Glued Wood Products for Structural Use
Cross Laminated Timber - Idea | Product | Building Technique

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Graz University of Technology

Presentation in the frame of the
3rd EUROPEAN FOREST WEEK - SILVA2015
Engelberg, 3rd November 2015
Introduction

From Idea to Product

From Product to Building Technique

Concluding Remarks
Introduction

- From Idea to Product
- From Product to Building Technique
- Concluding Remarks
Graz University of Technology
7 faculties | 12,800 students | staff 2,400 (2015/15)
budget: € 207 Mill. (1/3 3rd party budget)

Faculty of Civil Engineering Sciences
15 institutes | about 1,500 students (2014/15)

Institute of Timber Engineering and Wood Technology
1991: Chair for Timber Engineering
10/2004: Institute of Timber Engineering and Wood Technology
Scientific staff: 8 FTE | 3rd party-budget: € 380,000 (2015)

Competence Centre holz.bau forschungs gmbh
12/2002 Competence Centre holz.bau forschungs gmbh
11/2012 3rd acceptance of a 4-year-funded programme: COMET-Project “focus_sts”
Scientific staff: 11 FTE | budget: € 680,000 (2014)
R&D topics regarding timber engineering and wood technology at Graz University of Technology

- Shell and Spatial Timber Constructions (SSTC)
- Innovative and Intelligent Connection Systems (IICS)
- Lightweight and Hybrid Hardwood Applications (LHHA)
- Evaluation and Maintenance of Historic Structures (EMHS)
R&D topics regarding timber engineering and wood technology at Graz University of Technology

- Shell and Spatial Timber Constructions (SSTC)
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Classification of Construction Techniques

Construction Techniques

Lightweight Constructions

Solid Constructions

Solid Construction in Brickwork

Solid Construction in Reinforced Concrete

Solid Timber Construction

Timber Lightweight Construction

...
Classification of Construction Techniques

**Timber** Lightweight Construction
- bar-like
  - post and beam constructions
  - frame constructions
- frame-like

**Solid Timber** Construction
- bar-like (∥ to grain)
- bar-like (⊥ to grain)
  - bar-like wall constructions (especially in Scandinavia)
  - "Blockhaus"-constructions (especially in alpine regions)

Solid Timber Constructions have always been part of the European building culture, especially well-wooded regions such as...
Classification of Construction Techniques

**Timber Lightweight Construction**
- bar-like
- post and beam constructions
- frame-like
- frame constructions

**Solid Timber Construction**
- locked crosswise (‖ and ⊥ to grain)

**Innovation**
- Introduction
- From Idea to Product
- From Product to Building Technique
- Concluding Remarks
STEPs intermediate products | steps in production

**STEP I**

log

Original Aim - adding value:
utilisation of side boards (regarded as fall-out, ~ 15% of total crop) for timber engineered products
STEP I
log

Situation Nowadays:
utilisation of main and side boards for CLT production

500 to 600 mm
STEP I
log

STEP II
board

STEP III
finger jointed lamella

**intermediate products | steps in production**

**breakdown**
- classification / grading
- trimming

**FROM IDEA TO PRODUCT**
- 500 to 600 mm

**finger jointing**
STEPs

STEP III
finger jointed lamella

intermediate products | steps in production

STEP IV
cross laminated timber (CLT)

FROM IDEA TO PRODUCT

finger jointing

detail

edge bonding

surface bonding

STEP III
finger jointed lamella

STEP IV
cross laminated timber (CLT)

1.25 m to 3.0 m

till 16.5 m (or longer)

intermediate STEP
single-layer panel
Lay-ups | Dimensions | Combinations | Solutions

MINIMUM
Walls, Secondary Constructions
51 mm
3 x 17 mm
3 layers

STANDARD
Walls, Floors
(l ≤ 5.5 m)
160 mm
40 | 20 | 40 | 20 | 40 mm
5 layers

MAXIMUM
Floors, Bridge Decks
400 mm
2 x 40 | 30 | 40 | 30 | 40 | 30 | 40 | 30 | 2 x 40 mm
11 layers

SUBSTITUTION
similar local species regarding mech. properties (e.g. Sugi, Sitka Spruce, SPF)

STANDARD
Norway Spruce

HYBRID
diff. strength classes (C16/C30), diff. species (birch/spruce | eucalyptus/radiata pine)

FROM IDEA TO PRODUCT
Lay-ups | Dimensions | Combinations | Solutions

<table>
<thead>
<tr>
<th>Lay-ups</th>
<th>Dimensions</th>
<th>Combinations</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT</td>
<td>GLT</td>
<td>Ripped Plate</td>
<td></td>
</tr>
<tr>
<td>CLT</td>
<td>GLT/CLT</td>
<td>Box Girder</td>
<td></td>
</tr>
<tr>
<td>CLT</td>
<td>RFC</td>
<td>Composite Floor</td>
<td></td>
</tr>
<tr>
<td>CLT</td>
<td>UHPP</td>
<td>Trapezoidal Cross Section</td>
<td></td>
</tr>
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<tr>
<td>CLT</td>
<td>STEEL</td>
<td>Trapezoidal Cross Section</td>
<td></td>
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</tbody>
</table>
CLT element ready for cutting and joining

hydraulic CLT press

adhesive application next layer stand-by

cross layers composing & compressing

fully automated CLT production line by MINDA

- CLT production of single lamellas
- ≤ 14 press cycles / shift; 1K-PUR (Purbond)
- ≈ 20 TSD m³ / shift / year

© Minda Industrieanlagen GmbH

Schickhofer G (2011) Presentation, Zurich, Switzerland, 25th October 2011; adapted
Transport & Assembling …

storage (production site)

charging and transport

discharging (building site)

assembling of roof elements

assembling of ceiling elements

assembling of wall elements
Introduction

From Idea to Product

From Product to Building Technique

Concluding Remarks
Parallel Development in AT (theoretical preparation) and DE (practical execution)

draft of a first 4 storey building in solid timber construction with CLT


CLT elements
residential housing Aichach (DE | 1995):

- first multi-storey timber building in solid timber construction with CLT („Dickholz“)
- production and execution by Merk Holzbau GmbH & Co. (K. Moser)

Sources: © Bauen mit Holz 11/95
## Use of CLT as 2D Elements

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Walls</strong></td>
<td>line supported, cantilever, with openings, point supported</td>
</tr>
<tr>
<td><strong>Ceilings</strong></td>
<td>line supported, cantilever, with openings, point supported</td>
</tr>
<tr>
<td><strong>Plates</strong></td>
<td>line supported, cantilever, with openings, point supported</td>
</tr>
<tr>
<td><strong>Roofs</strong></td>
<td>line supported, cantilever, with openings, point supported</td>
</tr>
<tr>
<td><strong>Folded</strong></td>
<td>line supported, cantilever, with openings, point supported</td>
</tr>
<tr>
<td><strong>Elements</strong></td>
<td>line supported, cantilever, with openings, point supported</td>
</tr>
<tr>
<td><strong>Curved</strong></td>
<td>line supported, cantilever, with openings, point supported</td>
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- **e.g.** balcony, chimney, staircase, glass facade, porch roof, roof light
Use of CLT as 1D Elements

**DETAIL 1**
beam without openings

detail 1: built up of a 5-layered beam element

**DETAIL 2**
tapered beam with notched support and openings

detail 2: notched support

**DETAIL 3**
beam as `Vierendeel system´
detail 3: opening

vertical (cross) layers as `reinforcement´ of CLT
(high capacity in shear and tension perp. to grain)
Residential Buildings

Hartberg (AUT) | 2008
CLT by KLH

Graz (AUT) | 2007
CLT by Mayr-Melnhof Kaufmann

Eichgraben (AUT) | 2008
CLT by Stora Enso Timber

© Pictures: holz.bau forschungs gmbh, Graz
© Pictures: Paul Ott, Graz
© Pictures: Stora Enso Timber
Multi-Storey Buildings

3-storey building
Judenburg (AUT) | 2002
CLT by KLH

4-storey building
Judenburg (AUT) | 2002
CLT by KLH

5-storey building
Berlin (GER) | 2010
CLT by KLH

© Pictures: holz.bau forschungs gmbh, Graz
© Pictures: KLH
© Pictures: KLH

FROM PRDUCT TO BUILDING TECHNIQUE
Multi-Storey Buildings

5-storey building
Vienna (AUT) | 2005
CLT by KLH

8-storey building
London (UK) | 2008
CLT by KLH

10-storey building
Melbourne (AUS) | 2012
CLT by KLH

© Pictures: KLH

FROM PRODUCT TO BUILDING TECHNIQUE
Storey Development of the Last 20 Years

- Aichach, 3 S (DE)
- Judenbg., 4 S (AT)
- Wien, 5 S (AT)
- London, 8 S (UK)
- Melbourne, 10 S (AU)
- Bergen, 14 S (NO)
Storey Development of the Last 20 Years

M. Green: “The race is on!”

TU Graz Recommendation
(up to 5 storeys)
Kindergarten

Peggau (AUT) | 2009
CLT by Mayr-Melnhof Kaufmann

Innsbruck (AUT) | 2008
CLT by Binderholz Bausysteme

Augsburg (GER) | 2013
CLT by KLH

© Pictures: Mayr-Melnhof Kaufmann
© Pictures: Binderholz Bausysteme GmbH
© Pictures: KLH
Office Buildings

© Pictures: Mayr-Melnhof Kaufmann

Headquarter Mayr-Melnhof
Leoben (AUT) | 2008
CLT by Mayr-Melnhof Kaufmann

© Pictures: Binderholz Bausysteme GmbH

Headquarter Binder Holz
Fügen (AUT) | 2007
CLT by Binderholz Bausysteme

© Pictures: holz.bau forschungs gmbh, Graz

Building Research Center
TU Graz (AUT) | 2006
CLT by Holzleimbau Stingl
Special Constructions

Vennesla Library
Vennesla (NOR) | 2011
CLT by KLH

Swimming Pool at top level
Hagenberg (AUT) | 2010
CLT by Mayr-Melnhof Kaufmann

Footbridge over the river Raab
Feldbach (AUT) | 1998
CLT by Holzleimbau Stingl
Special Constructions

Timber Tower®
Hannover (GER) | 2012
CLT by KLH and Stora Enso

Monte Rosa
Valais (CH) | 2010
CLT by Schillinger

Endless Stair
London (GBR) | 2013
CLT by Imola Legno

© Pictures: KLH and Stora Enso

© Pictures: Schillinger

© Pictures: AHEC
Introduction

From Idea to Product

From Product to Building Technique

Concluding Remarks
Global Production of CLT | 1995-2015

Phase 1: Niche
- ideas | patents | prototypes

Phase 2:
- pilot projects
- regional | national challenge

Phase 3: Mass (?)
- worldwide | international challenge
- ≈ 650 ÷ 700 tsd.
- ≈ 550 tsd.

Markets:
- KLH production volume
- SET | BBS | MM

Approximate production volumes:
- ≈ 25 tsd.
- ≈ 50 tsd.
- ≈ 140 tsd.
- ≈ 550 tsd.

Time:
- 1995
- 2000
- 2005
- 2010
- 2013
- 2014
- 2015

CONCLUDING REMARKS
Global Production of CLT | 1995-2015

Phase 1: Niche | Phase 2: | Phase 3: Mass (?)

visibility

„don’t join because it’s in“

market entrance

KLH

≈ 140 tsd.

≈ 550 tsd.

phase 2

market entrance

SET | BBS | MM

≈ 5 %*

„don’t miss because it’s out“

20 %*

* volume in % of the total market potential (BSP|CLT ≡ BSH|GLT)

Gartner’s Hype Cycle

[J. Fenn, Gartner, Inc., 1995]
CONCLUDING REMARKS

Research at Graz University of Technology

Product Optimisation and Standardisation

 surface treatment (excellence lamella, coating cube)
 efficiency (stiffness grading, utilisation of wood diversity)

“green_city” = “green_building” + “green_mobility”

 focus on 3- to 5-storey residential buildings

Source: A. Thiel, Stockholm (SE), 2015
CONCLUDING REMARKS

Product Optimisation and Standardisation

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“green_city” = “green_building” + “green_mobility”

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Constructing with Hybrids

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CONCLUDING REMARKS

Research at Graz University of Technology

**Product Optimisation and Standardisation**

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- efficiency (stiffness grading, utilisation of wood diversity)

“green_city” = “green_building” + “green_mobility”

- focus on 3- to 5-storey residential buildings

**Constructing with Modules**

source: http://architektur.mapolismagazin.com/
CONCLUDING REMARKS

Transfer at Graz University of Technology

Master Thesis | Diplomas

- Spiehs (1996)
- Jöbstl (2002)
- Pürgstaller (2008)
- Ehrhart (2014)

Seminars | Conferences | Books

- 5. GraHFT’06
- 1. GraHSofT’08
- BSPhandbuch (2009)
- COST FP1004 CLT conference proceedings (2013)

Software Applications

- CLTdesigner (2009)
- CLTcalculator (2013)
- CLT Wiki (2015)

50 out of 147 (since ’92) \( \equiv \frac{1}{3} \)
THANKS FOR ATTENTION!

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Approvals and Standardisation

1st STEP
National Approvals

2nd STEP
ETAs

3rd STEP
Standardisation

Austria
France
Germany
Russia
Spain

ISO 165
prEN 16351
EN 1995