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**FACHVERBAND
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Bulletin

Cross laminated timber

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1 General

Load-bearing cross laminated timber (X-Lam) components are structurally designed and meticulously manufactured, high-quality construction elements. They are used as large-dimension plates and diaphragms or as beams in service classes 1 or 2 according to DIN EN 1995-1-1: 2010-12.

Cross laminated timber may only be produced in accordance with a German technical approval (abZ) of Deutsches Institut für Bautechnik or a European technical assessment (ETA). A list of current German technical approvals and European technical assessments can be found at www.brettsperholz.org (filed under Brettsperholz / gültige Zulassungen).

DIN EN 16351:2021, the European product standard for cross-laminated timber, has not yet been cited in the official journal of the EU and is therefore not a basis for a declaration of performance or CE mark.

In the following sections, general material-dependent rules are explained which ensure a long service life and the preservation of appearance.

Furthermore, terms important to the determination of the quality of cross laminated timber are explained.



Figure 1
Cross laminated timber



Figure 2
Evangelical Church in Regensburg (D)

Table 1

Tolerances at a reference moisture content of 12 %

Plate thickness	for $t \leq 300$ mm for $t > 300$ mm	± 2 mm ± 3 mm
Plate widths and openings	for $b \leq 3.000$ mm for $b > 3.000$ mm	± 2 mm ± 3 mm
Plate lengths	for $l \leq 3.000$ mm for $3.000 < l \leq 10.000$ mm for $l > 10.000$ mm	± 3 mm ± 4 mm ± 5 mm

2 Lay-up

Cross laminated timber consists of at least three orthogonally arranged and bonded softwood layers. If there are more than three solid-timber layers, neighbouring layers may be glued with the grain aligned if permitted by the German technical approval or European technical assessment.

The lamellae in each timber layer may be arranged along their narrow sides either with or without gaps. If arranged without gaps, the narrow sides may be edge bonded.

Some German technical approvals and European technical assessments allow the inclusion of layers of structural wood-based panels. The surfaces of X-Lam members may have factory-applied non-load-bearing layers for aesthetic or building physics reasons.

3 Standard dimensions and tolerances

Cross laminated timber should be requested with thicknesses starting at 60 mm and increasing in 10 mm steps. The tolerances listed in Table 1 apply.

4 Strength class

The strength, stiffness, and density parameters of cross laminated timber are usually given as the properties of the individual layers in the European technical assessments or German technical approvals of the manufacturers. The properties given apply to the direction of the grain of the individual layers.

Various mechanical methods can be used to determine the internal forces and stresses in the layers and the deformations of the entire system. System coefficients can be used for the structural verifications of the individual layers parallel to the grain.

Cross laminated timber is usually made of solid-timber layers of strength classes C 24 or T 14 according to DIN EN 338. The strength and stiffness parameters refer to the solid-timber layers parallel to grain of the respective stress. The strength, stiffness, and density parameters for cross laminated timber of strength class CL 24 are shown in Table 2 (page 4).

The manufacturer-specific German technical approvals and European technical assessments do not yet allow the declaration of strength class CL 24 instead of the declaration of the list of individual values.

The manufacturer-specific individual values for solid-timber lamellae of strength class C 24 or T 14 can be higher than those of strength class CL 24. Figure 4 assigns the strength and stiffness parameters listed in Table 2 to the actions.

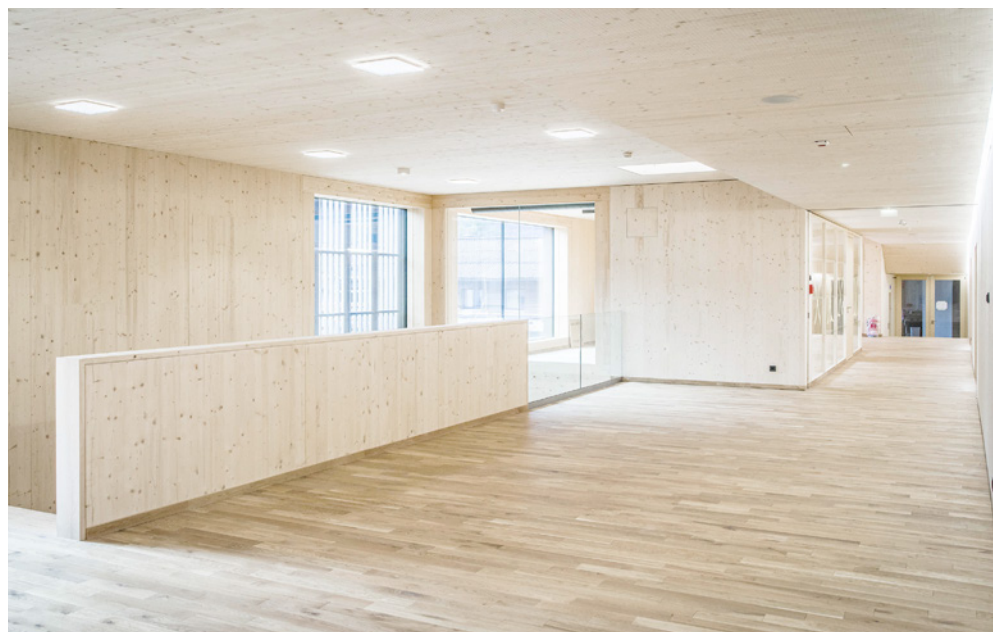


Figure 3
Holztechnikum Kuchl (A)

Table 2
**Minimum values of the strength and stiffness parameters of the solid-timber layers
 of cross laminated timber of strength class CL 24 (in N/mm²) and density parameters (in kg/m³)¹⁾**

Property ²⁾		Symbol	Value
Bending strength³⁾	For out-of-plane bending moments	$f_{m,k}$	24
Tensile strength	In plane	$f_{t,0,k}$	14,5
	Out of plane	$f_{t,90,k}$	0,40
Compressive strength	In plane	$f_{c,0,k}$	21
	Out of plane	$f_{c,90,k}$	2,50
Shear strength⁴⁾	Longitudinal	$f_{v,k}$	3,50
	Rolling shear	$f_{r,k}$	0,70
Young's modulus⁵⁾	In plane	$E_{0,mean}$	11.600
	Out of plane	$E_{90,mean}$	370
Shear modulus^{5) 6)}	Out of plane	G_{mean}	650
	Rolling shear	$G_{r,mean}$	50
Density		ρ_k	385

¹⁾ For verifications using the net cross section.

²⁾ See Figure 4 (Page 5).

³⁾ For in-plane bending moments, such as those present in the design of columns and cantilevering panels, the characteristic value of the in-plane edgewise bending strength $f_{m,edge,k}$ is required. This value is generally not found in the German technical approval or European technical assessment. According to FprEN 16351:2020, a value of $f_{m,edge,k} = 20,5 \text{ N/mm}^2$ may be used. Any information supplied by the manufacturer must be taken into account.

⁴⁾ For the verification of the shear strength of the entire cross section or the torsion strength of the glued intersection areas of the lamellae of neighbouring solid-timber layers, further parameters are necessary which generally cannot be declared, based on the German technical approval or European technical assessment. According to FprEN 16351:2020, the shear strength of the entire cross section can be assumed as $f_{v,xy,k}$ or $f_{vyx,k} = 5,50 \text{ N/mm}^2$. The torsion strength of the intersection areas is given as $f_{tor,node,k} = 2,5 \text{ N/mm}^2$. Any information supplied by the manufacturer must be taken into account.

⁵⁾ The 5% quantiles of the Young's and shear moduli may be assumed to be 5/6 of the mean values: $E_{05} = E_{mean} \cdot 5/6$ and $G_{05} = G_{mean} \cdot 5/6$

⁶⁾ The in-plane shear modulus may be assumed to be $G_{xy} = 250 \text{ N/mm}^2$. This parameter is generally not found in the German technical approval or European technical assessment. Any information by the manufacturer must be taken into account.

Action	Parameters for the verification of the layers parallel to the grain
	f_m f_v and f_r E_0 G and G_r
	$f_{m, edge}$ $f_{v,xy}$ and $f_{tor,node}$ E_0 G_{xy}
	$f_{t,0}$ $E_{t,0}$
	$f_{t,90}$ E_{90}
	$f_{c,0}$ $E_{c,0}$
	$f_{c,90}$ $E_{c,90}$

Figure 4
 The strength and stiffness parameters listed in Table 2 assigned to actions.

5 Wood preservation and wood species

Structural protection of wood should take precedence over preservative treatment. Preservative treatment of wood is uncommon and not required as per DIN 68800: cross laminated timber is manufactured from kiln-dried timber and only used for service classes (SC) 1 and 2. An attack by wood-destroying fungi is unlikely due to the expected moisture content of the timber being less than 20% ($u < 20\%$). Pursuant to DIN 68800-1: 2011-10, adequate durability against insect attack may be assumed in SC 1 and SC 2, irrespective of species.

Cross laminated timber is generally manufactured from spruce; however, other types of softwood may also be used.

6 Surface qualities

Cross laminated timber components can be manufactured with varying surface qualities. Three surface qualities are defined in Table 3 (see Page 7). Other, manufacturer-specific definitions of surface quality also exist. The following general criteria apply:

- Additionally, for example for knot sizes, grading requirements apply.
- Glue lines and finger joints are not defects since they are specific to the product.
- Wood-based panels are generally butt-joined.
- Additional treatment of the surface, such as sanding, brushing, or profiling, can be arranged.
- The desired surface texture of the member must be contractually agreed on and specified in the tender.
- The surfaces of a cross laminated timber member may be supplied with different surface qualities.
- Unless otherwise agreed, agreed, industrial quality is provided.

7 Cracking

Moisture is absorbed mainly by the outer layers of cross laminated timber. The moisture content must gradually approach the moisture expected during later use.

As is the case with all structural solid timber products, the cracks appearing due to the moisture content of the material progressing towards the equilibrium moisture content of the product at its final location are product specific and cannot be avoided.

Figure 5
Office building in Schönau (D)



Figure 6
Kindergarten in Murg (D)



Table 3
**Surface qualities of the visible area (surface layer made of solid-timber lamellae)
 of the cross-laminated timber at 12 % wood moisture**

Criterion	Surface quality (non-visible quality)	Surface quality (industrial quality)	Surface quality (room quality)
Wood species	Addition of other species possible	One species; spruce/fir are deemed one wood type	One species; spruce/fir are deemed one wood type
Surface	Smoothed, without further surface treatment	Planed or sanded	Planed or sanded
Gap width¹⁾	Maximum 6 mm	Maximum 4 mm	Maximum 2 mm
Knots	No restrictions	Fixed knots permitted; black and missing knots over 30 mm mean diameter must be patched	Fixed knots permitted; black and missing knots over 15 mm mean diameter must be patched
Pitch pockets¹⁾	Permitted	Permitted	Up to 5 mm × 50 mm or equivalent area permitted; larger areas must be patched
Discolouration¹⁾	No restrictions	Up to 20% of the surface area	Up to 5% of the surface area
Insect attack	Worm grooves up to Ø 2 mm permitted	Not permitted	Not permitted
Ingrown bark	Permitted	Permitted	Isolated occurrence permitted
Pith	Permitted	Permitted	Isolated occurrence permitted
Cracks¹⁾	Criteria according to strength grading	Criteria according to strength grading	Criteria according to strength grading


¹⁾ Condition upon delivery

8 Marking

Cross laminated timber components comply with the requirements of the building authorities. Components manufactured in accordance with a German technical approval bear the German conformity mark (Ü-Zeichen) (see Figure 7); those manufactured in accordance with a European technical assessment carry the CE-mark (see Figure 8).



Figure 7
 Example of a Ü-Zeichen (Ü mark)

 4321
Manufacturer XY XX NB – xyz
ETA xx/yyyy Cross laminated timber of Class CL24 as load-bearing element in buildings and timber structures
<p style="text-align: center;">Strength, stiffness and density properties to be listed as individual values</p> <p style="text-align: center;">Embedment strength, k_{mod} and k_{def} according to EN 1995-1-1</p> <p style="text-align: center;">Tolerances for widths and thicknesses up to xx mm ± yy mm for widths and thicknesses > xx mm ± zz mm</p> <p style="text-align: center;">MC ≤ 12%</p> <p style="text-align: center;">$\alpha = 5 \times 10^{-6}/K$</p> <p style="text-align: center;">DC 5</p> <p style="text-align: center;">SC 1 oder 2</p> <p style="text-align: center;">Area: xxxxx Finger joints: yyyyy Glue line integrity test: passed</p> <p style="text-align: center;">D-s2, d0</p> <p style="text-align: center;">Fire resistance according to Table xx of Annex yy of ETA xxxx/yyyy</p> <p style="text-align: center;">E1</p> <p style="text-align: center;">$\mu = \mathbf{xx}$ (dry); $\mu = \mathbf{yy}$ (moist)</p> <p style="text-align: center;">Soft body impact resistance test: passed</p> <p style="text-align: center;">R = xx dB</p> <p style="text-align: center;">$L'_{n,w} = \mathbf{XX}$ dB</p> <p style="text-align: center;">$\alpha = \mathbf{xx}$ for yy Hz to zz Hz; $\alpha = \mathbf{ss}$ for tt Hz to uu Hz</p> <p style="text-align: center;">$\lambda = 0, 12 \text{ W}/(\text{m}/\text{K})$</p> <p style="text-align: center;">$C \leq \mathbf{X} \text{ m}^3 / [\text{h} \cdot \text{m}^3 / (\text{h Pa})^n]$</p> <p style="text-align: center;">$c_p = 1.600 \text{ J}/(\text{kg}/\text{K})$</p>

- < CE-mark pursuant to Directive 93/68/EEC
- < Number of the notified body
- < Name and address or sign of the manufacturer
- < Last two digits of the year in which the CE-mark was first applied
- < Number of declaration of performance
- < Number of the ETA
- < Intended purpose and identifying code of the product type
- < Mandated properties

Figure 8
 Example of a CE-mark for cross laminated timber according to an ETA based on EAD 130005-00-0304 (manufacturer-specific text in bold)

Figure 9, 10

Assembly of prefabricated room modules for a hotel in Amsterdam (NL)

9 Transport and assembly

Cross laminated timber components should be transported and installed only by experienced, suitably equipped, and trained specialist companies.

The following should be considered:

- The members must be protected from moisture and dirt during transport and until installation. To prevent discolouration and rust marks, the components must be covered when in the vicinity of steel being welded or cut.
- Transport packaging must be removed soon after delivery to reduce the risk of condensation, which leads to blue stains or mildew.
- Members must be stored at an adequate distance from the ground, covered with tarpaulins, and secured against toppling.
- Adequately dimensioned lifting gear and slings must be used for lifting.
- Cross laminated timber members must be accurately aligned.
- Components must be supported temporarily if necessary.
- Installed members must be kept covered until the final weather protection is in place.
- To prevent rust marks on the timber members, corrosion protection must be applied to steel parts before installation.
- See also Chapter 10.

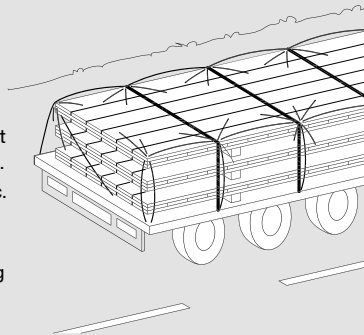


10 Important notes
 for working with cross laminated timber (X-Lam)

Figure 11

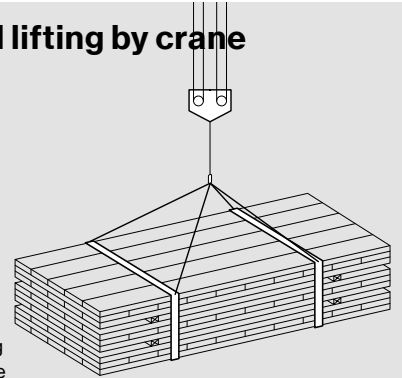
1 Transport and delivery

- The loading sequence should be discussed with the manufacturer if necessary.
- During transport, the members must be protected from moisture and dirt.
- Keep driveways clear to allow traffic.
- If elements are stored on the building site, the ground must be dry and have adequate load-bearing capacity.



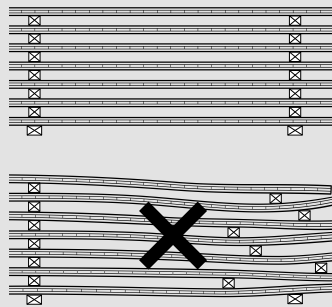
2 Fastening and lifting by crane

- Operation only by trained staff.
- Heed accident prevention regulations.
- Use suitably dimensioned lifting gear and slings according to the installation instructions.
- Before use, check lifting gear, slings, and attachment points for damage.



3 Storage at building site

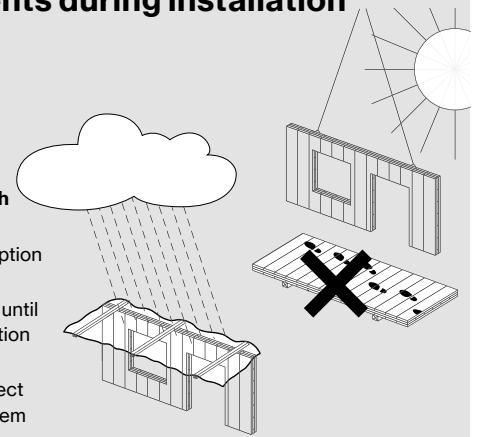
- Use timber spacers.
- When stacking members horizontally, align timber spacers vertically.
- Secure stored members against toppling.
- Remove packaging to prevent condensation.
- Provide adequate ground clearance and tarpaulins to protect members from rain, water spray, and rising damp.
- For extended storage, use additional timber spacers to prevent creep deformations.



4 Components during installation

Install in accordance with installation instructions.

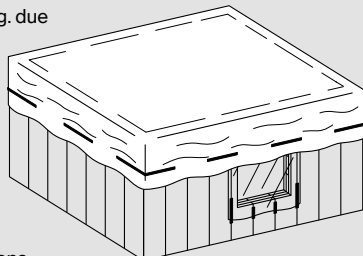
- Avoid detrimental absorption of moisture.
- Keep members covered until the final weather protection is in place.
- Prevent soiling and protect members by covering them if necessary.



5 Protection of installed members

Avoid staining by covering visible surfaces

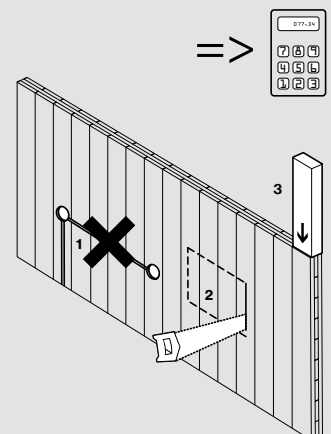
- Ensure adequate ventilation to prevent discolouration due to moisture absorption during construction (e.g. due to screeding or rendering).
- Dry components which have absorbed moisture as soon as possible, but very carefully.
- Tarpaulins should be attached in a way that prevents water accumulation and limits capillary absorption of water in gaps.
- Heed accident prevention regulations.



6 Modifications on-site

Notches (1), holes (2), and additional loads (3)

- The effect of opening holes and recessing on-site on load-carrying capacities must be discussed in advance with the site engineer.
- The capacity for carrying additional static loads must be verified.



11 Design

11.1 General

The design is carried out in accordance with EN 1995-1-1:2010-12 (Eurocode 5-1-1, including the A2 amendment and the national annex), considering the requirements of the manufacturer's technical approval or ETA.

Cross laminated timber members may be designed carrying load along one or two axes. The load-bearing capacity is determined by considering the static system and load configuration. Usually, the layup is declared, specifying the properties of the layers.

The manufacturers provide design aids for conventional systems and load distributions.

Since strength and stiffness values vary depending on the cross-sectional layup and the manufacturer's production methods, the design of the load-bearing construction and, where applicable, the building physics verification should be checked when products are exchanged.

Verification of fire protection is carried out in reports or assessments of the manufacturer according to the requirements of the respective German technical approvals or European technical assessments.

11.2 Tension perpendicular to the grain

Tension perpendicular to the grain (tension perpendicular to the plane of the panel) must be sustained by orthogonal reinforcement, e.g. by self-drilling fully threaded screws.

11.3 Holes, notches, cut-outs, bore holes and cuts executed on-site, and additional loads

Execution of holes, notches, bore holes, and cuts, as well as changes to the static system and additional loads, must be discussed with the designer of the structure.

11.4 Further information about design and construction

General

The design of plates, diaphragms and beams made of a layered orthogonal material differs from the design of the linear structural elements commonly found in timber construction. In the past years, numerous reference books and booklets containing an introduction to the design of cross laminated timber elements have been published. The following list of useful publications is not exhaustive.

Material parameters

The material parameters to use must be taken from

- the respective German technical approval of the Deutsches Institut für Bautechnik (DIBt) (abZ) or
- the European technical assessment (ETA). To use these parameters for designs executed in Germany, a manufacturer-specific general technical application rule (aBG) issued by DIBt, if existing, must be considered.

Design requirements

For use in Germany, the following applies:

- the design rules of the respective abZ or ETA, if necessary with aBG
- in conjunction with DIN EN 1995-1-1 (Eurocode 5-1-1) and DIN EN 1995-1-1/ NA (National Annex).
- DIN EN 1995-1-2 with DIN EN 1995-1-2/NA must also be observed for fire design.

Components / Connections

- A catalogue with building physics parameters, including those of cross-laminated timber components, can be found under www.dataholz.com.
- Fire protection requirements valid in Germany as well as necessary verification procedures can be determined with the Fire Protection Navigator (www.brandschutznavigator.de).

- Dederich, L. et al: INFORMATIONSDIENST HOLZ, holzbau handbuch, Reihe 3, Teil 5, Folge 2, Leitdetails für Bauteilanschlüsse in den Gebäudeklassen 4 und 5 <https://informationsdienst-holz.de/publikationen/leitdetails-fuer-bauteilanschluesse-segebaeudeklasse-4-und-5>
- Many manufacturers have sample details.
- Further information can also be found in the planning aids of fastener and fire bulkhead manufacturers.

Further literature

Detailed design information can be found in:

Augustin, M.; Blaß, H.; Bogensperger, T.; Ebner, Ferk, Heinz J.; Fontana, M.; Frangi, Hamm, P.; Jöbstl, R.; Moosbrugger, T.; Richter, K.; Schickhofer, G.; Thiel, A.; Traetta, G.; Uibel, T.: BSPhandbuch. Holz-Massivbauweise in Brettsperrholz, 2nd revised edition Auflage, 2010 (only available as Download)

Wallner-Novak, M.; Koppelhuber, J. und Pock, K.: Brettsperrholz Bemessung – Grundlagen für Statik und Konstruktion nach Eurocode. proHolz Austria, Vienna, Austria, 2013, ISBN 978-3-902320-96-4

Wallner-Novak, M.; Augustin, M., Koppelhuber, J. und Pock, K.: Brettsperrholz Bemessung – Band II: Anwendungsfälle. proHolz Austria, Vienna, Austria, 2019, ISBN 978-3-902320-96-4

Many manufacturers provide product-specific information for design.

Software

An extensive software package including background documentation can be found at ww.cltdesigner.at. Many manufacturers provide product-specific design information.

12 Tendering and billing of cross-laminated timber

12.1 General

VOB ATV DIN 18334:2016-09 does not contain sufficiently detailed rules for the tendering and billing of cross-laminated timber elements. During tendering and billing, it needs to be considered that

- not all dimensions and details required for billing may have been defined at the time of tendering, and
- the amount of offcut is difficult to estimate, as
 - no nesting (optimised pattern for the cutting of structural elements from raw cross-laminated timber panels) can be performed without the geometries having been defined,
 - manufacturers use different production dimensions and
 - the manufacturer is generally not known at the time of tendering.

In the following sections, information about tendering for detailed and non-detailed planning is presented.

12.2 Tendering for detailed planning

12.2.1 Total quantities, offcut and billed dimensions

The offcut to take into account is calculated by subtracting the billed dimensions from the nominal dimensions. The billed dimensions must therefore be defined.

For the billing of cross-laminated timber elements according to volume or area, one of the following billing dimensions should be chosen:

- for the shorter edge length: 2.45 m / 2.75 m / 2.95 m / 3.2 m / 3.5 m;
- for the longer edge length: the dimensions must be rounded up to the next 10 cm (minimum dimension 8.0 m).

Note 1: Minimum and maximum production lengths and widths depend on the manufacturer. Different billing dimensions can be agreed upon.

Note 2: Maximum production lengths of 14.5 m and larger are available only from some manufacturers.

- The nominal thickness of the element shall be used for billing.

Note 3: element thickness (minimum 60 mm) shall be stated in steps of 10 mm. Maximum production thicknesses of 280 mm and larger are available only from some manufacturers.

Total quantities are to be differentiated according to element thickness, cross-section structure (number of layers and orientation) and surface quality. Elements with the same surface requirements on both sides must be grouped together.

For nested elements, the billed dimensions apply analogously.

12.2.2 Openings, notches and bevels

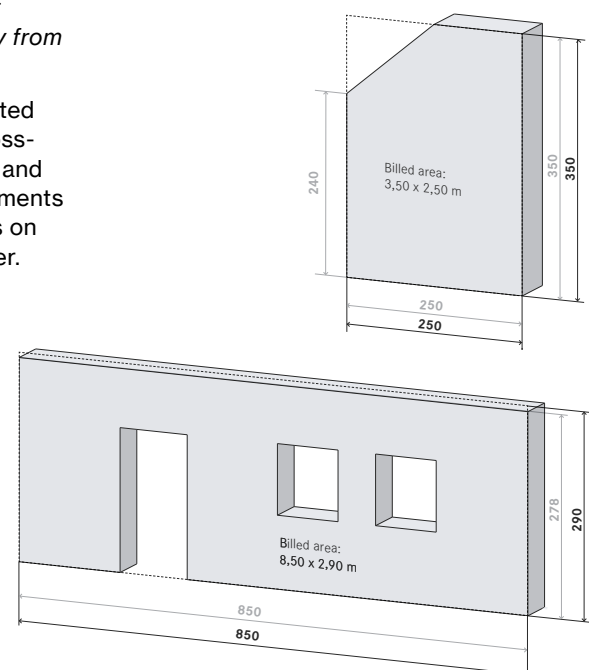
It is more efficient to cut smaller openings out of entire panels. Only for very large openings is it worthwhile to join the elements and add lintels and window walls. In such cases, lintels often consist of a different material. The necessary joints of individual elements are generally executed by the client, unless agreed otherwise.

Openings cut or milled from an entire panel are not deducted from the billed areas.

If openings are formed by lintels and window walls, only the notches for the supports are ignored in the billed areas.

Lintels or window walls made of other materials must be tendered separately. Notches and bevels (see Fig. 12) are also not deducted from billed areas.

Figure 12
 Billed measurements of wall elements with openings and bevels



12.2.3 Cutting

It is possible to tender individual structural elements, but 'nesting' – where a pattern is used to cut the required elements from the raw panels – is far more common.

A fixed cutting price per m² is commonly used. The areas of all elements, even those without openings, are considered.

Alternatively, cutting actions (horizontal or vertical joints, joints for openings, edges, openings etc.) can be tendered per running metre or per item.

Openings are to be differentiated according to sharp edges or round edges with a radius of about 4 cm into groups according to Table 4 and tendered per item.

12.2.4 Surfaces

The standard surface quality is non-visible NSi according to Table 3 (page 7) of this bulletin. For other surface qualities, a surcharge per m² is billed.

12.3 Tendering for non-detailed planning

The provisions in Section 8.2.1 apply analogously.

It is more difficult to estimate the cutoff, as nesting cannot be planned without knowing the exact element geometries. Openings are ignored in the measurements.

The cutting of the elements is tendered as a fixed price per m².

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Table 4
Groups for billing of openings per item

Dimensions [in mm]			Element thickness [in mm]		
			Standard processing	60 – 160	160 – 200
Diameter	≤ 40	Holes	+	+	+
Shorter edge length	l ≤ 80	Grooves	+		
Shorter edge length	80 < l ≤ 200	Grooves	+	+	
Shorter edge length	l > 200	Grooves / notches	+	+	+
In curves	d ≥ 200 mm	Grooves / notches	+	+	+



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