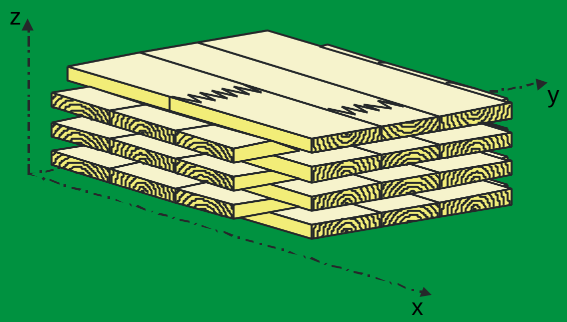
RESEARCH

TUG

STUDY

SOLID Timber Construction

A construction system for residential houses, office and industrial buildings



Gerhard Schickhofer
Graz University of Technology

Björn Hasewend
Lignum Research Graz

Graz, September 2000

contact:

Graz University of Technology,
Institute for Steel, Timber and Shell Structures,
Department of Timber Engineering
Prof. Dr. Gerhard Schickhofer
Lessingstraße 25, A-8010 Graz
phone: (0043) 0316 873-6702, fax: -6707
email: schickhofer@steel.tu-graz.ac.at
schickhofer@lignum.tu-graz.ac.at
homepage: www.lignum.at

Lignum Research
Association for Timber Research
Graz
Dipl.-Ing. Björn Hasewend
Lessingstraße 25, A-8010 Graz
phone: (0043) 0316 873-6703, fax: -6707
email: bjoern.hasewend@lignum.tu-graz.ac.at
homepage: www.lignum.at

Solid timber construction

A construction system for residential houses, office and industrial buildings

Gerhard Schickhofer
Graz University of Technology, Institute for Steel, Timber and Shell Structures, Department of Timber Engineering, Austria

Björn Hasewend
Lignum Research Graz, Austria

Abstract: The central theme and focus of the COST Action E5 'Timber Frame Building Systems' is to promote the competitive strength of 'lightweight timber construction' and international co-operations based on this system. This short paper is intended to discuss so-called 'solid timber construction' as an alternative to 'lightweight timber construction' as part of the 'Timber Construction in the New Millennium' workshop. The Department of Timber Engineering at Graz University of Technology (TUG) has been focusing research on this subject since 1990, documented by numerous scientific papers (dissertations, research, post-doctoral theses), implementation efforts (approvals in Austria and Germany), and tests with this system of construction (buildings). This paper will briefly describe the current status of these efforts. Starting with a chronological outline of the development of this system of construction – 'milestones' in the form of a C.V. of 'solid timber construction' regarding papers written at the Department of Wood Construction at TUG – the paper will then discuss the principle structure of cross-laminated timber and possible product combinations. The paper will also discuss other (product) development potentials concerning 'solid timber construction' – veneered plywood and particle plywood, subsequently presenting housing, office and industrial buildings completed or currently in planning. These buildings are documented in detail in the transfer project 'Quality Profile Styria (QPS)' – also: 'Quality Profile Austria (QPA)' – in order to provide a basis for drawing up a 'solid timber construction' quality profile.

1 C.V. OF SOLID TIMBER CONSTRUCTION

1.1 The period between 1990 and 2000

1990:
Start of activities regarding area-covering composite structures. Study of fibre-plastic composites.
1994:
Presentation of the dissertation on the subject of 'Rigid and flexible composites in area-covering laminated wood structures'.
1997:
Implementation of the research project 'Development of high-performance and economical construction elements to add value to low-grade sawn timber'.
'Physical investigation and development of jointing details for multi-storey housing using cross-laminated solid timber board'.
1998:
Preparatory work for obtaining the necessary approvals, entitled 'Construction product guideline as a basis of the approval procedure for the cross-laminated solid timber product'.
Cross-laminated timber is approved by the Austrian Technical Approval (ÖTZ) authorities at the end of the year.
The same year, cross-laminated timber board elements were used as T-cross section board carriageway slabs on road bridges.
1999:
'Wooden carriageway slabs – example: solid cross-laminated board'.
Start of planning and construction work for the Building Technology Centre (BTZ) of Graz University of Technology, primarily using cross-laminated timber board as the load-bearing product.
Presentation of the post-doctoral thesis 'From basic research to applied research to using innovative wood construction products such as high-performance glued laminated timber and

optimised cross-laminated timber'.
2000:
Cross-laminated timber, as a construction product, is approved for use in Germany on the basis of a expert's statement.
Start of the transfer project 'Quality profile and mark of quality: innovative wood construction in Styria', in short. Quality Profile Styria (QPS).

2 FROM BUILDING PRODUCT TO BUILDING

2.1 Cross-laminated timber – an approved building product

In order to obtain a high-quality plywood board product, the following minimum parameters must be observed:

Cross-laminated timber is produced mainly on the basis of boards from the edge of the trunk. At least 90 % of individual boards must conform to grade S10. It is noted that the material benchmarks in the trunk edge zones are usually higher (often grade S13) than so-called 'bulk timber' sawn timber.

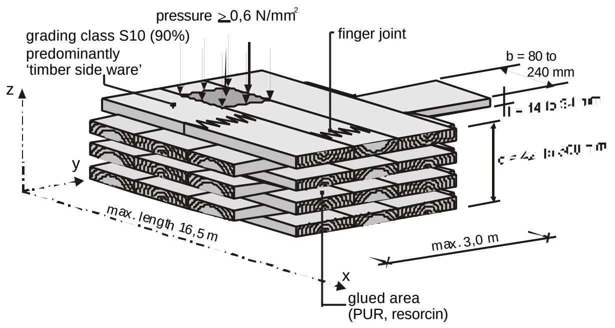
The width of the individual board must be between 80 mm and 240 mm. The finished board must consist of at least three layers and be of symmetrical make-up. The thickness of the layer – and thus the thickness of the boards planed and dovetailed on four sides – ranges from 14 mm to a maximum of 34 mm. In addition, the width-thickness ratio must be 4:1.

The board is made up by layering the individual boards; the separate layers are usually applied at an angle of 90 degrees to each other. The quasi-rigid connection of the individual layers is ensured by gluing the boards together with an outdoor glue.

The 'laminate package', in accordance with the static-structural requirements for such components, is then transported to the press and pressed with a pressure of at least 0.6 N/mm^2 to form cross-laminated timber board (approx. 3000 to at board dimensions of 3.0 m x 16.5 m).

The plate thus produced is cut to size, inserting any openings and break-throughs required and prepared for transport.

Cross Laminated Timber
cross section with 7 layers



2.2 Cross-sectional shapes with cross-laminated timber (CLT) and combinations with glued laminated timber (GLT)

Observing the aforementioned requirements for product approval, the cross-laminated timber boards are area-covering products available as load-transferring boards and discs.
A three-layer (min.t = 42 mm – max.t = 102 mm) and five-layer (min.t = 70 mm – max.t = 170 mm) cross-laminated timber board is presented below. These boards are mainly used in this form as wall elements for housing and office buildings.

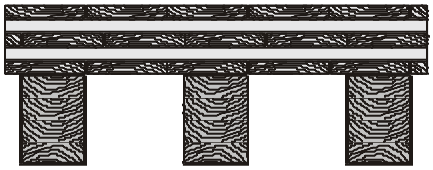
CROSS LAMINATED TIMBER (CLT):

CLT, 3-l:
min.t = 42 mm (3 x 14 mm)
max.t = 102 mm (3 x 34 mm)

CLT, 5-l:
min.t = 70 mm (5 x 14 mm)
max.t = 170 mm (5 x 34 mm)

Boards with T-cross-sections and cellular cross-sections can be produced by combining cross-laminated timber board elements with glued laminated timber in the form of a quasi-rigid composite. The applications for these high-performance cross-sectional shapes range from wide-span ceiling and roof elements to high-load wall elements for industrial construction. In addition, the boards have also been tested as carriageway slabs on wooden bridges.

T-cross section,
e.g.: CLT, 5-l + GLT GL24 to GL36



Cellular box girder cross section,
e.g.: CLT, 3-l + GLT (GL24 to GL36) + CLT 3-l

2.3 *Prefabricated large-format cross-laminated timber board components*

Thanks to the possible dimensions, from w = 3.0 m, l = 16.5 m and min.t = 42 mm – max.t = 500 mm, it is possible to prefabricate large-format, load-transferring components for walls, roofs and ceilings. The aim of 'solid timber construction' is thus to achieve a maximum level of prefabrication, to develop a suitable jointing technology so as to reduce on-site assembly time. One example is construction of the Building Technology Centre (BTZ) of Graz University of Technology.

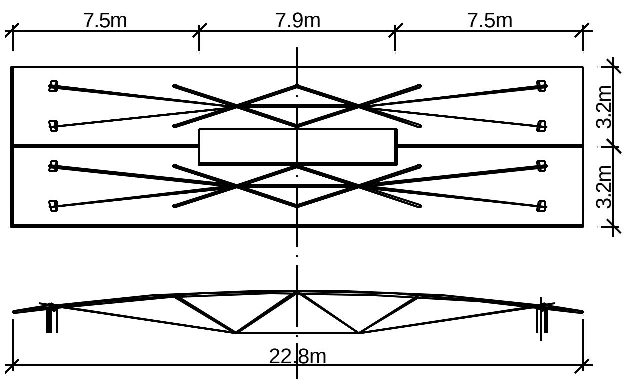


Figure: Roof elements for the large test hall of the new Building Technology Center Graz: CLT-plates with steel underspanning

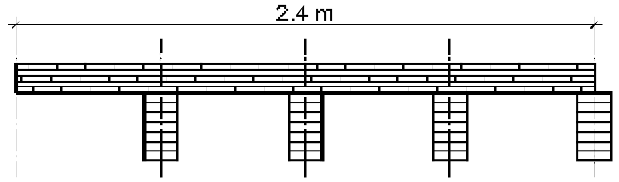


Figure: Roof elements for the offices of the new Building Technology Center Graz: T-cross section

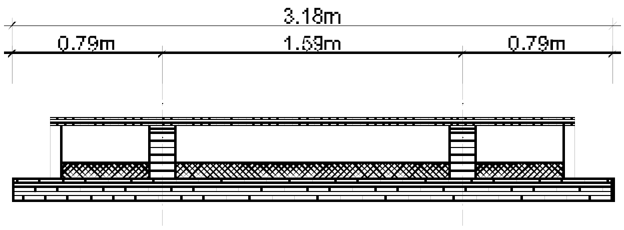
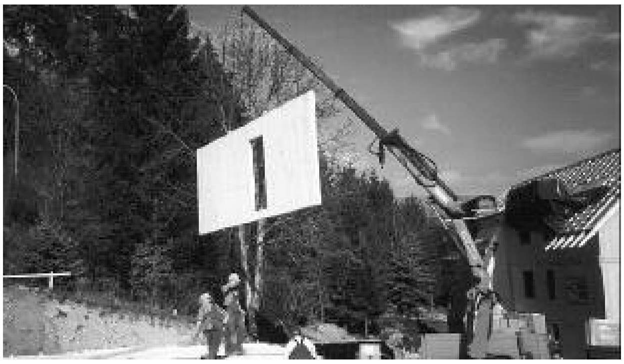


Figure: Wall elements for the large test hall of the new Building Technology Center Graz: Cellular box girder cross section

2.4 *Transport and assembly – building construction*

The size and shape of the prefabricated elements is generally determined by restrictions regarding transport and assembly. Of course, these specifications also influence planning work and thus possible applications for these elements. The following pictures provide an insight into handling of such prefabricated components ex works.



2.5 *'Quality Profile Styria (QPS)' – criteria and quality standards for 'solid timber construction' in multi-storey housing construction*

There were several objectives in developing this quality profile, as outlined below:

1. The aim is to develop a catalogue of requirements for multi-storey housing construction with wood. The catalogue of requirements is to contain all essential, quality-assuring criteria with relevant standards, guidelines and other rules. The catalogue covers all stages of implementing a wooden building from (1) planning to (2) products, (3) production, (4) transport and assembly, to (5) certification of the necessary steps, to completion.

2. The aim is to elaborate a 'matrix of requirements'. This 'matrix of requirements' is to reflect the content of the catalogue of requirements in a clear-cut, comprehensible form.

3. The aim is to build up a wood construction database. Extensive documentation of wooden constructions (description of building, planning documents, photos and test certificates). The buildings in this database are also used to check and, if necessary, improve the practical usefulness of the 'matrix of requirements'.

4. The aim is to specify guiding details. Construction details taken from the building documentation are revised and optimised. The resultant guiding details correspond to the requirements of the catalogue of requirements and the 'matrix of requirements' and thus serve as a planning aid for users (planner, companies, authorities).

5. The aim of the project, finally, is to develop and establish a mark of quality, 'Innovative Wood Construction in Styria', taking into account the catalogue of requirements according to the first project objective. The mark of quality 'Innovative Wood Construction in Styria' should be awarded to companies by a constitutive association of marks of quality based upon a system of internal and external monitoring. Only these companies are entitled to bear the mark of quality 'Innovative Wood Construction in Styria'.

The matrix of requirements, the building database and the guiding details of this quality profile are electronically prepared (Internet, CD-ROM) and networked. The result is an efficient instrument for implementing high-quality 'solid timber' housing projects.

3 OBJECTS WITH CROSS LAMINATED TIMBER

3.1 Terrace houses, Frohnleiten, Styria, A

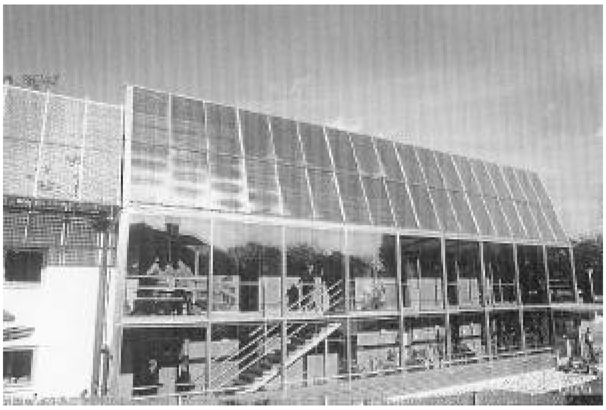
Building owner:
Non-commercial Styrian Building Society
Architect:
D. Groß-Ransbach
F. v.Hohenzollern
Building information:
2 ½ floors
12 flats
Year of construction:
1999-2000

3.2 Multi-storey residential building, Leitendorf I, Leoben, Styria, A

Building owner:
Non-commercial Styrian Building Society
Architect:
R. Paschek
Building information:
3 floors
6 flats
Year of construction:
1998

3.3 Multi-storey residential buildings, Leitendorf II, Leoben, Styria, A

Building owner:
Non-commercial Styrian Building Society
Architect:
R. Paschek
Building information:
2 buildings
3 floors
12 flats
Year of construction:
1999 - 2000

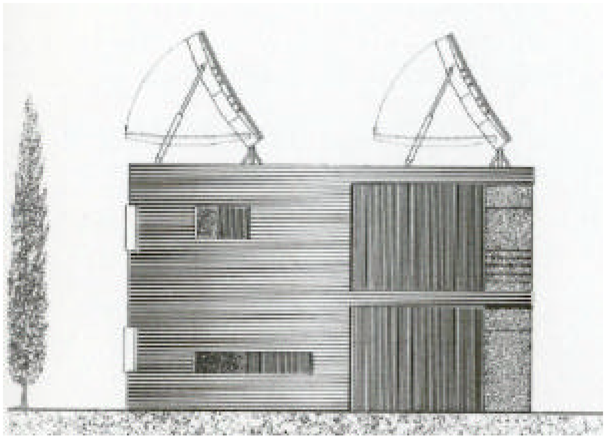


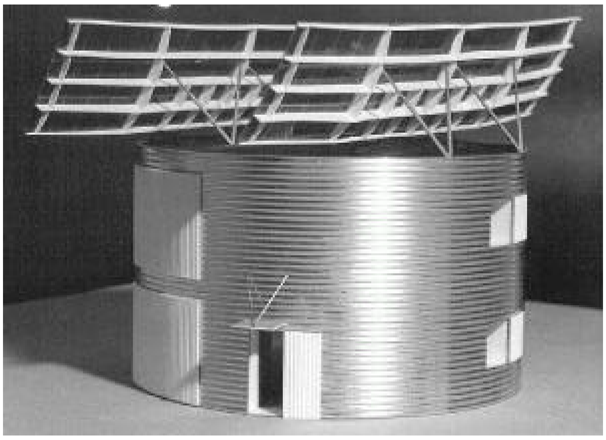
3.4 *Residential and office buildings 'Sundays' Gleisdorf, Styria, A*

Building owner:
Lieb Bau Weiz
Architect:
G. W. Reinberg
Building information:
3 buildings (1 office building, 2 terrace buildings)
2 floors
6 flats
Year of construction:
1998 - 1999

3.5 *Residential house 'Gemini'*

Building owner:
Working Group 'Gemini'
Architect:
E. Kaltenegger
Building information:
2 floors
1 flat / 120 m^2
Object in planning





3.6 Central office of the Austrian Federal Forestry AG, Vienna, Austria

Building owner:
    Austrian Federal Forestry AG
Architect:
    H. Ronacher
Building information:
    4 floors
    3500 m^2
Object in planning

3.7 Production hall, Katsch/Mur, Styria, A

Building owner:
    KLH Massivholz GesmbH.
Architect:
    J. Riebenbauer
Building information:
    650 m^2
Year of construction:
    1998 - 1999

3.8 Production hall, Preding, Styria, A

Building owner:
    Holzindustrie Preding.
Building information:
    6260 m^2
Year of construction:
    1998

3.9 *Building Technology Center, Graz, Styria, A*

Building owner:
Graz University of Technology
Architects:
W. Kampits
W. Nussmüller
Building information:
600 m^2 office area
3480 m^2 labs and large test hall
Object in implementation

Other objects in planning or implementation, e.g.:

- **Terrace buildings, Frohnleiten, Styria, A**

Building owner:
Non-commercial Styrian Building Society
Architects:
D. Groß-Ransbach
F. v.Hohenzollern
Building information:
2 ½ floors
18 flats
Object in implementation

- **Multi-storey building, Judenburg, Styria, A**

Building owner:
Non-commercial Building Society Ennstal
Architect:
H. Hierzegger
Building information:
3 floors
36 flats
Object in implementation

4 DEVELOPMENT POTENTIAL OF SOLID TIMBER CONSTRUCTION

Both the above buildings already implemented and such buildings in planning show clearly that the test phase of ‘solid timber construction’ can be regarded as having been completed. As a result, the situation is that this system of construction must prove successful in the long term with regard to quality demands and economic efficiency. In order to achieve this objective, the following steps should be taken in terms of development:

Elaboration of calculation and planning aids in the form of software modules (e.g. for calculation of cross-sections for various composite cross-sections, calculation of cross-section loads, and calculation and verification for wall, roof and ceiling elements, etc.) and release of guiding details (see ‘Quality Profile Styria (QPS)’).

Development of a suitable jointing technology for optimum, powerful connection of large-format building elements.

Further development and improvement of existing cross-laminated timber board products and definition of other possible combinations and applications.

Development of innovative solid plywood products using basic wood products with a varying degree of breakdown (veneers and strands).

Creation of universal guidelines regarding production and use of CLT board in order to establish ‘solid timber construction’ at the international level.

This description of ‘solid timber construction’ is intended to present the importance of this system of construction and, on the other hand, to discuss whether and in what way joint activities are possible to help establish ‘solid timber construction’ more quickly. Further international activities should take into account both ‘wood construction systems’ in the form of research and co-operation projects.