kg/m³ Separating layer Impact sound insulation board, 110 kg/m3, s' ≤ 7 MN/m³ Bonded EPS granulate, 135 kg/m³ Trickle protection 5s KLH® - CLT, 470 kg/m³ Acoustical mounting including 50 mm glass wool, 15 kg/m³ 2 x Gypsum plasterboard, 1000 kg/m³	**$R_w(C; C_{tr})$ = 74 (-3; -10) dB** **$L_{n,w}(C_I)$ = 44 (4) dB** 

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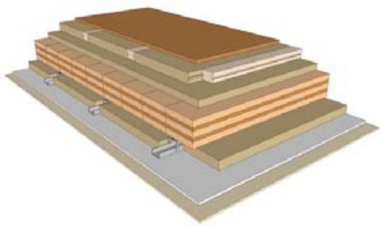
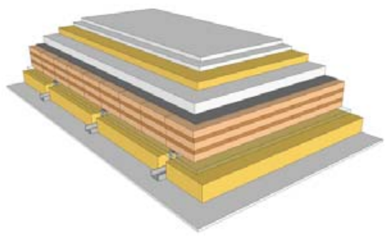
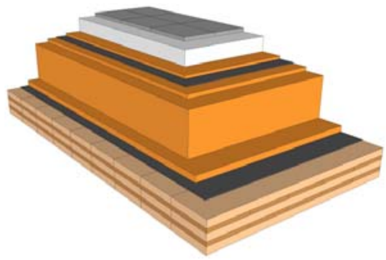
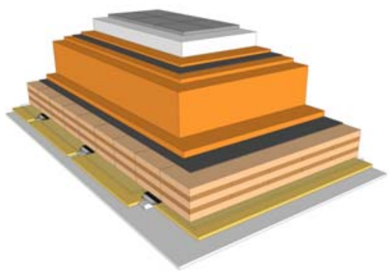
№	**Floor elements**		
GD14.05	60 mm 40 mm 60 mm 145 mm 60 mm 12.5 mm 6 mm	Wood flooring, 470 kg/m³ Wood fiber board, 140 kg/m³ Wood fiber board, 140 kg/m³ 5s KLH® - CLT, 470 kg/m³ Acoustical mounting including 50 mm wood fiber board, 50 kg/m³ Gypsum plasterboard, 1200 kg/m³ Clay finish	**$R_w(C; C_{tr})$ = 71 (-5; -13) dB** **$L_{n,w}(C_I)$ = 48 (5) dB** 
GD14.03	46 mm 40 mm 50 mm 145 mm 100 mm 12.5 mm	2 x Gypsum fibreboard dry screed element, 1250 kg/m³ Impact sound insulation board, 110 kg/m3, s' ≤ 20 MN/m³ Ballast weight, 1600 kg/m³ Separating layer 5s KLH® - CLT, 470 kg/m³ Acoustical mounting including 80 mm glass wool, 15 kg/m³ Gypsum plasterboard, 1000 kg/m³	**$R_w(C; C_{tr})$ = 70 (-3; -10) dB** **$L_{n,w}(C_I)$ = 41 (2) dB** 

№	**Roof elements**		
DT14.02	35 mm 50 mm 20 mm 20 mm 200 mm 20 mm 145 mm	Concrete layer, 2200 kg/m³ Ballast weight, 1600 kg/m³ XPS, 30 kg/m³ PE-foil Impact sound insulation board, 110 kg/m³, s' ≤ 10 MN/m³ EPS, 30 kg/m³ Wood fiber board, 110 kg/m³ PE-foil 5s KLH® - CLT, 470 kg/m³	**$R_w(C; C_{tr})$ = 55 (-2; -6) dB** **$L_{n,w}(C_I)$ = 49 (0) dB** 
DT14.01	35 mm 50 mm 20 mm 20 mm 200 mm 20 mm 145 mm 27 mm 12.5 mm	Concrete layer, 2200 kg/m³ Ballast weight, 1600 kg/m³ XPS, 30 kg/m³ PE-foil Impact sound insulation board, 110 kg/m³, s' ≤ 10 MN/m³ EPS, 30 kg/m³ Wood fiber board, 110 kg/m³ PE-foil 5s KLH® - CLT, 470 kg/m³ Acoustical mounting including 15 mm mineral wool, 110 kg/m³ Gypsum plasterboard, 680 kg/m³	**$R_w(C; C_{tr})$ = 64 (-3; -9) dB** **$L_{n,w}(C_I)$ = 45 (2) dB** 

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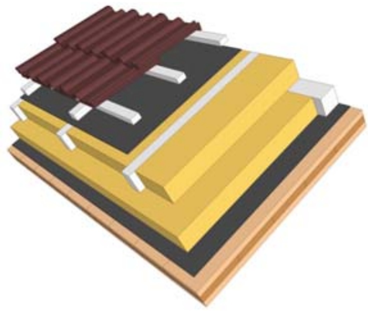
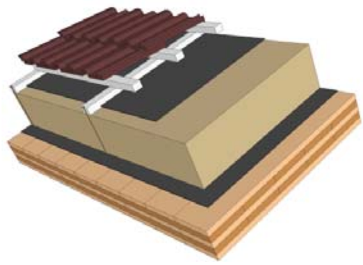
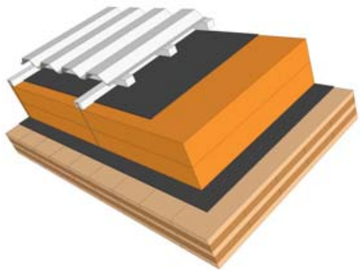
№	Roof elements		
STD12.03	 30 mm 40 mm 100 mm 100 mm 94 mm	Roof covering of roof tiles, 40 kg/m³ Wooden battens, horizontal, 470 kg/m³ Wooden battens, vertical, 470 kg/m³ PE-foil Wooden battens, vertical, 470 kg/m³ including 100 mm stone wool clamping plate, 30 kg/m³ Wooden battens, horizontal, 470 kg/m³ including 100 mm stone wool clamping plate, 30 kg/m³ PE-foil 3s KLH® - CLT, 470 kg/m³	**$R_w(C; C_{tr})$ = 53 (-1; -5) dB** 
STD12.02	 30 mm 40 mm 240 mm 158 mm	Roof covering of roof tiles, 40 kg/m³ Wooden battens, horizontal, 470 kg/m³ Wooden battens, vertical, 470 kg/m³ PE-foil Wood fiber board, 160 kg/m³ PE-foil 5s KLH® - CLT, 470 kg/m³	**$R_w(C; C_{tr})$ = 50 (-4; -11) dB** 
STD12.01	 30 mm 40 mm 240 mm 158 mm	Roof covering of corrugated sheet, 4 kg/m² Wooden battens, horizontal, 470 kg/m³ Wooden battens, vertical, 470 kg/m³ PE-foil PU insulation, 30 kg/m³ PE-foil 5s KLH® - CLT, 470 kg/m³	**$R_w(C; C_{tr})$ = 50 (-3; -8) dB** 

Fasteners

The determination of the load bearing capacities of the fasteners in KLH® - CLT shall be carried out according to EN 1995-1-1 and/or the European Technical Assessment which has been granted for the relevant fastener for softwood and/or for glued laminated timber or the wood based panel used.

Only wood screws and split ring connectors may be employed as load bearing fasteners in the edges of the solid wood slabs.

To all fasteners apply

- Only nails, wood screws, bolts, dowels and connectors according to EN 1995-1-1 and/or a European Technical Assessment may be used as fasteners, observing the following particularities.
- The edge of the solid wood slab is the edge of the member. As long as the maximum joint width according to Annex 2 is not exceeded individual joints need not to be considered.

Nails

- Nails shall have a diameter of at least 4 mm.
- The load bearing capacity of nails shall be determined according to EN 1995-1-1. Minimum spacing and distances shall be determined following the direction of grain of the surface layer.
- Smooth nails shall not be employed for axially loading. For axially loaded nails the recommendations of the ETA holder shall be observed.

Wood screws

- Laterally loaded screws shall have a nominal diameter of minimum 4 mm and a nominal diameter of minimum 8 mm if driven in the edges of the solid wood slab.
- The load bearing capacity of laterally loaded screws shall be determined according to EN 1995-1-1. The embedment strength shall be determined according to the direction of grain of the surface layer. If driven in end grain, the embedment strength shall be reduced by 50 %. Minimum spacing and distances shall be determined according to the direction of grain of the surface layer.
- Axially loaded screws shall have a minimum diameter of 4 mm. Axially loaded screws driven in end grain shall have a minimum diameter of 8 mm.
- The load bearing capacity of axially loaded screws shall be determined according to EN 1995-1-1. The load bearing capacity of screws driven in end grain shall be reduced by 25 %.

Bolts and dowels

- Bolts and dowels shall have a diameter of at least 10 mm.
- The load bearing capacity of bolts and dowels shall be determined according to EN 1995-1-1. The embedment strength shall be determined following the direction of grain of the surface layer. Minimum spacing and distances for dowels and bolts are
  - 5 · d from the loaded edge and between each other and
  - 3 · d from the unloaded edge.

  This applies regardless to the angle between the direction of force and the direction of grain.
- Self-tapping dowels shall be used only in the face of KLH® - CLT. The minimum nominal diameter should be 5 mm. The requirements of the European Technical Assessment for the fastener shall be observed.
- For connections with steel plates as the central member the direction of the nearby layers shall be taken into account.

Reference documents

EAD 130005-00-0304, European Assessment Document for “Solid wood slab element to be used as a structural element in buildings”

EN 338 (04.2016), Structural timber – Strength classes

EN 1995-1-1 (11.2004), +AC (06.2006), +A1 (06.2008), +A2 (05.2014), Eurocode 5 – Design of timber structures - Part 1-1: General – Common rules and rules for buildings

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