KLH®

MADE FOR BUILDING
BUILT FOR LIVING

FIRE DESIGN GUIDE
FOR AUSTRALIA AND NEW ZEALAND

IMPRINT

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CONTENT

01 INTRODUCTION

This brochure covers the basics of fire behaviour, fire resistance and the associated fire protection of KLH® - CLT solid wood panels. The aim is to provide the user with an overview of the relevant topics and a guideline for the associated fire protection planning.

The brochure does not replace project-related fire protection planning and structural engineering and cannot be used as untested evidence. Notes on more detailed planning and technical documentation are provided in the respective chapters.

Figure 1. KLH® - CLT wall fire test according to AS 1530.4

The information provided to the relevant fire authority should include, but may not be limited to:

- Panel layup details (including cladding and adhesive details) and method of production
- Construction method details (e.g. connections, fixings, penetrations)
- Compliance with international standards or codes if applicable (e.g. Eurocodes) without „cherry picking“ from multiple standards
- Calculations for fire endurance and containment to validate fire resistance
- Calculations for panel charring rate with consideration to AS 1720.1, AS 1720.4 and published literature
- Test information identifying that the proposed panel layup can achieve the required FRL

02 PRODUCT DESCRIPTION

The generic terminology for cross-laminated timber varies and may be country-specific. The terms include, among others, CLT or X-Lam. KLH® - CLT is a versatile building material characterised by its dimensional stability, its dimensional accuracy and its high level of prefabrication. Therefore, KLH® solid wood superstructure components are used for structural wall, floor slab and roof elements.

KLH® solid wood elements are made up of at least 3 layers of timber laminations that are typically arranged perpendicular to each other and face-bonded under high laminating pressure to form large-format structural solid wood panels.

ADHESIVES AND LAMINATION

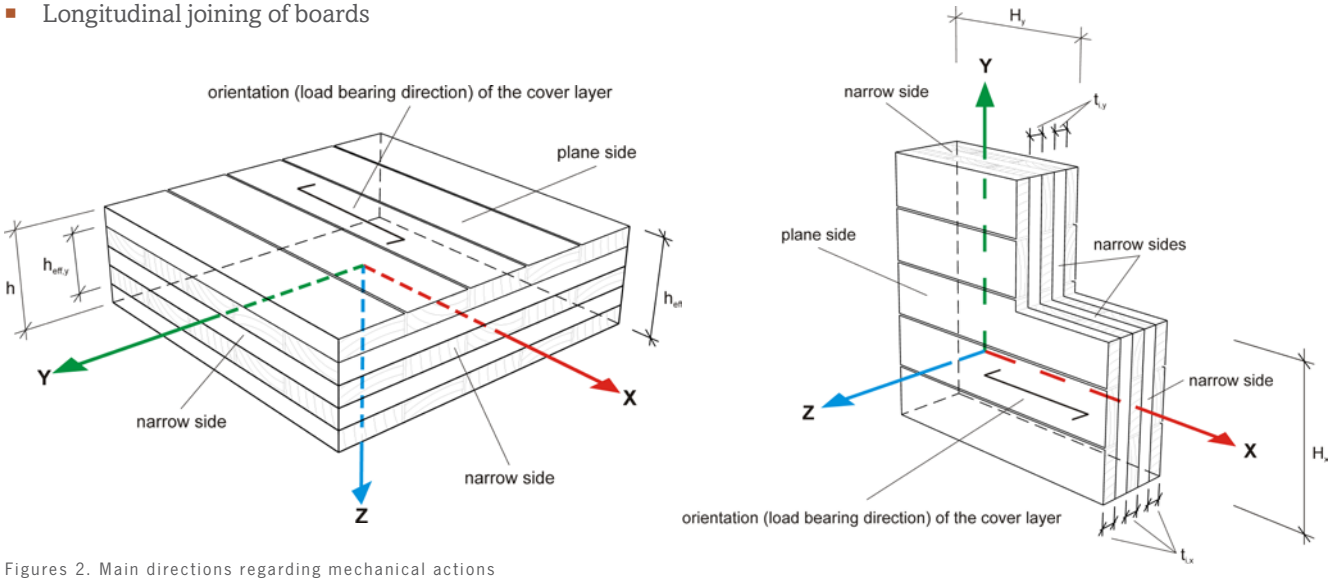
VOC-FREE AND FORMALDEHYDE-FREE PUR ADHESIVES IN ACCORDANCE WITH EN 15425

The PUR adhesives are tested and classified as Type 1 adhesives and have been approved to be suitable for use in load-bearing timber components. The adhesive is applied automatically over the entire surface at approx. 0.15 kg/m² per glue line.

The laminating pressure at 0.6 N/mm² used during the manufacture of KLH® solid wood panels is 6 times higher compared to vacuum press technology. The performance of the glue lines in KLH® - CLT is therefore of high quality and the load-bearing capacity comparatively higher.

FACTORS IMPACTING THE FIRE PERFORMANCE ARE (BUT NOT LIMITED TO):

- Wood type
- Thickness of layers
- Number of layers
- Orientation of layers
- Orientation of the panel (e.g. wall, ceiling, floor)
- Adhesive used between adjoining layers
- Fixing methods (mechanical or adhesive used between adjacent boards)
- Longitudinal joining of boards



Figures 2. Main directions regarding mechanical actions

BEHAVIOUR IN CASE OF FIRE

Structural fire design of KLH® - CLT shall be performed 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.

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 using the KLHdesigner data+ values, according to ETA-06/0138.

Figure 3. Charred surface after fire test

Figure 4. Large scale fire test with CLT

Depending on the adhesive used for face-bonding, either the step model or the linear charring model shall be applied. By default, KLH uses the step model (adhesive not fulfilling the bond line integrity of face-bonds in fire requirements). The values to be found in our KLHdesigner tool are based on that behaviour.

https://www.klhdesigner.at/en

PRODUCT DESCRIPTION

PRODUCT NAME/BRAND	KLH® - CLT
OTHER PRODUCT NAMES	Cross-laminated timber (CLT), X-Lam
APPLICATION	Structural elements for walls, floors and roofs
DURABILITY	Service classes 1 and 2 according to EN 1995-1-1
WOOD SPECIES	Spruce (pine, fir, stone pine and other wood types on request)
PANEL BUILD-UP	3, 5, 7 or more layers depending on structural requirements
LAMELLAE	Thickness 20 to 45 mm, technically dried, quality-sorted and finger-jointed
STRENGTH CLASS	C 24 according to EN 338, maximum 10% C 16 permitted (compare ETA-06/0138)
ADHESIVE	Formaldehyde-free PUR adhesive, approved for load-bearing and non-load-bearing components indoors and outdoors according to EN 15425
LAMINATING PRESSURE	At least 0.6 N/mm²
WOOD MOISTURE CONTENT	12% (+/- 2%) on delivery
MAXIMUM ELEMENT DIMENSIONS	Length 16.50 m | width 3.50 m | thickness 0.50 m
INVOICING WIDTHS	2.27 | 2.45 | 2.50 | 2.73 | 2.95 | 3.10 | 3.20 | 3.30 | 3.40 | 3.50 m
SURFACE QUALITY	Non-visual quality (NVQ) | Industrial visual quality (IVQ) Domestic visual quality (DVQ) Special surfaces on request
WEIGHT	5.5 kN/m³ according to ÖNORM B 1991-1-1:2011 for structural analysis 500 kg/m³ for determination of transport weight
MOISTURE MOVEMENT	In panel plane 0.02% per % change in wood moisture content, perpendicular to panel plane (panel thickness direction) 0.24% per % change in wood moisture content
THERMAL CONDUCTIVITY	λ = 0.12 W/(m*K) according to EN ISO 10456
HEAT STORAGE CAPACITY	c_p = 1600 J/(kg*K) according to EN ISO 10456
VAPOUR RESISTANCE	μ = 300 (dry) to 46 (wet) according to EN ISO 12572
AIR TIGHTNESS	KLH® - CLT can generally be used as airtight layers (class 4 acc. to EN 12207). Connections to other components, butt joints, penetrations, etc. must be sealed appropriately.
REACTION TO FIRE	AS 5637.1 Group Number: 3 | ASEA 21.03 m²/kg | or Euroclass D-s2, d0
RESISTANCE TO FIRE	Fire analysis parameters according to AS 1530.4:2014 | and to ETA - 06/0138

03 FIRE PERFORMANCE TESTING

Tests according to AS 1530.4:2014

REPORT	FR17704-01-1	FR17704-02-1	FR17704-03-1	FR17704-04-1
Type	Floor	Floor	Wall	Wall
Panel	5s 200 mm	5s 180 mm	5s 120 mm	5s 120 mm
Duration	132 minutes NF*	170 minutes NF*	150 minutes NF*	93 minutes NF*
Loading	3.1 kN/m²	3.1 kN/m²	26.7 kN/m²	26.7 kN/m²
Visible/cladding	Visible spruce	13 mm GIB Fyreline® plasterboard	13 mm GIB Fyreline® plasterboard	Visible spruce

*NF = no failure

To confirm KLH® - CLT fire performance for Australia and New Zealand, additional tests according to AS 1530.4:2014 requirements were carried out.

Test principles:

- Defined fire load
- Time until resistance failure
- Classification according to resistance times

All tests apply a defined fire load to a building part and measure the time until the resistance requirements fail. It is also possible that the test specimens do not fail at all, and the test will be stopped by choice.

Based on the test performance, a classification can be issued according to the measured resistance times.

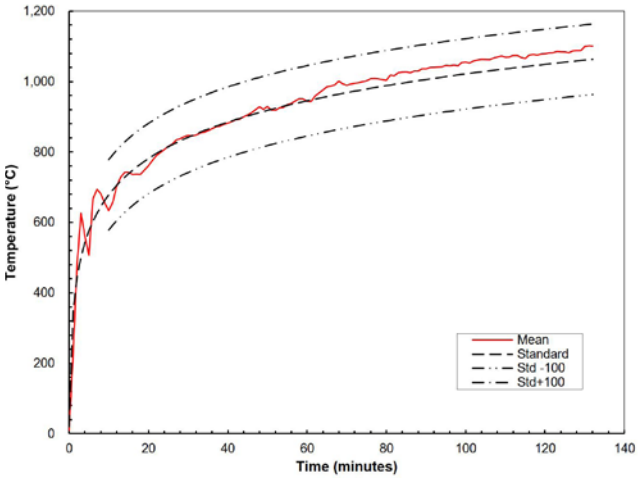


Figure 5. Furnace temperature

KLH carried out numerous fire tests all over the world. The most common standard used was EN 1365 “Fire resistance tests for load-bearing elements”.

	FR17704-01-1	FR17704-02-1	FR17704-03-1	FR17704-04-1
Structural adequacy	132 minutes NF	170 minutes NF	150 minutes NF	93 minutes NF
Integrity	132 minutes NF	170 minutes NF	150 minutes NF	93 minutes NF
Insulation	132 minutes NF	170 minutes NF	150 minutes NF	93 minutes NF

The tested specimens have achieved an FRL in accordance with AS 1530.4:2014.

FLOOR/WALL FIRE TEST KLH

Figures 6. Exposed side of test specimen prior to testing

Figures 7. Unexposed side of test specimen prior to testing

Figures 8. Exposed side of test specimen immediately after testing

04 FIRE RESISTANCE ACCORDING TO THE STANDARDS

Performance requirements of the NCC (NCC 2019 Volume One: Schedule 5 or NCC 2022 Volume One: Specification 7) and AS 1530.4

Just like AS 1530.4 determines the FRL (Fire Resistance Level), EN 13501-2 determines a similar fire resistance classification, REI (Résistance, Etanchéité and Isolation).

The NCC DTS provisions determine the FRL required for various elements within a building. These FRLs vary due to the height of the building, distance from fire sources, the inclusion of sprinklers, building use or construction material.

There may be more than one solution within the NCC DTS provisions for a particular building type and height.

KLH® - CLT WAS TESTED ACCORDING TO:

AS/NZS 3837:1998: Method of testing for heat and smoke release rates for materials and products using an oxygen calorimeter

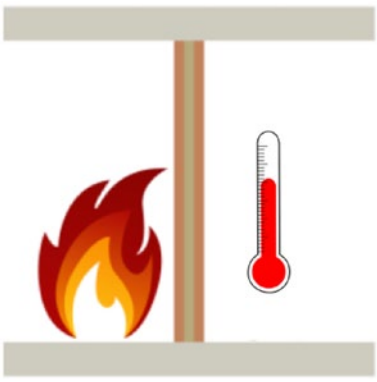
CERTIFICATION:

IGNL- 9110-07-01C I01R00 (Test Certificate)
IGNL- 9110-14-01C I01R00 (AS 5637.1 Certificate)

KLH® - CLT ACHIEVES:

AS 5637.1 Group Number: 3 I ASEA 21.03 m²/kg

FRL
FIRE RESISTANCE LEVEL

STRUCTURAL ADEQUACY	INTEGRITY	INSULATION
		
Maintain strength and serviceability at the conclusion of the FRL period	Prevent the passage of flames, smoke or hot gases through the surface or joints	Maintain an average increase in surface temperature on the non-fire side of less than 140°C and a peak increase of 180°C

05 KLH® FIRE DESIGN IN PRACTICE

According to ETA-06/0138 for KLH® - CLT:

The reaction to fire is Euroclass D-s_2, d_0.

The resistance to fire was obtained by test data, described in Annex 5 of ETA.

The reaction to fire is based on glued laminated timber products made of softwood products (CWFT decision).

The calculation of resistance follows one of two approaches according to EN 1995-1-2. The resulting charring rate is used to calculate the charring depth and the residual cross section. Then it is possible to either subtract what is known as "zero-strength layer d_0" or to reduce the remaining load-bearing capacity of the cross section according to the 300°C isotherm profile.

Advantages of KLH® - CLT in Fire Safety

KLH® - CLT's predictable fire behaviour allows for accurate design calculations.

KLH® - CLT can often be used without complex fire protection cladding in open reveals.

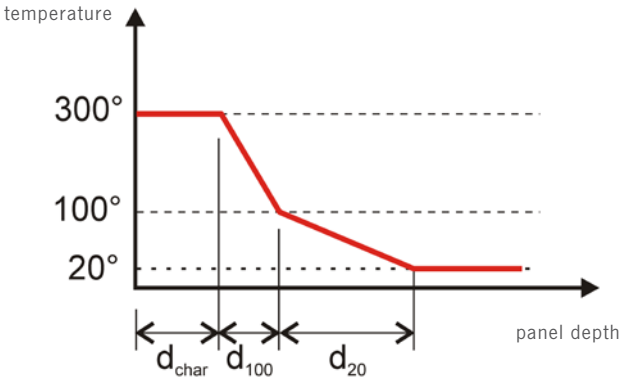


Figure 9. Temperature profile for KLH® - CLT

Inclination α	Cladding system KLH	d_{Start} mm		β_1 mm/min	β_2 mm/min
α > 75°	none	0		0.55 / 0.65	0.80 / 0.90
	1 x 12.5 GPB-F/GFB	-3	4	0.55 / 0.65	0.80 / 0.90
		15	22		
	1 x 15 GPB-F/GFB	-12	-6		
		11	16		
	2 x 15 GPB-F/GFB	-35	-25		
		-15	-10		
		0	5		
		8	13		
	2 x 18 GPB-F/GFB	-30	-25		
		-20	-15		
		-10	-5		
		5	10		
	VS70 with 1 x 15 GPB-F/GFB	-25	19		
		0	6		
		17	23		
α ≤ 75°	none	0		0.65 / 0.75	1.00 / 1.10
	1 x 15 GPB-F/GFB	-12	-6	0.65 / 0.75	1.00 / 1.10
		30	34		
GPB-F GFB	Gypsum plasterboard Type F Gypsum fibreboard				

Charring rates according to ETA-06/0138

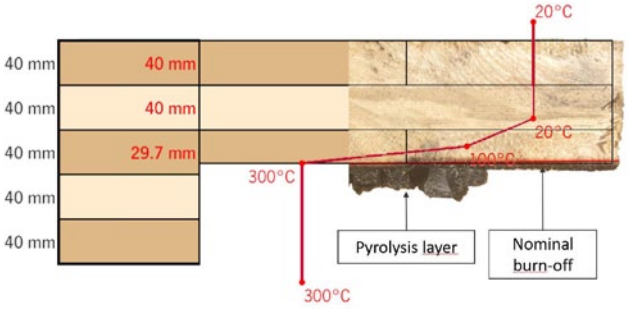


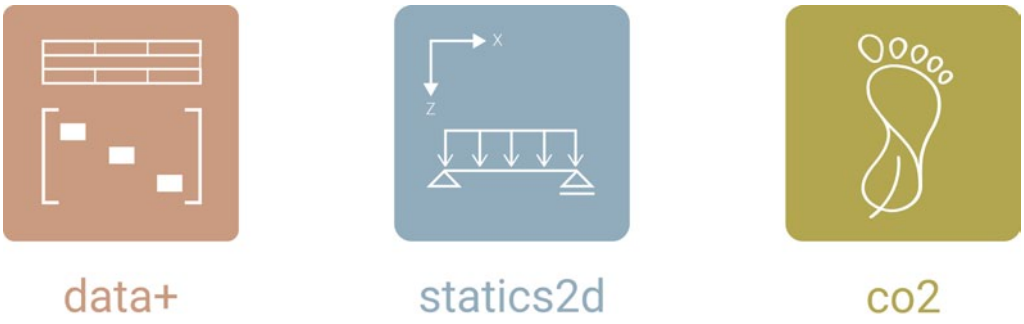
Figure 10. Cross section of a charred KLH® - CLT element

KLHdesigner

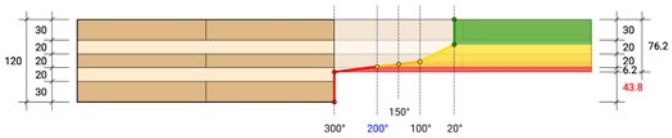
The results and findings from the tests, stated in ETA 06/0138, are integrated in a versatile online tool called KLHdesigner.

KLHdesigner also offers a full version of a structural design tool, “statics2d” for dimensioning of panels, but it only covers European design standards.

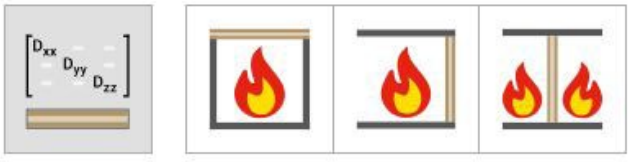
https://www.klhdesigner.at/en



KLHdesigner data+ provides all the necessary KLH® - CLT element properties in normal and fire conditions, that can be used in any other structural design calculation.



Input



KLH® panel

KLH 5s 120 TL

Time of fire exposure

30	60	90	120

Surface 1

Wood surface

Value	Input
KLH® panel	KLH 5s 120 TL
Fire type	Floor/Roof
Design standard	ETA
Time of fire exposure	60 minutes
Surface 1	Wood

Criterion E Integrity

Criterion I Insulation

Results will also provide:

- Cross section data
- Cross section properties for manual calculation
- Resistance for membrane actions (i.e. mainly walls)
- Resistance for plate actions (i.e. mainly floors/roofs)

06 ADDITIONAL DESIGN CONSIDERATIONS AND DETAILING

LOCAL CHARRING

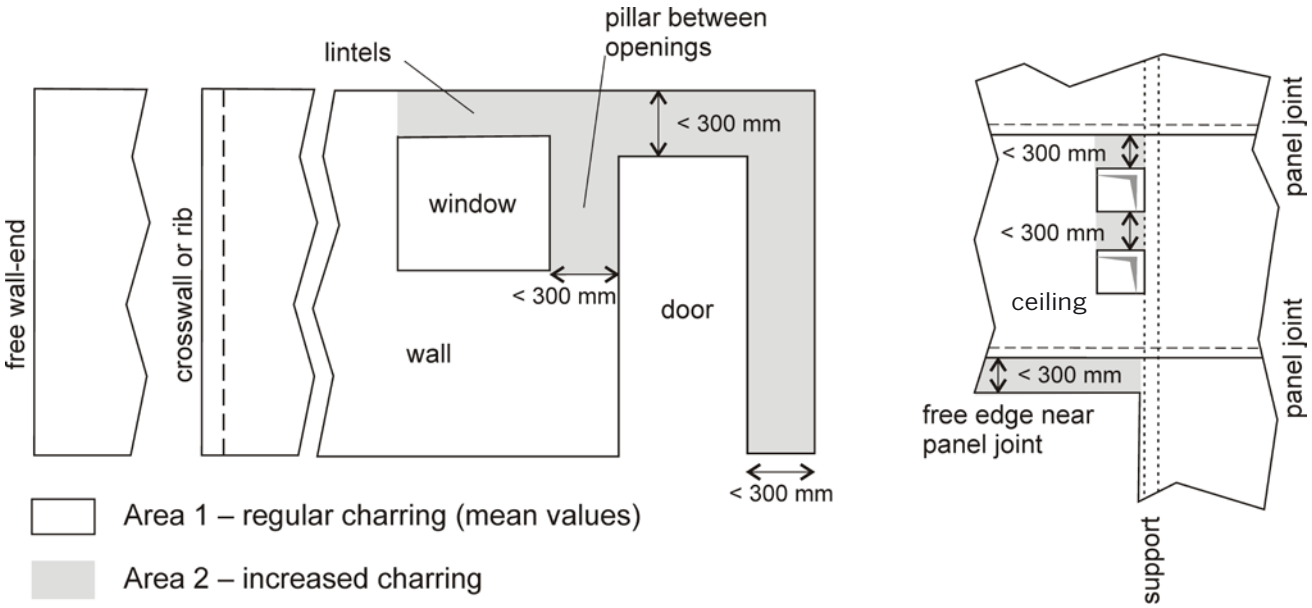


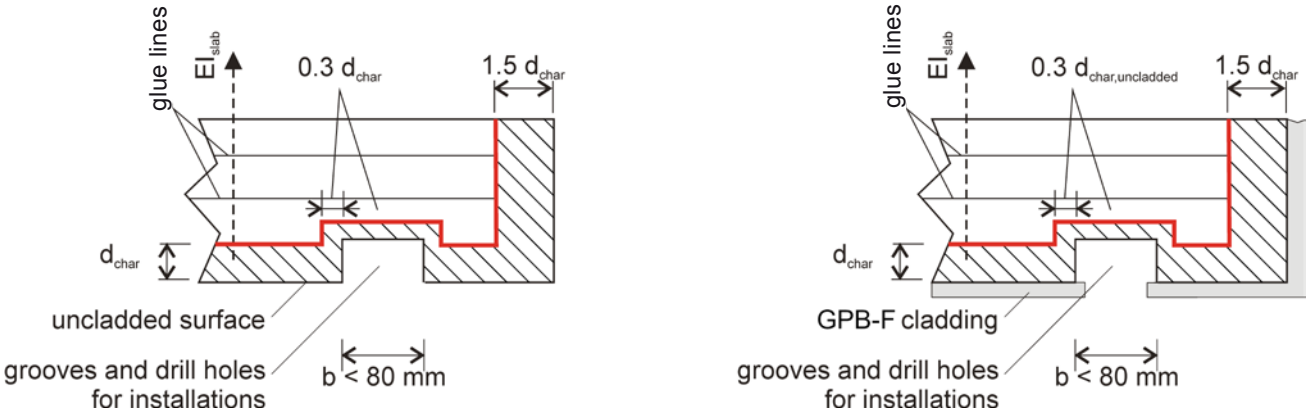
Figure 11. Definition of regions for the application of regular and increased charring rates

The principles for the design of details in the event of fire are described in ETA-06/0138, Annex 5 Structural fire design.

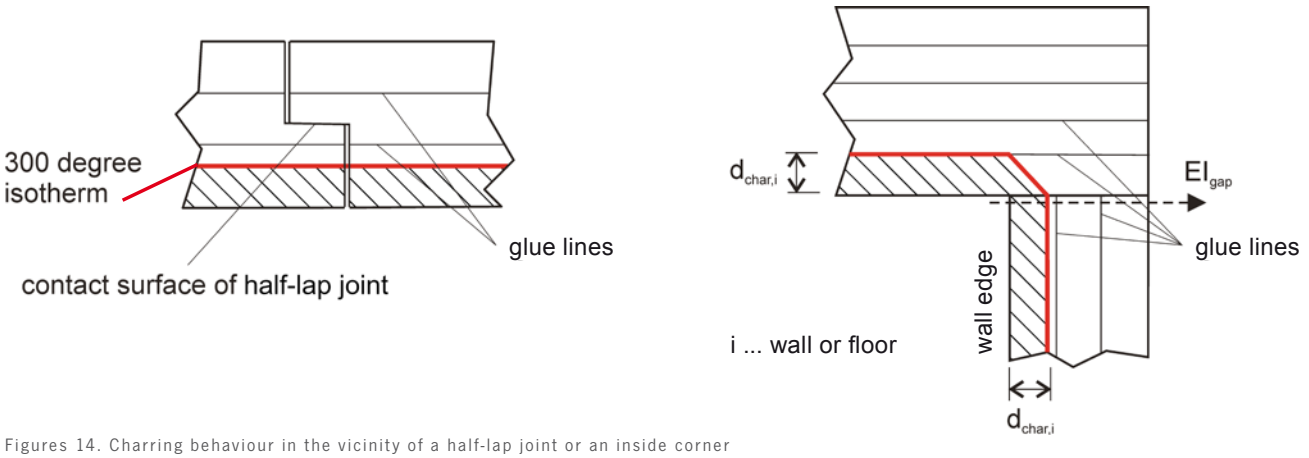
Figures 12. Performance of façade details, large scale fire test

The depth of the 300°C isotherm may be taken according to Figures 13. Grooves with a cross section ≤ (20/20) mm may be disregarded. Grooves smaller than 80 mm in width shall be considered as shown in Figures 13.

To account for the increased charring at the edges, the charring rate at the edges of solid wood slabs shall be taken to 1.5 times the rate at the face.



Figures 13. Charring at a groove and at an edge of a wall



Figures 14. Charring behaviour in the vicinity of a half-lap joint or an inside corner

CONNECTIONS

The capacity of connections may be assumed to be 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.

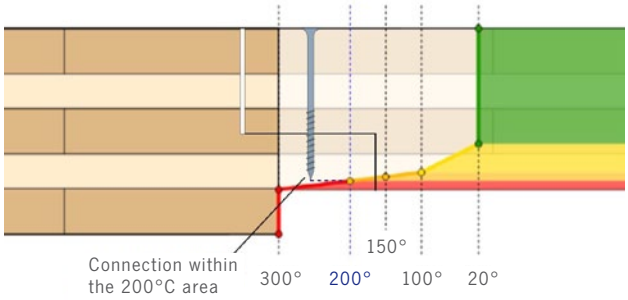


Figure 15. Half-lap connection

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 layer on the unexposed side,
- one glue line, and
- the distance between glue line and 300°C isotherm is bigger than 15 mm.

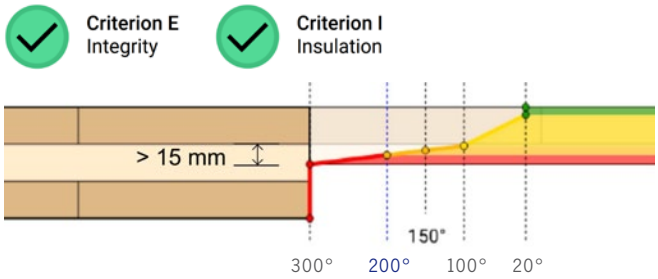


Figure 16. EI criterion limits

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 the corners of two solid wood slabs, if the maximum centre spacing of the screws is c/c = 250 mm.
- The temperature in the contact surface of half-laps, with the contact surfaces parallel to the face of the solid wood slab, shall not exceed 150°C. The half-lap joint shall be connected with wood screws with a maximum centre spacing of c/c = 250 mm.

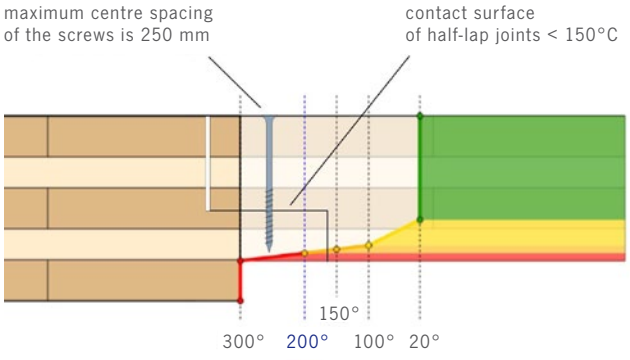


Figure 17. Requirements to avoid sealing tapes for EI

CLADDING

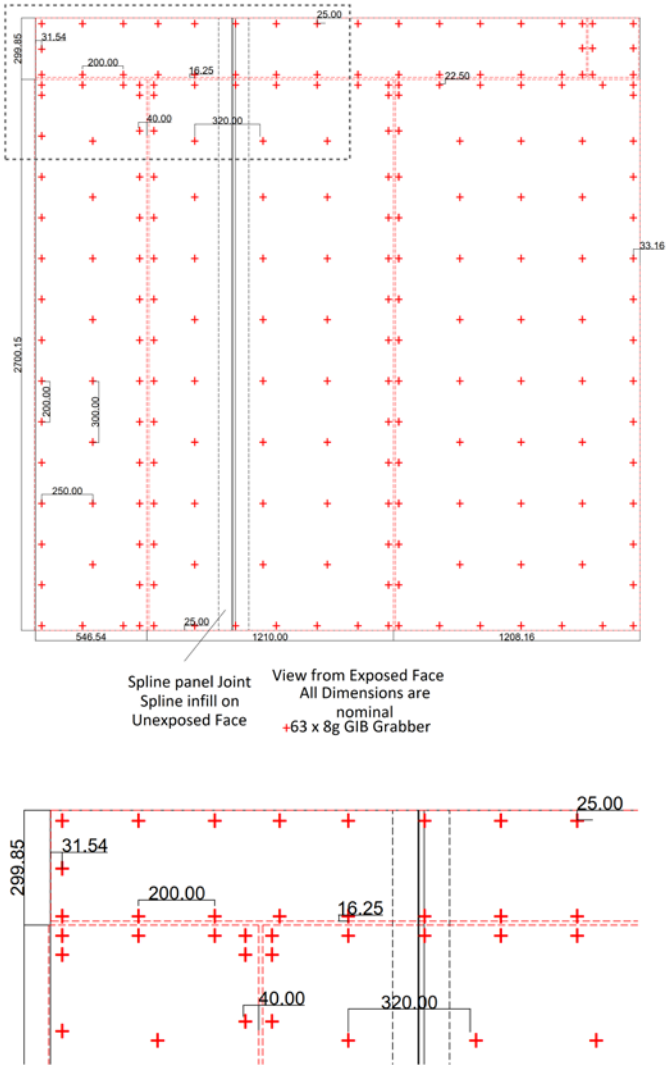


Figure 18. GPB Type F, plasterboard setup for the wall test

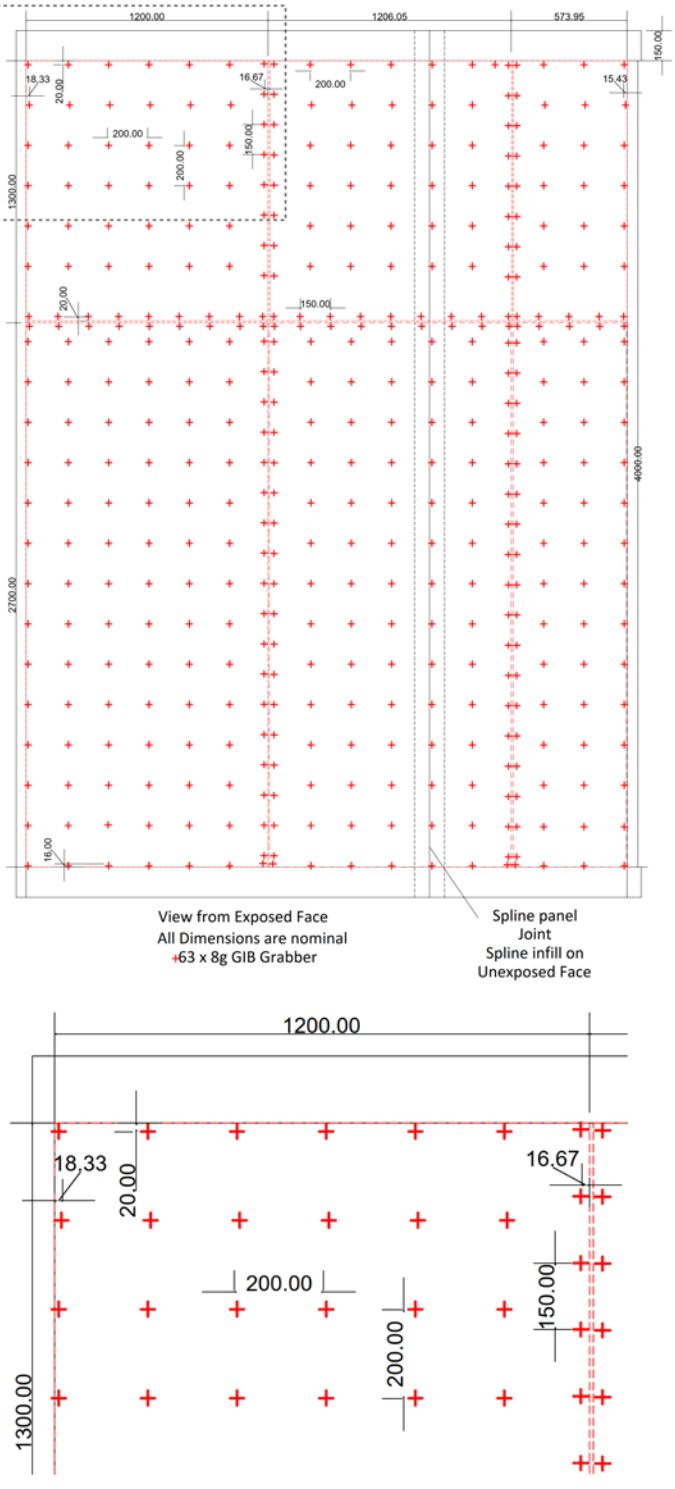


Figure 19. GPB Type F, plasterboard setup for the floor test

Cladding is carried out according to typical procedures specified in standards and manufacturer guidelines. The design for the tests in accordance with AS 1530.4:2014 is shown in Figures 18 and 19. The conditions under which the tests backing ETA-06/0138 were carried out are explained in more detail in the KLH installation guidelines which can be found in the download area of the KLHdesigner data+.

SHAFTS/FIRESTOPS

Penetrations in components and shafts that form fire compartments require appropriate firestops or partitions to prevent the spread of fire during a fire event.

Some manufacturers of firestop equipment have already tested suitable solutions with CLT.

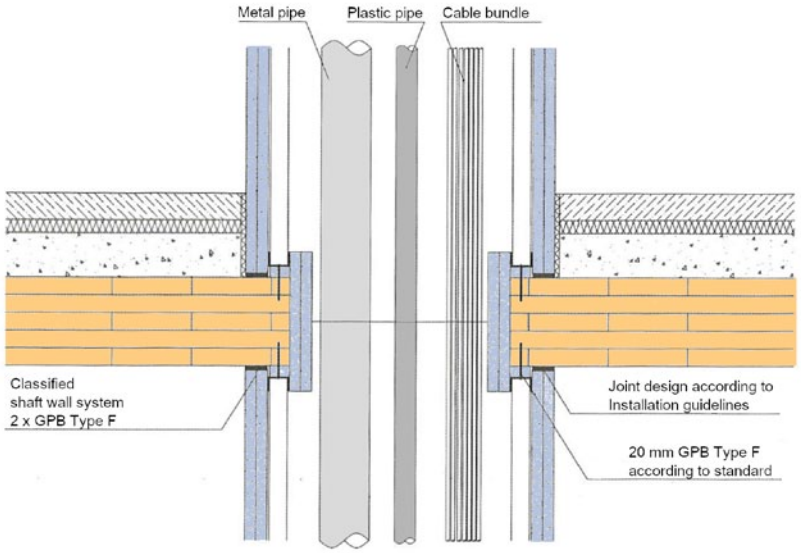


Figure 20. Shaft with fire protection panelling

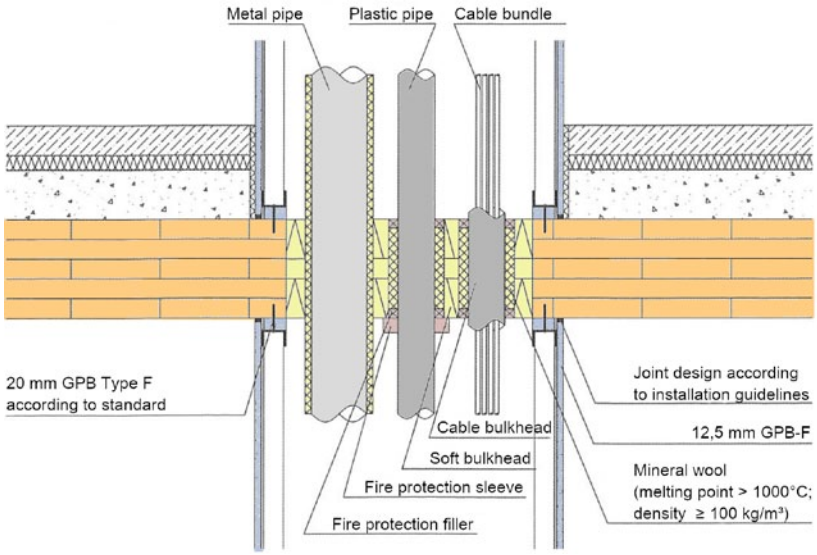


Figure 21. Shaft with fire protection bulkhead

07 KLH® STRUCTURAL PERFORMANCE

Deflection limits applied in the tables enclosed:
Short-term: L/300
Long-term: L/250

Moisture content ≤ 15% and duration of action ≥ 1 year

Appendix B AS1720.1, Guidelines for serviceability

Critical loads for wall ULS according to AS1720.1

Vibration limit for floor class 2 (according to EC 5)
No screed stiffness considered
No shear included for single point load deflection

Fire design method according to ETA and EC 5

Charring rates according to ETA, comparable to tested values according to AS 1530.4:2014

REFERENCE STANDARDS

AS/NZS 1170.0:2002 Structural design actions Part 0

AS/NZS 1170.1:2002 Structural design actions Part 1

AS 1720.1 Timber Structures – Design Methods

Eurocodes EC 5 European Timber Design Codes

Load combination fire	
SDL + ψ_1 * Q	
ψ_1 factor used to calculate quasi-permanent values for short-term actions	0.4
K_1 factor for load duration	0.94

Note:
The charring rates for the wall tests with 13 mm GIB Fyreline® plasterboard, stated in chapter 3, have been compared to charring rates, stated in KLH® - CLT ETA-06/0138. As a conclusion, the charring behaviour is similar to 15 mm GPB Type F and can therefore be used as a supplement to calculate additional panels with that combination, according to KLHdesigner method (reduced properties according to EC 5 1995-2).

This is not unexpected, as the number of screws per m² used to fix the plasterboards in the tests was high compared to European standards. Since the k_{12} factor for stability is much more conservative compared to EC 5 design methods, ULS design results in considerably thicker panels overall.

KLH® AS FLOOR

SINGLE SPAN

Permanent load	Imposed load	Span of single-span beam ℓ								
SDL	Q	3.00 m	3.50 m	4.00 m	4.50 m	5.00 m	5.50 m	6.00 m	6.50 m	7.00 m
[kN/m²] / kPa	[kN/m²] / kPa									
0.50	2.00	3s 110 TL	3s 120 TL	3s 120 TL	5s 130 TL	5s 140 TL	5s 150 TL	5s 170 TL	5s 190 TL	7ss 200 TL
	3.00					5s 150 TL	5s 160 TL	5s 180 TL	5s 200 TL	7ss 220 TL
	5.00			5s 130 TL	5s 150 TL	5s 160 TL	5s 190 TL	7ss 200 TL	7ss 220 TL	7ss 240 TL
1.00	2.00	3s 110 TL	3s 120 TL	3s 120 TL	5s 130 TL	5s 140 TL	5s 160 TL	5s 180 TL	7ss 200 TL	7ss 220 TL
	3.00				5s 140 TL	5s 150 TL	5s 180 TL	5s 200 TL		7ss 220 TL
	5.00			5s 140 TL	5s 150 TL	5s 180 TL	5s 200 TL	7ss 200 TL	7ss 220 TL	7ss 240 TL
2.00	2.00	3s 110 TL	3s 120 TL	5s 130 TL	5s 140 TL	5s 160 TL	5s 180 TL	7ss 200 TL	7ss 220 TL	7ss 240 TL
	3.00			5s 140 TL	5s 150 TL	5s 170 TL	5s 200 TL		7ss 220 TL	
	5.00		5s 130 TL	5s 150 TL	5s 170 TL	5s 190 TL	7ss 200 TL	7ss 220 TL	7ss 240 TL	7ss 260 TL

R 0 | R 30 | R 60 | R 90 | R 120

KLH® AS WALL

FIRE SINGLE SIDED

Surface side 1	SDL | Q	F_d	$F_{d,fi}$	Wall height (buckling length $\ell_k \leq 2.95$ m)				
	[kN/m]	[kN/m]	[kN/m]	REI 0	REI 30	REI 60	REI 90	REI 120
Wood	20 | 20	54	28	3s 60 TT	3s 80 TT	5s 110 TT	5s 130 TT	5s 150 TT
	40 | 40	108	56	3s 80 TT	3s 100 TT			5s 160 TT
	60 | 60	162	84		3s 110 TT	5s 120 TT	5s 140 TT	
	80 | 80	216	112	3s 90 TT		5s 130 TT	5s 150 TT	-
	100 | 100	270	140	3s 100 TT				
1 x 13 mm GPB-F	20 | 20	54	28	3s 60 TT	3s 60 TT	3s 80 TT	3s 110 TT	5s 120 TT
	40 | 40	108	56	3s 80 TT	3s 80 TT	3s 90 TT		5s 130 TT
	60 | 60	162	84			3s 100 TT	5s 110 TT	
	80 | 80	216	112	3s 90 TT	3s 90 TT	3s 110 TT	5s 130 TT	5s 140 TT
	100 | 100	270	140	3s 100 TT	3s 100 TT			

08 REFERENCES AND FURTHER LINKS

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   https://www.klh.at/en/booklets/
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IMAGE REFERENCES

Figure 1. Unexposed side during testing, KLH® - CLT, Fire test report FR17704-01-1 to 04-1, 2024

Figures 2. Main directions regarding mechanical actions, ETA-06/0138

Figure 3. Charred surface after fire test, RISE project, Fire Safe Implementation of Mass Timber in Tall Buildings

Figure 4. Large scale fire test, RISE project, Fire Safe Implementation of Mass Timber in Tall Buildings

Figure 5. Furnace temperature, KLH® - CLT, Fire test report FR17704-01-1 to 04-1, 2024

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Figures 12. Performance of façade details, RISE project, Fire Safe Implementation of Mass Timber in Tall Buildings

Figures 13. Charring at a groove and at an edge of a wall, ETA-06/0138

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Figure 20. Shaft with fire protection panelling, Schachtausführungen, Brandabschottung im Holzbau, Planungsbroschüre; Dr. M. Teibinger, DI I. Matzinger, HFA; Vienna 2012

Figure 21. Shaft with fire protection bulkhead, Schachtausführungen, Brandabschottung im Holzbau, Planungsbroschüre; Dr. M. Teibinger, DI I. Matzinger, HFA; Vienna 2012

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