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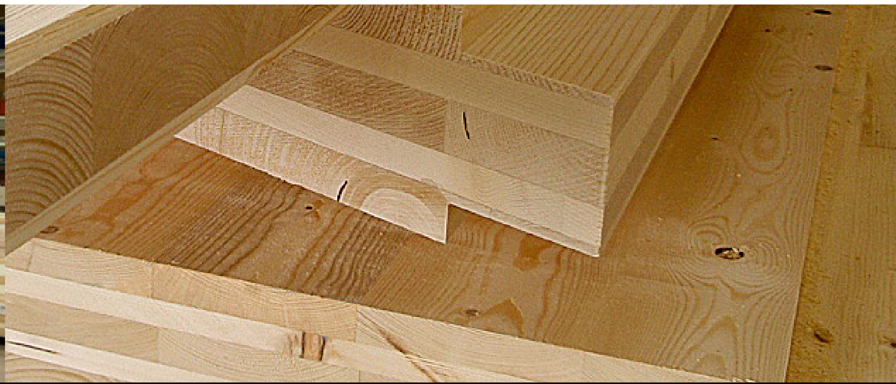
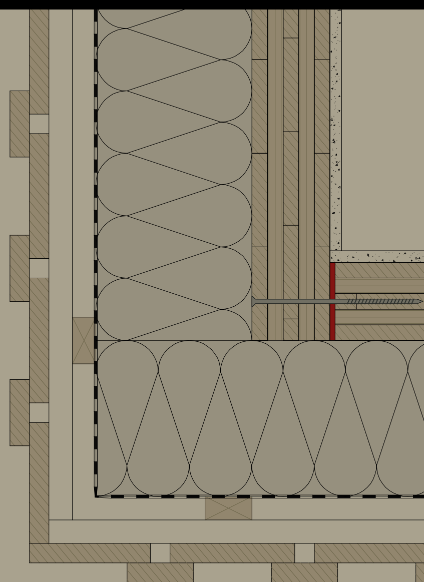


Building with cross laminated timber

Load-bearing solid wood components for walls, ceilings and roofs



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Heinz-Fangman-Straße 2
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+49 (0)2 02 / 769 72 73-5 Fax
info@brettsperrholz.org
www.brettsperrholz.org
www.ingenieurholzbau.de

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Project management:
Dr.-Ing. Tobias Wiegand, Wuppertal

Introduction, construction documentation, editorial department:
Dipl.-Ing. Arnim Seidel,
Fachagentur Holz, Düsseldorf

Section 1:
Dipl.-Ing. Peter Mestek, München
Dipl.-Ing. Norman Werther, München
Prof. Dr.-Ing. Stefan Winter, München

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Introduction

Figure 0.1
9 storey residential construction as a timber structure in London (Waugh Thistleton Architects, London (GB))

Boards from bars

The constant expansion of wood construction in architecture coincides with the development of new building materials and new building systems. As particularly successful is demonstrated by the establishing of cross laminated timber that, since more than ten years, has experienced considerable popularity with architects and civil engineers. The principle of its manufacture has already long since been commonly used for blockboard or plywood – novel perspectives, however, have opened up the unusual dimensions of the material.

Building with cross laminated timber has an impact in as much as it allows for a fundamentally new approach to solid wood as construction material. Besides the present day customary tectonics of the frame and skeleton construction methods from bar shaped components, an almost non-attached, non-modular application of large surface construction components is provided. By crosswise glueing of individual board layers from the straightened raw wood material is formed a material with board or panel properties that allows for applications as wall, ceiling or roof construction components and also for base plates in bridge constructions.

Thus the planner, in regard to wood construction, can also think in terms of surfaces. Thanks to CNC controlled beam machines the form of cross laminated timber construction components are basically not subjected to any limitations. Window and door openings are simply cut out of the huge wall components without consideration to an overlaying grid. The laminar bearing structure allows for the implementation of intended monolithic architectural concepts which appeared, up to now, to be reserved for solid construction (something with homogeneous concrete) – however, always under the legalities of wood construction.

Application technology allows for cross laminated timber, besides construction of single and multiple family housing or commercial buildings, to also be used for construction of higher buildings. After the construction of the first seven storey block of flats in Berlin a nine storey town hall is, for the first time, developed in London. Based on the slim wall construction, high load bearing strength and very good fire and sound properties the solid wood construction has a good chance, with these construction tasks, to catch up with mineral construction methods.

The present publication shall be an interim result of the circulation of a construction product, in principle, of new significance for wood construction. Austria and Germany are the most significant producers of cross laminated wood. In view of climate protection, earthquake protection, prefabrication and production runs a growing demand is observed which is also revealed with exports within Europe and overseas. Above all, however: Planners such as constructors should, with this publication, envisage a wide application spectrum as well as the technical foundation for planning and utilisation of cross laminated timber.

1 _ Planning and building with cross laminated timber

1.1.1 _ What is cross laminated timber?

Cross laminated timber (BSP or X-Lam) is a laminated, solid wood product for load bearing applications. It consists of a minimum of three glued board layers of coniferous wood glued to each other at right angles (Figure 1.1). Details of the cross-sectional layup are specified in section 2.5.

Besides the multisupplier German product designation, Brettsperrholz (BSP) and the English designation, Cross Laminated Timber (BSP or also X-Lam), manufacturer designations, such as thick wood or cross laminated timber are also commonly used.

Cross laminated timber constructions are among the solid wood construction methods.

Cross laminated timber can be produced in very large dimensions and is therefore suitable for the manufacture of load bearing, and at the same time, room dividing construction components such as wall, roof and ceiling boards.

The first experiences with large-scale elements from cross glued board lamination were collected in the 1990's within the parameters of acceptance in individual cases. Since 1998 cross laminated timber is regulated via various national and, increasingly also European technical approvals of German, Austrian and Swiss manufacturers. The continually growing number of production facilities and technical approvals account for the distinct acceptance and attractiveness of this ecological wood construction method.

Figure 1.1 (left)
Cross laminated timber (BSP, X-Lam)

Figure 1.2 (right)
Wall diaphragms of a single family house

1.1.2 _ Advantages of cross laminated timber construction

Cross laminated timber elements exhibit many positive characteristics:

– The weather impartial production of large-scale, already joined in the factory, wall, roof and ceiling members allows for a very high grade of prefabrication. Thus building shells can be erected in the shortest possible time.

– The construction components are dry and therefore do not bring any moisture into the structure.

– The layered construction allows for the assembly of decorative or also sound and fire protection technically adapted protective layers.

– Through the crosswise arrangement of the board layers and the blocking effect connected with this, humidity changes in the panel layers only lead to minor swelling and skrinkage. The cross laminated timber construction members therefore remain, also with the usual humidity changes, very accurately fitted and dimensionally stable.

– There is basically no specified grid. Limitations of the construction component dimensions are merely the result of the manufacturer specific maximum and conveyance dimensions.

– As a result of the lateral load transfer construction components with a lower component height and low net weight can be provided.

– Cross laminated timber , in comparison to other construction materials, has a very low thermal conductivity.

– The common softwoods have a high specific humidity and heat storage capacity. Solid cross laminated timber elements therefore regulate the climate of living spaces and through a distinctive phase displacement and amplitude insulation of the surface temperatures, produce a high protection against summerly heating.

– The planar construction with closed surface layers achieves considerable benefits for heat, moisture, fire and sound protection since air movements within the structure are prevented.

– Solid cross laminated timber construction components are not subject to any limitations regarding the fastening of loads (for example, heavy kitchen cabinets).

– Cross laminated timber is manufactured using softwood from sustainably managed forests. Compared to other solid construction methods the manufacture and processing of cross laminated timber components requires very little energy. It contributes to sustainable carbon storage and thus to the minimization of the greenhouse effect through the fusion of CO_2.

– At the end of its use cross laminated timber can be, materially or thermically, recycled. In the event of thermical recycling of reinstated cross laminated timber elements, only the CO_2 which was stored during the growth period of the timber is discharged into the atmosphere.

Figure 1.3
Large-scale wall diaphragms from cross laminated timber

1.2 _ Cross laminated timber building products

1.2.1 _ Technical basic principles

Technical rules for the usage of cross laminated timber are given as national technical approvals by the Deutsches Institut für Bautechnik (DIBt) or European technical approvals (ETA). The approvals contain the minimum requirements of production, the requirements of the product as well as quality control and rules for marking and labelling. In addition they contain regulations for design and building physics. For design, regulations exist for both the design according to national standard (DIN 1052) and also according to the European standard (Eurocode 5).

1.2.2 _ Manufacturing

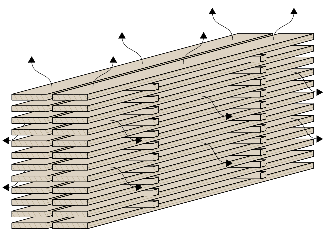
The manufacturing of cross laminated timber includes several work stages. The manufacturing process is depicted in figure 1.4.

1.2.3 _ Material and surface quality

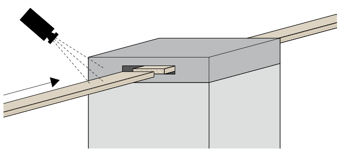
Cross laminated timber predominantly uses spruce laminations as a raw material. The use of fir, pine, larch and Douglas fir is also common. According to the approval for use in load bearing board layers, other softwoods are acceptable. Wood types that are not mentioned in the approvals can be used as decorative non-load bearing top layers.

The surfaces are sanded or planed. The manufacturer frequently offers special surface qualities. Thus particular acoustic profilings are also available.

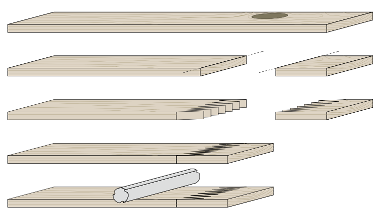
Figure 1.4
Manufacturing of cross laminated timber



The boards intended for the manufacturing of cross laminated timber are first kiln dried in drying chambers to a humidity of 12% ± 2% or less.



After the drying follows the visual or machine strength grading of the boards. The top layers can be assessed additionally after aesthetical grading criteria.

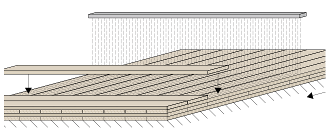


Board sections having a lower strength or a poor appearance are, if necessary, lopped out and the boards and/or board section is shaped via finger joints to laminations of the desired length. Then follows the planing or sanding of the laminations to the desired thickness.

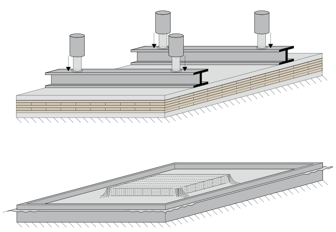
Occasionally, because of optical reasons or also for increasing the strength, wood board panels are arranged as top or middle layers.

Fire protection technology required top layers, for example plaster construction boards, are also applicable, factory provided.

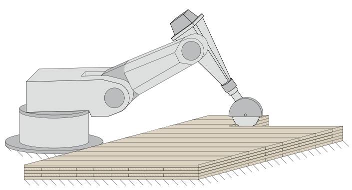
Figure 1.5
Decorative ceiling underside



After the lengthwise inlaying of the laminations in a pressure rack, glue is applied. Adjacent layers are, as a rule, arranged at 90° to each other. Details for possible cross-section constructional systems are located in section 2.5.



The necessary bonding pressure for the adhesion is produced hydraulically or in a vacuum process.



Factory assembly of the members is carried out mostly in the manufacturing plant.

1.2.4 _ Bonding

The bonding of the commercially available cross laminated timber elements takes place, at present, via two glue types (PUR, MUF). These glue systems facilitate fast curing times and transparent glue lines.

1.2.5 _ Layup and dimensions

Mostly the layup consists of at least three crosswise arranged board layers and is symmetrical (Figure 1.6a).

With particularly high strength requirements in the main load bearing direction many manufacturers offer layup with which several parallel layers are arranged, in the main load bearing direction, over each other (Figure 1.6b).

Depending on approval the boards can be laid in individual layers with systematic spacing from each other (Figure 1.6c).

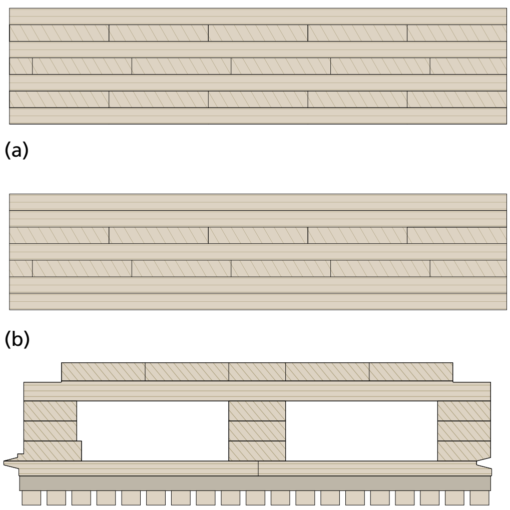
The cross laminated timber consists of boards which correspond to at least the grading class S7/C18, however, as a rule, to S10/C24. The boards can be finger-jointed in the longitudinal direction. Depending on the manufacturer, they have board thicknesses of between 17 mm and 45 mm.

Individual layers are formed from wood based panels such as, for example, OSB or LVL.

The total thickness of the element may amount to 500 mm depending on the approval of the manufacturer, in general the thicknesses are of up to 300 mm. The board dimensions vary depending on the manufacturing procedure. In general element widths are up to 2.95 m (upon request and depending on the manufacturer up to 4.80 m are possible) and element lengths up to 16.00 m (upon request and depending on the manufacturer up to 20.00 m are possible).

Individual system providers supply elements with grid widths of 625 mm up to 700 mm.

Since the manufacturer produces different standard thicknesses and widths the precise dimensions are to be derived, in the planning phase, from the manufacturer's product information.



(a) (b) (c)

Figure 1.6
Selection of possible layups

(a) crosswise layers
(b) parallel gluing of adjacent layers
(c) systematic spacing of individual laminations in layers

1.2.6 _ Marking – Quality control

With manufacturing according to a German technical approval (abZ) the manufacturing company must have a general certificate of competence for gluing work, the so called gluing approval (proof of suitability for the gluing of load bearing wood construction components according to DIN 1052, appendix A). The cross laminated timber is additionally subject to a factory production control and also biannual external quality control by independent authorities.

The fulfilling of the national approval requirements is documented via the compliance mark (Ü-Zeichen). The Ü-Zeichen is displayed on the member and also on the packing slips.

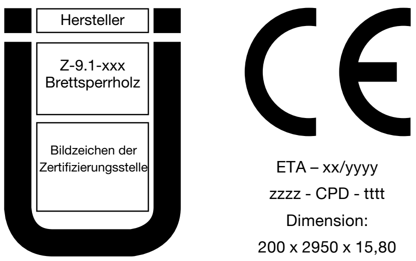


Figure 1.7
Ü-Zeichen according to German technical approval and CE mark according to European technical approval

The European approval ETA leads to a CE mark. The CE mark shows that the cross laminated timber was manufactured according to a ETA and therefore is freely marketable in Europe. As proof of legal construction usability the CE labelling is only applicable in conjunction with the German list of Building Rules of the DIBt.

1.3 _ Application potentials

1.3.1 _ General

Cross laminated timber is used for load bearing walls, ceilings and roof constructions for the construction of single and two family housing, in multi storey residential buildings, for school and other residence related utilisation as well as for hall constructions. However, you can also find applications in religious buildings, in commercial buildings or in special constructions such as bridges.

As a rule according to DIN 1052 the utilisation class 1 or 2 as well as a predominantly statical loading are available. However, experience has also already been gathered in bridge construction for variable loads.

Generally cross laminated timber construction components are suitable for application in the following described support functions:

1.3.2 _ Panels

Loads perpendicular to the element plane produce bending stresses which can mainly be distributed through board layers running parallel to the span direction in the case of ceiling systems. Cross laminated timber beams are thereby considered as single-axis spanned panel strips. A considerable advantage of cross laminated timber systems is, however, in the dual-axis load distribution which enables ceiling systems supported on all sides, cantilevers in corner areas or point supports.

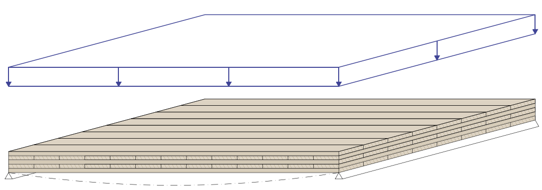


Figure 1.8
Application as panel

1.3.3 _ Plate – Wall plate

Vertical loads on wall elements create normal stresses in the layers parallel to the applied load. Bending stresses, which result from possible eccentric ceiling connections or occurring deformations, are also applied. Because of the crosswise arrangement of individual board layers, the wall plates also accept higher horizontal loads and can therefore be simultaneously used for building bracing. The higher stiffnesses and load-bearing capacity of glued cross laminated timber elements enables economic use in multi-storey residential and industrial structures.

1.3.4 _ Plate– Bending girder or ceiling plate

By crosswise arranging of the board layers cross laminated timber can also be applied as panel elements which transfers the parallel to the element layer effective loads through bending. This is typically the case for window lintels or stiffened roof and ceiling plates. This supporting action is used primarily in construction of additional storeys on existing buildings in as much as the loads of the additional storeys can be directed across considerable span widths to the load distributing external walls on the existing building.

Figure 1.9
Wall plate

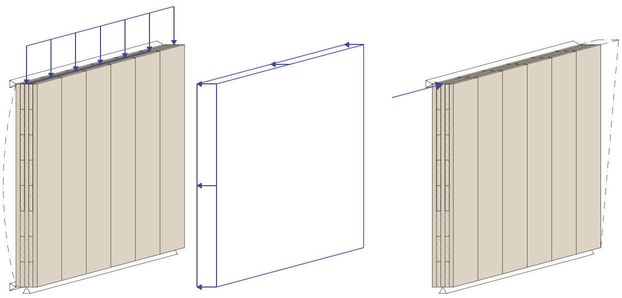
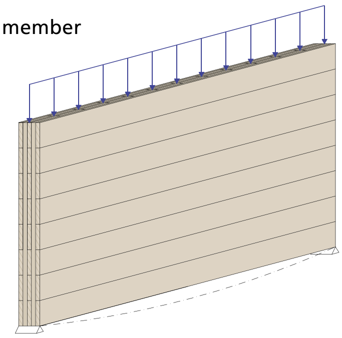


Figure 1.10
Plate as bending member



In addition through spatial arranging of cross laminated timber panels, folded plates can be formed simply.

1.3.5 _ Shell elements

Depending on the manufacturing procedure bended and curved elements can also be manufactured. Such shell elements, which are predominantly subject to normal forces or bending, are mainly used for special structures for special roof supporting systems.

1.4 _Design

Cross laminated timber stands out due to its high load bearing capacity and its dual-axis load-bearing performance when required. Design is the allowing for the specifications of the approval according to the national design standard DIN 1052 or the European design standard Eurocode 5-1-1. In Germany Eurocode 5-1-1 is currently only applicable as the prestandard DIN V ENV 1995-1-1.

The mechanical resistance can only be determined taking into consideration the flexibility of the cross layers, the statical system and the load configuration. The design can be done by means of, for example, shear force analogy as support grid. All manufacturers offer preliminary design assistance for customary load situations and support systems.

1.5 _ Building physics

1.5.1 _ General

For precise planning the relevant building physics data is to be derived from the respective manufacturer's product documentation because of the manufacturer specific constructional systems.

1.5.2 _ Thermal and moisture protection

Cross laminated timber has, depending on the moisture content and the gluing method, a water vapour diffusion resistance value between μ = 30-80. The elements are diffusion inhibiting with the usual element thickness. Depending on the diffusion resistance of the exterior layers a vapour barrier inside the room can be dispensed with.

At the same time the large, surface active and moisture retaining, interior surfaces in relation to the hygric tolerance of the entire structural element offers considerable advantages as compared to other materials.

Depending on the design, flow dense surfaces and the corresponding necessary airtightness for the construction component have already been achieved for laminar cross laminated timber elements. In addition the manufacturer specific arranging of board materials or side glued board layers in the top layer, takes place. Alternatively airtight sheeting can be applied. In the area of the mostly butt joined element seams, simple mountable and at the same time flexible, ductile compression bands and gasket hose from closed cellular material ensures a continuous airtightness between the construction components. Thus flow dense building shells are formed that display the minimum convective thermal heat loss.

For thermal insulation technical aspects a thermal conductivity of $\lambda = 0.13$ W/(m·K) can be assumed for the uninsulated element. Cross laminated timber elements can be combined on the exterior, free of a thermal bridge, with the most variable insulation materials (wood, mineral fibre insulation materials, thermal insulation bonded systems or rear ventilated facades). Additional interior, insulated installation planes lead to further improvements of the insulation standard. Elements constructed to the passive house standard are not uncommon.

As a result of the specific thermal capacity of wood, c = 2100 J/(kg·K), the cross laminated timber construction method in space limited areas offers a clear advantage in comparison to the light building constructions. With comparable U-values a, close to, three-fold thermal mass is achieved which leads to a greater phase displacement and amplitude suppression and therefore simultaneously increasing the comfort especially in the summer months.

1.5.3 _ Fire protection

Cross laminated timber construction components are classified according to their technical approvals to material class B2 according to DIN 4102-1 and/or the Reaction to fire class D-s2,d0 according to EN 13501-1. These classifications correspond to those of solid wood and glued laminated timber. Through the corresponding surface coating or top layers, flame-resistant member surfaces can be achieved.

With requirements to the fire resistance of coated or uncoated cross laminated timber elements, a design shall be made on the basis of the technical approval. The basis for this is experimental fire testing or design on the basis of DIN 4102-22 and/or DIN EN 1995-1-2 by means of the charring rates of the construction component cross section. The manufacturer has available a number of tested specific constructional systems for a fire duration of up to 90 minutes.

1.5.4 _ Sound insulation

Through the crossways bonded layer construction evolves, from an acoustical point of view, light and at the same time bending resistant elements. In order to also achieve good airborne sound insulation values for thin cross laminated timber wall constructions predominately two or multi layered structures are used. In connection with this, primarily, flexible layers which at the same time can serve as installation area come into use.

In ceiling construction components to achieve the required footfall sound insulation according to DIN 4109, through constructive measures, the direct structure borne sound transmission via the massive construction components through isolation of the sound input on the ceiling's upper surface from the radiating surface on the underside is minimised.

Through combinations of upper floor screeds and footfall sound insulation mats with a lower dynamic rigidity as well as weight suppression integrated into the elements or underside, and then possibly also flexible, ceiling coverings, a very good footfall insulation is achieved that also exceeds the increased requirements of the standard.

1.5.5 _ Durability

Cross laminated timber elements may only be applied in the service classes (SC) 1 or 2.
With the wood moisture u < 20% to be expected in the SC 1 and 2 an infestation from wood destroying fungi can be excluded.

Recent findings concerning basic insect insensitivity of kiln dried glue laminated timber in the SC 1 and 2 are, because of the similar manufacturing processes, also applicable to cross laminated timber. It is therefore to be assumed that in the future prepared, revised DIN 68800-1 "Wood preservation" for cross laminated timber, an insect threat in the SC 1 and 2 will be excluded.

1.6 _ Joints and connections

Because of the large scale element dimensions very few connections appear. Nevertheless their professional implementation is important for the static and building physics functionality of the building. Whilst, from the design point of view, a force-fit connection is required for the forwarding of stresses between the individual construction components, at the same time it is necessary to ensure that the impermeability of the connections for sound insulation, fire protection and airtightness of the building shell is guaranteed.

The design requirements are usually achieved through conventional pin shaped fasteners. Referred to here are, primarily, self drilling full or partial threaded screws which, because of their easy handling, guarantee a simple installation and thereby create efficient connections. Since the load bearing behaviour of the mentioned fasteners in combination with cross laminated timber differs in comparison to solid wood construction components because of joints and the variable orientation of the adjacent board layers, the necessary input parameters for dimensioning such as the embedding strength or the resistance to withdrawal force are given in the general building authority approval. Thus, in combination with the corresponding dimensioning standard, the load bearing capacity can be proven.

To achieve the required impermeability of the connections usually different types of sealing bands are used. With surfaces that are not visible the construction component joints and connection joints can be bonded conventionally with adhesive tape. Further notes concerning the implementation of connection details are to be found in the manufacturer's documentation.

Table 1

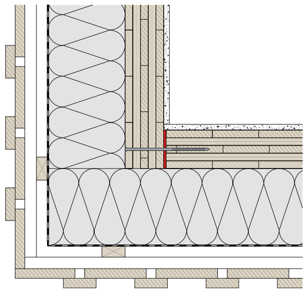
Example of connections

(no scale diagrams)

Constructive formation of connections

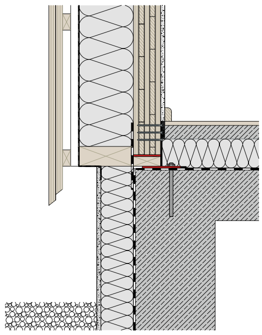
Corner joining, exterior wall

— Sealing tape



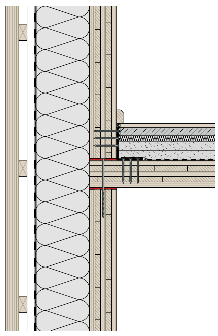
Foundation formation with anchoring

— Sealing tape



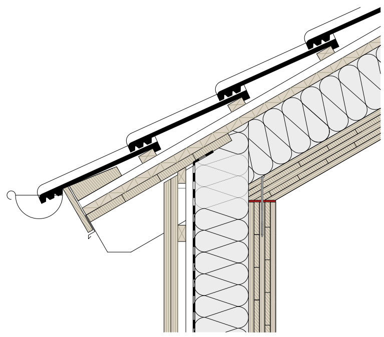
Ceiling connection, platform framing

— Sealing tape



Roof connection / eave detail

— Sealing tape



1.7 _ Ecology and healthy living

Cross laminated timber consists exclusively of softwood originating from European, sustainably managed forests. A major proportion of renewable energy is used for drying the timber. The amount of energy required for processing is very low due to the good workability. Therefore cross laminated timber has an excellent ecobalance.

Natural and healthy structural materials are an important requirement for modern projects. Cross laminated timber is dried to very low timber moisture values and has the capacity to absorb and buffer moisture from the surrounding room air. It therefore plays its part in a healthy room climate.

1.8 _ Tendering

Since the mechanical characteristics of cross laminated timber is also dependent on the manufacturing procedure and construction the regulated dimension values in the manufacturer's approvals vary. In the tendering is always therefore reference to the approval, taken as a basis, in the assessment. The manufacturers offer specific sample tendering text.

2 _ Construction documentation

2.1 _ Residential buildings

The industrial production of cross laminated timber facilitates a particularly high prefabrication grade that can reach up to factory assembly with routed in window and door openings, preinstalled wiring and finished visible surfaces. It allows for the implementation of, not only large-sized outer and inner walls or roof and ceiling elements but also flights of stairs and balcony boards or load relieving construction components such as lintels, girders and supports.
Supplemented with additional insulating layers, energy efficient and, at the same time, slim constructions are formed with cross laminated timber. Add to this an excellent sound insulation as well as an optimal room climate by means of moisture regulating walls. Cross laminated timber is particularly well suited in multi-storey residential and administration constructions because it is extremely load bearing capable and also has good physical construction and fire technological values.

Single family house in Eichgraben (A)

Building owners:
Johanna und Christian Hasenauer, Eichgraben (A)
Architects:
Superreal, Dold und Hasenauer, Wien (A)

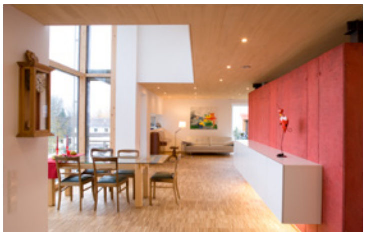



Figure 2.1 – 2.5
The interior rooms of the austere cubical dwelling are formed by the visible surfaces of the cross laminated timber.

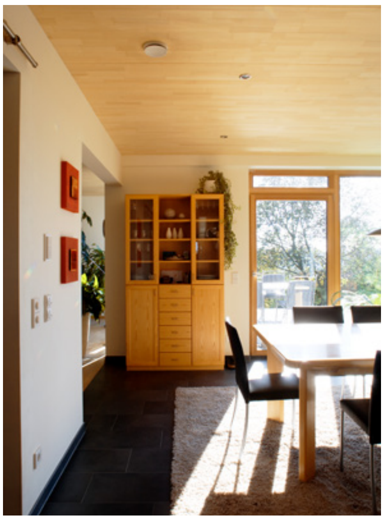
Single family house on Lake Constance (D)

Figure 2.6 – 2.8
Only 100 m from the Bodensee shore this dwelling was constructed as a passive house using heavy sound insulating cross laminated timber slab elements.

Architects:
Geckeler Architekten, Konstanz (D)



Single family house in the Dachau administrative district (D)



Architect:
Ralph Bibinger, Guggenberg (D)

Figure 2.9 – 2.12
In this exterior plastered passive house the knotless cross laminated timber elements in the slab underside are visible.

Semi-detached house in Sistrans (A)

Building owner:
Reinhold Hammerer,
Sistrans (A)
Architects:
maaars architecture,
Innsbruck (A)
Structural engineer:
DMH, Kufstein (A)

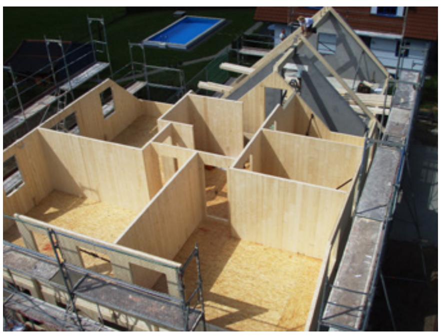



Figure 2.13 – 2.16
Wood as construction material is used with this passive house from the exterior larch finished facade via wall and slab construction up to the staircase, built-in shelves and table top.

Single family house in Grünhain (D)

Figure 2.17 – 2.19
This dwelling with gable end roof was also almost completely constructed from cross laminated timber.

Building owner:
Dr. Armin Trummer,
Grünhain (D)
Architects:
Plan & Vision GmbH,
Neunkirchen am Brand (D)
Structural engineer:
Ingenieurbüro Pauler + Lang,
Ebermannstadt (D)



Single family house in Puchheim (D)





Figure 2.20 – 2.24
The facade provides issues for discussion:
The small house is completely covered with roof tiles.

Building owners:
Familie Geier, Puchheim (D)
Architects:
Fürst & Niedermaier,
München (D) mit Katja Klingholz
Structural engineer:
Ludwig Krummbachner, Dachau (D)

Single family house in Idstein (D)

Figure 2.25 – 2.28
Also if here any indication of the use of wood construction materials has been avoided, it was still used in the load bearing construction components because of its advantages.

Architects:
architektur design,
Josh Heiderich, Idstein (D)
Structural engineer:
Martin Cremers, Idstein (D)


Heightened housing development in Cologne (D)

Building owner:
LEG Rheinland, Köln (D)
Architekten und Structural engineer:
Archplan, Münster (D)

The reconstruction of this housing development demonstrates how existing buildings are made future suitable by redensification. Since here the top floor slab was not designed for the loads created by living accommodations, a new slab from cross laminated timber boards was laid on the load bearing exterior and centre walls. It overhangs 45 cm over the existing substance to compensate for the imprecision of the old building and to facilitate the connection of the new exterior insulation of the existing building.

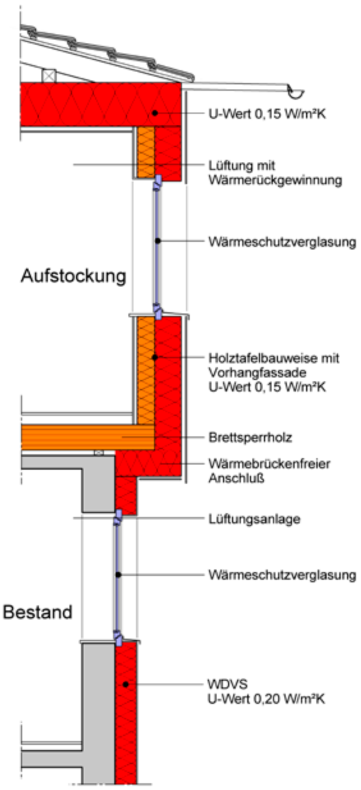


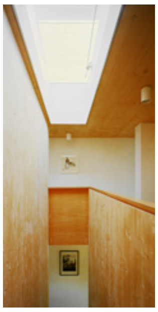
Figure 2.29 – 2.33
Besides the obviously recognizable heightening of the building, constructed in the 1950's, it was completely adapted inside and out to the present day requirements.

Terraced houses in Darmstadt (D)

The construction system of the terraced houses consists of prefabricated cross laminated timber boards which were installed in one and a half days per house unit. Besides the technical construction advantages, the architects emphasise fast acceptance of the structural work by the building owners, since the material corresponds to the construction and immediately after assembly imparts warmth and comfort. The entire building geometry leads to minimization of the surface areas. In combination with the solid wood construction method it allows for the achievement of an economical overall concept.

Building owner's representative:
Dr. J. Heilmann,
U. Sickinger, Darmstadt (D)
Architects:
zimmermann.leber.feilberg,
Darmstadt (D)
Structural engineer:
Benninghoven Ilgmeier
Partner, Langen (D)


Figure 2.34 – 2.37




Altenwohnheim in Stockerau (A)

Building owner:
Niederösterreichische
Landesregierung
Architects:
Büro Zieser, Wien (A)
Structural engineer:
Ingenieurbüro Bantsch,
Wien (A); Grossmann Bau,
Rosenheim (D)




Figure 2.38 – 2.41
This project deals with the first three storey solid wood building in Lower Austria.

2.2 _ Kindergardens and schools

Timber constructions for children and adolescents reflect, besides the surface qualities of the materials, also the constructive possibilities as well as the roll of wood in educational concepts. They offer good and cost favourable solutions for flexible interior concepts which can be adapted to the respective utilization requirements.

If no further requirements to the sheathing of the construction exist, wood, as a creative element in the interior, can prove to be advantageous. Through feel, smell and the flexibility with the character of the walls and floors, sanded, planed or with special acoustic profiling, cross laminated timber is especially predestined for kindergarden and school constructions.

Day-care centre in Darmstadt (D)

Building owner:
Bauverein AG, Darmstadt (D)
Architects:
zimmermann.leber.feilberg, Darmstadt (D)
Structural engineer:
Ilgmeier Partner, Langen (D)

Figure 2.42 – 2.47
The cross laminated timber exterior walls are insulated with 18 cm of mineral rock wool. The exterior sheathing of fibre cement boards form an effective completion against climatic influences.

School in Frankfurt on the Main (D)

Building owner:
Stadt Frankfurt am Main (D)
Architects:
marcus schmitt architekten, Frankfurt am Main (D)
Structural engineer:
Ingenieurbüro Roth, Klingenmünster (D)

Figure 2.48 – 2.49
The classrooms were formed by the spruce surface material and the integrated acoustic absorbing film.

Children's home in Deizisau (D)

Figure 2.50 – 2.53
The ceiling elements are 62.5 cm wide and up to 15 m long.

Building owner:
Gemeinde Deizisau (D)
Architects:
Burkle + Hahnemann, Stuttgart (D)
Structural engineer:
Weber Grauer Holl, Stuttgart (D)

The conspicuous geometric form and the applied acoustical elements add distinction to the building. For the walls in the hall partially curved elements were prefabricated. The ellipse required slanted bevel and round cuts of the ceiling and roof elements as well as a special face side profiling to the elements which only in the computer controlled trimming could be exactly carried out.

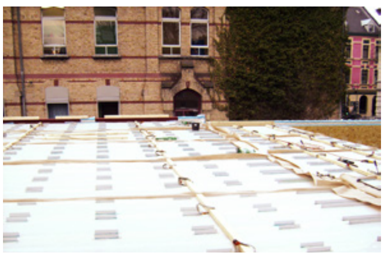
Expansion of a school in Düsseldorf (D)

Building owner:
Stadt Düsseldorf (D)
Architects:
wollenweber architektur, Düsseldorf (D)
Structural engineer:
Baues + Wicht, Korschenbroich (D)

With this expansion construction the ceilings consist of cross laminated timber elements in a wood-concrete combination. Thus the large span widths of 8.20 m could be carried out with a reduced ceiling construction height.

The necessary acoustic profiles and absorber were allowed to constructively integrate into the ceiling construction and at the same time form the finished under ceiling with a surface in knotless white fir wood.

Figure 2.54 – 2.58
The exterior cladding consists of enamelled steel sheets. Their varying yellow tones assimilate the chromaticity of the old building.



The elements for the wood-concrete combination ceiling were delivered complete with sheeting and shear connectors.

2.3 _ Commercial buildings

With cross laminated timber construction, components can be formed as storey height and building length elements. The creative freedom is still not restricted if the question arises "Fascia or punched window facade"? Cross laminated timber elements get by without additional provisions such as door or window lintels, replacements for ceiling break-throughs are dispensed with. For greater span widths and higher wall elements without intermediate support, ribbed plates with cross laminated timber ribs or box sections with cross laminated timber girders are suitable.

Exhibition building in Gaildorf (D)

Building owner:
Bad & Heizung,
Gaildorf (D)
Architect:
Margit Munz,
Gaildorf (D)
Structural engineer:
Firma Paul Stephan,
Gaildorf (D)

Figure 2.59 – 2.62
The new construction of a builders and trade contractors building for bathroom and heating incorporates a warehouse as well as offices and exhibition rooms.

Kaufhaus in Junglinster (L)

Building owner:
FNP Invest, Junglinster (L)
Architects:
Moreno, Luxemburg (L)
Structural engineer:
SGI Ingenieure, Junglinster (L); Bathon + Bahmer, Glattbach

The two storey department store could be accomplished in view of fire protection, sound insulation, large span widths and, last but not least, on the basis of the costs versus the planning of an concrete construction. Its distinctive features are cross laminated timber-concrete combination ceilings with a span width of 7.50 m, which are supported on Glulam joists. With this mixed construction method the compression strength of the blinding concrete with the high tensile strength of the cross laminated timber elements are combined into a advantageous composite construction.

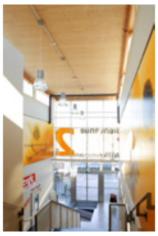




Figure 2.63 – 2.67
With the large-scale wood construction components an installation of 1,500 m² a day was achieved here.

Car dealership in Kirchseeon (D)

Building owner:
Franz Leitsch, Langenpreising (D)
Architects:
S & C, Weyregg (D)
Structural engineer:
Thoralf Fels, Landshut; Finnforest Merk, Aichach (D)


Figure 2.68 – 2.69
The construction was originally planned with reinforced concrete but then, for economical reasons and because of the short construction time frame it was completed in wood. The bearing structure consists of cross laminated timber elements, on the exterior timber frame construction elements are used for the facade.

Bakery in Annaberg (A)

Building owner:
Bäckerei Hauser, Annaberg (A)
Architect:
Peter Auer, Abtenau (A)
Structural engineer:
DMH, Kufstein (A)

Figure 2.70 – 2.73
Simple braced commercial building is built extremely economically into a cross laminated timber construction. Not only with bakeries but also with other buildings with special hygenic requirements, wood is enjoying a new appreciation.

Offices and dwelling in Augsburg (D)

Figure 2.74 – 2.76
The cubical formed building was completed in only six weeks.

Building owners:
Albert und Andrea Schöllhorn, Augsburg (D)
Architects:
Gerd Kolanowitsch, Kühbach (D)
Structural engineer:
Wenzel von Fragstein, Ramberg (D)

2.4 _ Exhibition / convention / Sports buildings

The massive wall, ceiling and roof elements can be finished exactly and independently according to plan and is assembled with a systematised and simple joining technology. Drawn-out alignments or adapting on the building site are dispensed with. Insulation, facing formwork and facade elements can be installed easily and quickly to the cross laminated timber elements.

The individual manufacturing of construction elements from cross laminated timber allows for application with the most varied of building forms. With five layer roof and ceiling boards, depending on the board and ceiling construction as well as the loading height, span widths between 4 and 5 m can be economically implemented. Cross sectional areas with more layers and, in particular, cross laminated timber ribs or box section elements achieve substantially greater span widths.

Multi-purpose hall in Hawangen (D)

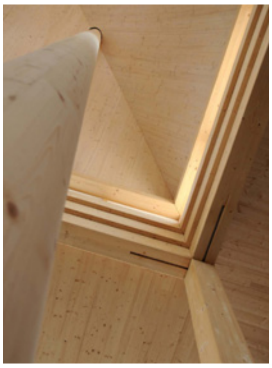
Building owner:
Gemeinde Hawangen (D)
Architects:
Manfred Fetscher,
Illmensee (D)
Structural engineer:
Rolf Bernauer,
Überlingen (D)

Figure 2.77 – 2.79
The hall was spanned with a spatial bearing structure of CL timber. Cross laminated timber elements, which have, on the interior surface, an acoustic profile from 25 mm wide battens with 8 mm wide joints and an underlying wood fibre absorber, serve as the bracing roof panel.

Church in Regensburg (D)

The church and steeple, rectory and the community house are consolidated into a central construction. Exterior walls and roofs consist of circular curved cross laminated timber shells. The horizontal loads were redirected via the, formed as panels, roof and/or cupola construction, to vertical construction components of cross laminated timber.

Figure 2.80 – 2.85
The belfry consists of four pyramid shaped convergent round glulam supports, which penetrate through the roof dome and provides character to the central sanctuary.



Building owner:
Ev.-Luth. Gesamtkirchenverwaltung, Regensburg (D)
Architect:
Ricco Johanson, München (D)
Structural engineer:
Planungsgesellschaft Dittrich, München (D)

"Müritzeum" in Waren (D)

Building owner:
Landkreis Müritz, Waren (D)
Architects:
Wingårdhs Arkitektkontor, Göteborg (S)
Structural engineer:
FB Engineering AB, Göteborg (S)

Figure 2.86 – 2.89

Nature museum, info centre and Germany's largest fresh water aquarium: the "House of the 1000 lakes" in Waren on the Müritz enjoys considerable popularity with visitors. The approx. 60 degree inclined exterior walls consist of load bearing, cut to a trapezium shape, cross laminated timber elements with visible surfaces of sanded three-layer larch slabs. On the outside the facade is completed by wood boards, which were carbonised on one side to protect the wood prior to assembly.

Sports hall in Brussels (B)

Building owner:
Ixelles community, Brussels (B)
Architects:
R²D² Architecture, Brussels (B)
Structural engineer:
JZH & Partners SCRL, Brussels (B)

Building in the confines of the city: Wood can prove its advantages here thanks to its light weight and the high amount of prefabrication. The sports hall construction site is located within a compact perimeter block development. Without space for an interim storage facility, the large format, assembly ready, prepared wall construction components of cross laminated timber could be lifted directly from the lorry, over the four storey building into the yard and then assembled.

New trade fair in Hamburg (D)

Each field of the spanned steel hollow box girder covers ellipsoidal glulam shell, which was completed with cross laminated timber roof elements. These elements not only provide for a pleasant view from below in the halls, but also offer acoustic quality, satisfy the fire protection requirements F30 and B1 (flame resistant) and absorb enormous shearing force.

Building owner:
Messe und Congress GmbH, Hamburg (D)
Architects:
ingenhoven architects, Düsseldorf (D)
Structural engineer:
Werner Sobek, Stuttgart (D); IB Bertsche, Prackenbach (D)

Figure 2.95 – 2.99
The wood construction acts as a barrel jacket and thus supports the steel construction. All wood construction components are firmly connected to the steel construction via tensile and compression strong connections.

Figure 2.90 – 2.94
Provisions for the redensification, heightening and in-fill development are economically implemented in the urban environment with wood material.

2.5 _ Towers, bridges and special constructions

The technical characteristics of cross laminated timber are particularly noticeable with tasks that place special demands on the construction material. With large-scale span widths that have high applied loads such as in bridge construction, cross laminated timber as a t-beam system for the carriageway slab is applied. The high prefabrication grade of the construction component, large-scale dimensions with a light weight, a high dimensional accuracy as well as the dry construction method, predestines it also for the historical monument custodial sector. The fact that large wood constructed buildings are also earthquake resistant is demonstrated by the experiment with a seven storey building from cross laminated timber in Japan.

Look-out tower in Stetten (A)

The 17.50 m high tower of complicated geometric shapes forms the new emblem for an exhibition park for fossils. Around a steel corkscrew staircase was developed a 16 angled load bearing system on which cross laminated timber elements were fitted for the installation of the exterior sheathing.

Building owner:
Fossilienwelt, Stetten (A)
Architekten und Structural engineer:
basis-ZT, Öblarn (A)

Figure 2.100 – 2.105
The building was completely put together from only eight prefabricated tower segments.

Lift shaft of a school in Bad Reichenhall (D)

The St. Zeno abbey historical monument protected building was carefully renovated by means of current school operation. The cross laminated timber lift shaft was completely prefabricated at the factory and delivered to the building site in one piece. The wooden construction component does not bring any building moisture into the existing building. Integrated fire protection solutions and the reduced self weight led to the carrying out of this individual solution. The very short assembly duration of a few hours increased the cost-effectiveness and minimized the weather influence on the historical monument protected existing building.

Building owner:
Erzbischöfliches Ordinariat Diözese München und Freising (D)
Architect:
Friedrich Wehmeyer, Bad Reichenhall (D)
Structural engineer:
Finnforest Merk, Aichach (D) (Aufzugsschacht)


Figure 2.106 – 2.107
The roof was opened over an area of approx. 24 m² and after the lift shaft was levitated in, reclosed as quickly as possible.

Street bridge in Kössen (A)

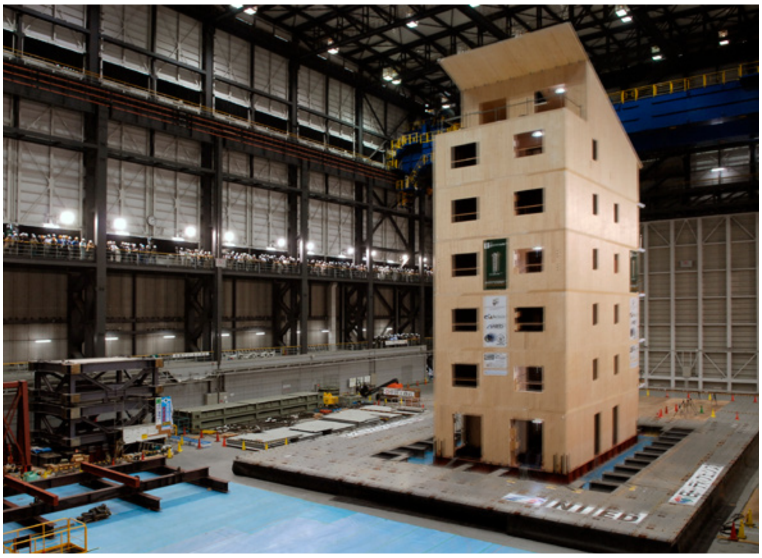


Figure 2.108 – 2.110

The two lane street bridge of bridge class I with a span width of 50 m was built in less than four months. The main load bearing system is a framework construction of glued laminated timber with steel tension members. The carriageway construction consists of a cross laminated timber ribbed board with bituminous sealing throughout and an asphalt coating. To protect the load bearing construction from direct exposure the entire bridge is covered.

Building owner:
Gemeinde Kössen (A)
Architects and Structural engineer:
Reinhard Exenberger und Michael Flach, Innsbruck (A)

Wood construction in the earthquake experiment in Japan



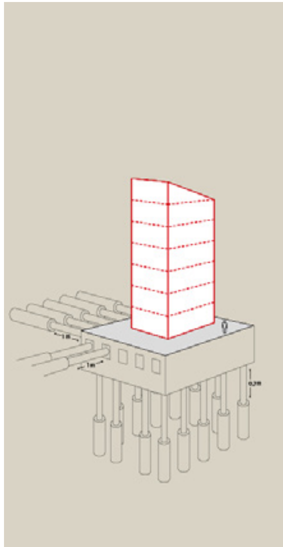


Figure 2.111
The seven storey building during the simulation. On the largest earthquake table in the world it is subjected to the power of one of the worst earthquakes in the last decade (7.2 on the Richter scale).

Figure 2.112 (right)
The earthquake table is agitated by five cylinders in x- and y-directions respectively, 14 cylinders are required vertically.

Wood construction is effective, on the basis of its lower mass, as especially suitable for earthquake construction use. Historically as modern wood constructions have demonstrated, they not only endure an earthquake but are also afterwards still habitable. Scientifically this research is corroborated by practical experiments such as the last one in Japan.

In Miki by Kobe an original-sized, seven-storey, wood building was subjected to the power of the heaviest earthquakes of Kobe in 1995 by Italian engineers, on the largest test stand in the world, in the Japanese catastrophe research institute NIED. The 7.50 m wide, 13.50 m deep and 23.50 m high building was composed entirely from cross laminated timber. Walls and ceilings were connected with steel plate connectors, nails and self-boring wood screws. Tension anchors interconnected the walls through the ceiling boards. The earthquake table was allowed to move horizontally in both directions with a maximum speed of 2 m/s up to 1 m, vertically with 70 cm/s up to 70 cm. The effect on the "Test specimen" could then be measured and evaluated.

The results of the experimental series with a whole series of heavy earthquake simulations were impressive. The building withstood the loads without enduring deformations. Smaller damage could be repaired thus the building was completely usable even after the experiments, from structural collapse – not a trace. With the rebuilding of the Italian city L'Aquila, which was destroyed by an earthquake in the spring of 2009, earthquake-proof wooden housing will now be developed.

Figure 2.113
An international team of experts evaluate the results.

Picture credits

Title:
Stora Enso Timber, Bad St. Leonhard (A)

0.1:
Ludger Dederich, Bonn (D)

1.1, 1.3:
Stora Enso Timber, Bad St. Leonhard (A)

1.2, Single family house in Grünhain (D), Exhibition building in Gaildorf (D):
Paul Stephan, Gaildorf (D)

1.5, Single family house on Lake Constance (D), Single family house in the Dachau administrative district (D), School expansion in Düsseldorf (D), Department store in Junglinster (L), Multipurpose hall in Hawangen (D), New trade fair in Hamburg (D): Lignotrend, Weilheim (D)

1.4, 1.9., 1.10, 1.11 Table 1:
Chair in wood and building construction of the TU München (D)

Single family house in Eichgraben (A):
Superlab, Wien (A);
Stora Enso Timber, Bad St. Leonhard (A)

Semi-detached house in Sistrans (A):
DMH, Kufstein (A);
Bruno Klomfar & Christian Grass, Vienna (A)

Single family house in Puchheim (D), Single family house in Idstein (D), Car dealership in Kirchseeon (D), Residential house + Offices in Augsburg (D), Nature experience centre in Waren (D), Lift shaft for a school in Bad Reichenhall (D):
Finnforest Merk, Aichach (D)

Heightened housing development in Cologne (D): Archplan, Münster (D); Ludger Dederich, Bonn (D)

Terraced houses in Darmstadt (D):
Thomas Ott, Mühltal (D); Finnforest Merk, Aichach (D)

Senior citizens home in Stockerau (A):
Grossmann construction, Rosenheim (D)

School in Frankfurt (D):
Kraneburg Photographie, Cologne (D)

Children's home in Deizisau (D):
Dietmar Strauss, Besigheim (D);
Lignotrend, Weilheim (D)

Day-care centre in Darmstadt (D):
Holzabsatzfonds, Bonn (D)

Bakery in Annaberg (A):
Stora Enso Timber, Bad St. Leonhard (A);
DMH, Kufstein (D)

Church in Regensburg (D):
Siegfried Wameser, Munich (D);
Architect's office Ricco Johanson;
Finnforest Merk, Aichach

Sports hall in Brussels (B):
Eugen Decker Holzindustrie, Morbach (D)

Traffic bridge in Kössen (D):
R. Exenberger, J. Pohlmann

Look-out tower in Stetten (D):
Stora Enso Timber, Bad St. Leonhard (A);
Graf Holztechnik, Horn (A)

Earthquake experiment in Japan:
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Studiengemeinschaft Holzleimbau e.V.

Studiengemeinschaft Holzleimbau e.V.
Heinz-Fangman-Straße 2
D-42287 Wuppertal
+49 (0)2 02 / 769 72 73-5 Fax
info@brettsperrholz.org
www.brettsperrholz.org
www.ingenieurholzbau.de

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