Glued Wood Products for Structural Use

Cross Laminated Timber - Idea | Product | Building Technique

Prof. G. Schickhofer
Institute of Timber Engineering and Wood Technology
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**"

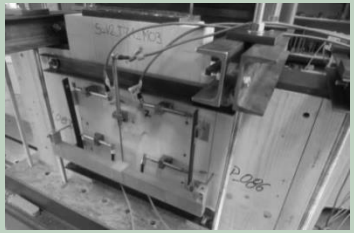
Scientific staff: **11 FTE** | budget: **€ 680,000** (2014)

lignum

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)


LAB | MECH | STOCH

lignum

R&D topics regarding timber engineering and wood technology at Graz University of Technology

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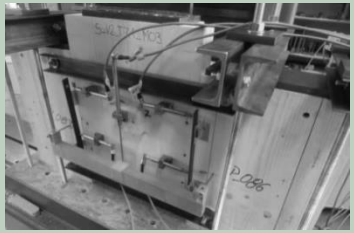
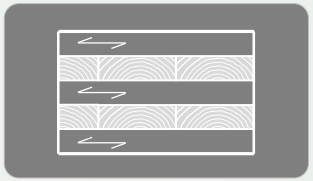



Lightweight and Hybrid Hardwood Applications (LHHA)


Evaluation and Maintenance of Historic Structures (EMHS)


LAB | MECH | STOCH



Classification of Construction Techniques

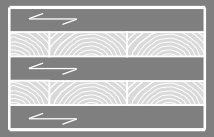
Construction Techniques

Lightweight Constructions

- ...
- ...
- **Timber Lightweight Construction**
- ...

Solid Constructions

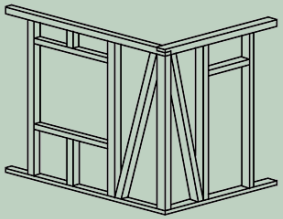
- **Solid Construction in Brickwork**
- **Solid Construction in Reinforced Concrete**
- **Solid Timber Construction**
- ...



Classification of Construction Techniques

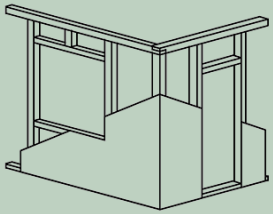
Timber Lightweight Construction

bar-like



post and beam constructions

frame-like



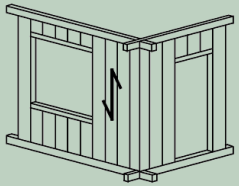
frame constructions

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

Solid **Timber** Construction

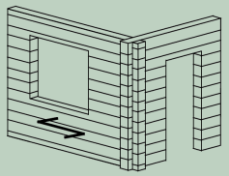
Tradition

bar-like (∥ to grain)

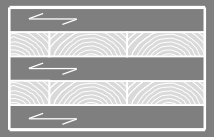


bar-like wall constructions (especially in Scandinavia)

bar-like (⊥ to grain)



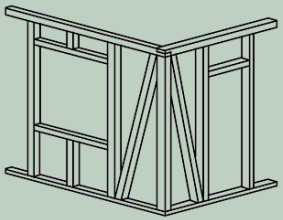
„Blockhaus“-constructions (especially in alpine regions)



Classification of Construction Techniques

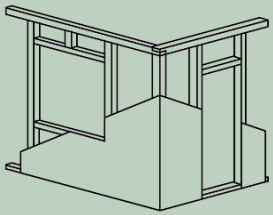
Timber Lightweight Construction

bar-like

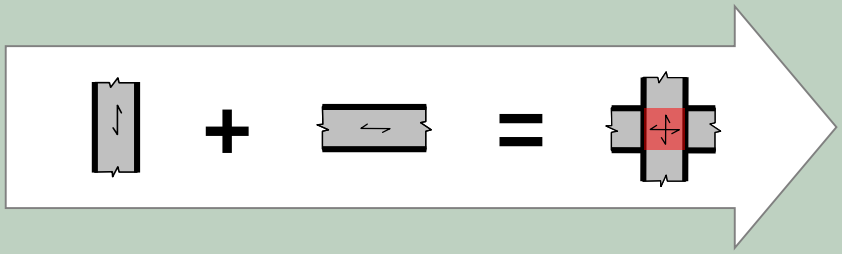


post and beam constructions

frame-like



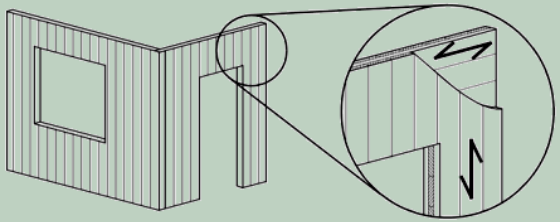
frame constructions



Innovation

Solid **Timber** Construction

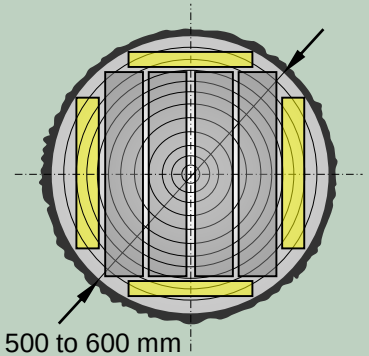
locked crosswise (∥ and⊥ to grain)



- Introduction
- **From Idea to Product**
- From Product to Building Technique
- Concluding Remarks

STEPs intermediate products | steps in production

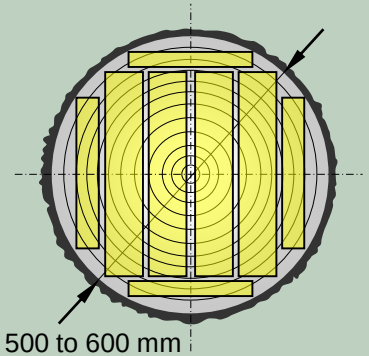
STEP I
log



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

STEPs intermediate products | steps in production

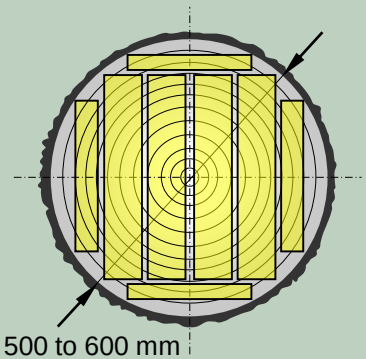
STEP I
log



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

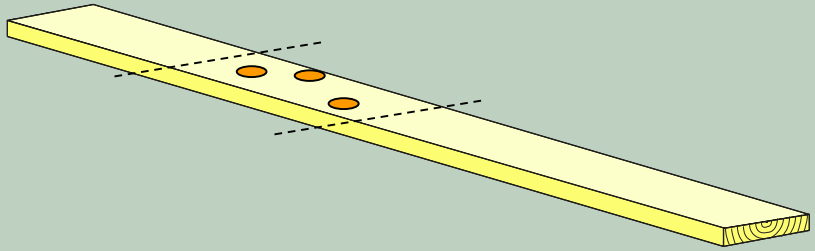
STEPs — intermediate products | steps in production

STEP I
log



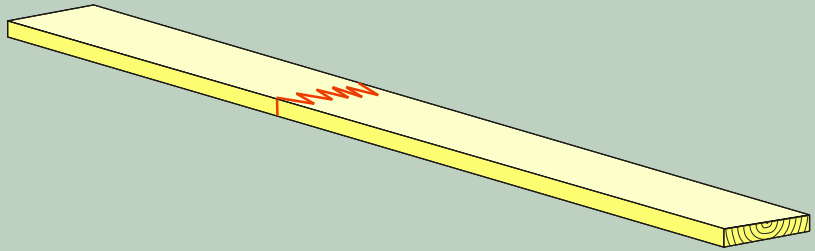
breakdown

STEP II
board



classification / grading
trimming

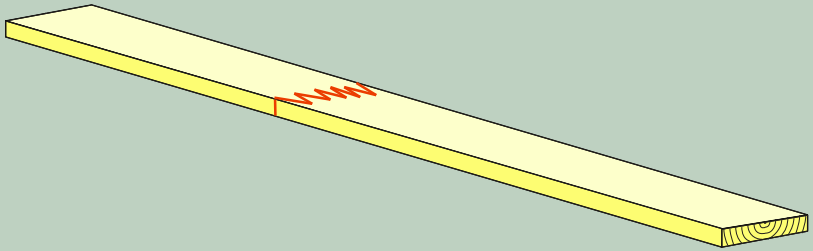
STEP III
finger jointed lamella



finger jointing

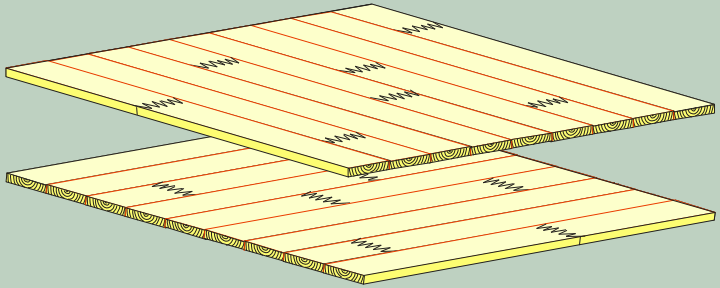
STEPs intermediate products | steps in production

STEP III
finger jointed lamella



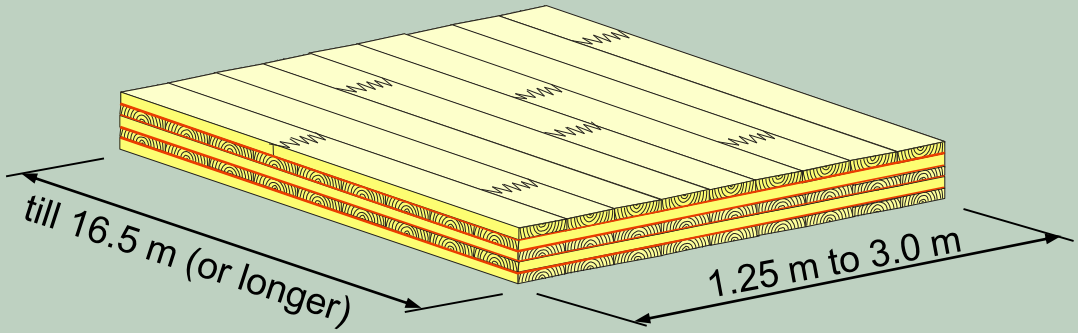
finger jointing

intermediate STEP
single-layer panel



edge bonding

STEP IV
cross laminated timber (CLT)



surface bonding

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

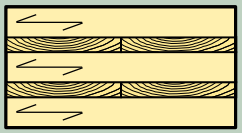
400 mm

2 x 40 | 30 | 40 | 30 | 40 | 30 | 40 | 30 | 2 x 40 mm

11 layers

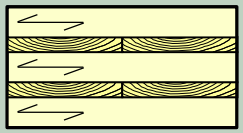
SUBSTITUTION

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



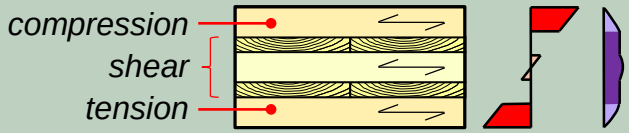
STANDARD

Norway Spruce



HYBRID

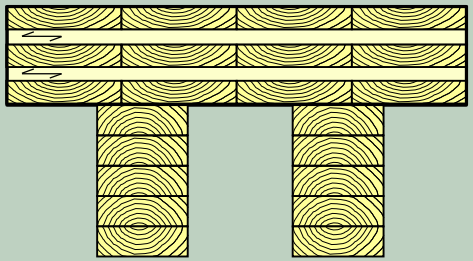
diff. strength classes (C16/C30), diff. species (birch/spruce | eucalyptus/radiata pine)



Lay-ups | Dimensions | Combinations | Solutions

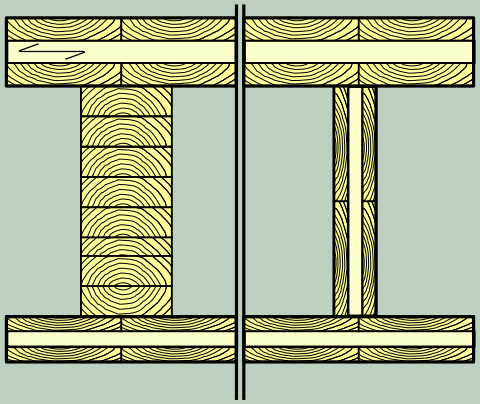
CLT | GLT

Ripped Plate



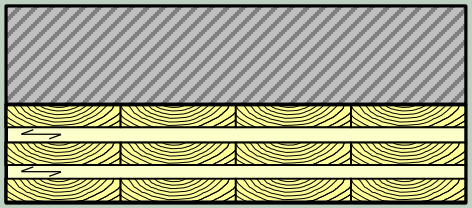
CLT | GLT/CLT

Box Girder



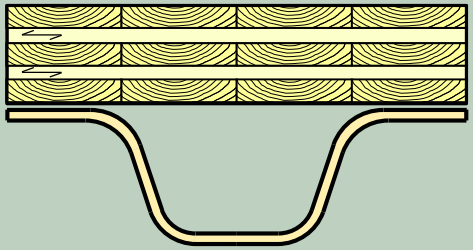
CLT | RFC

Composite Floor



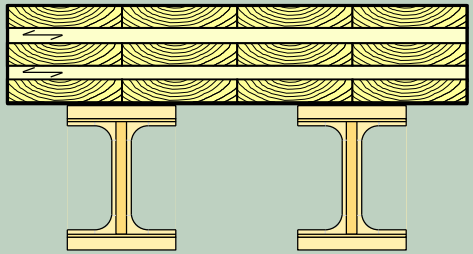
CLT | UHPP

Trapezoidal Cross Section



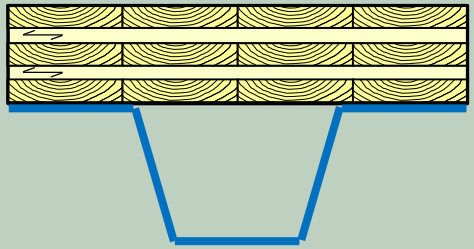
CLT | UHPP

I-Beam



CLT | STEEL

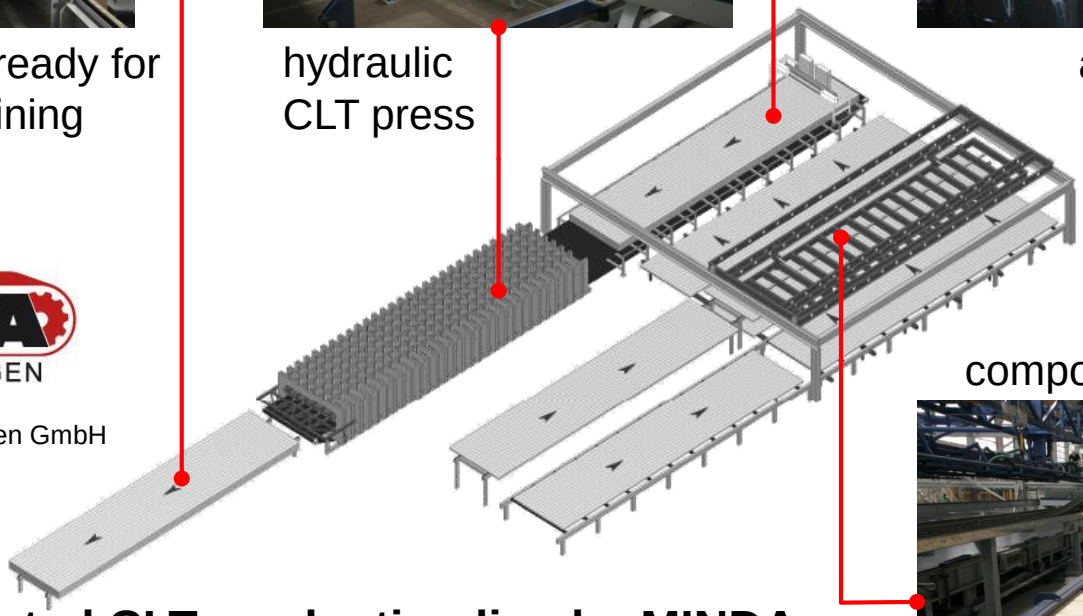
Trapezoidal Cross Section



CLT element ready for cutting and joining

hydraulic CLT press

adhesive application next layer stand-by



cross layers composing & compressing

© Minda Industrieanlagen GmbH

fully automated CLT production line by MINDA

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

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

Schickhofer G (2012) Presentation, Edinburgh, Scotland, 30th October 2012, adapted

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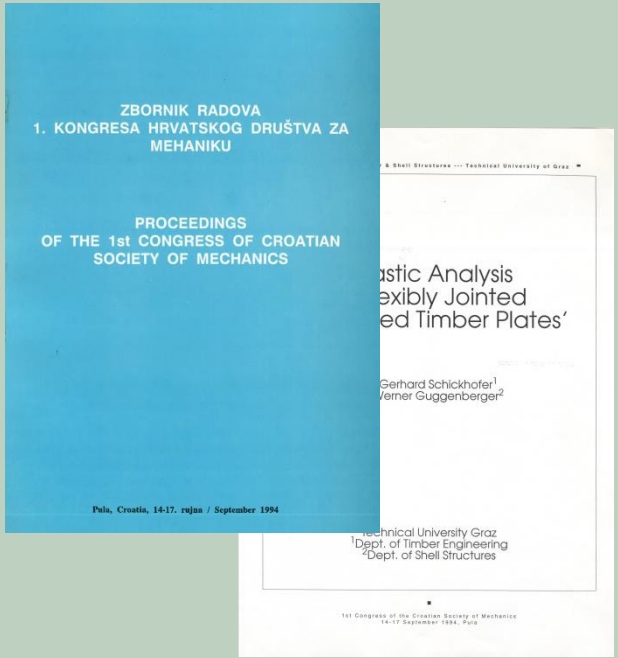
Parallel Development in AT (theoretical preparation) and DE (practical execution)



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

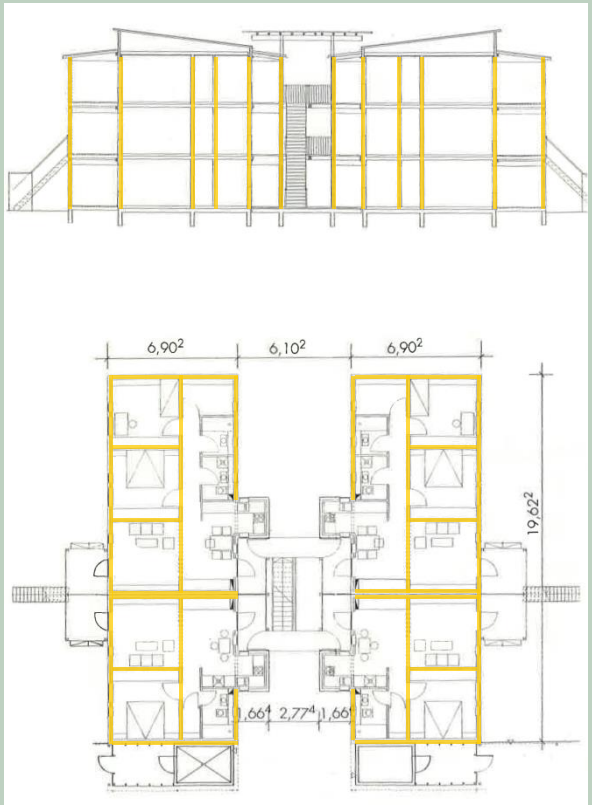
Schickhofer G, Guggenberger W (1994) Elastic Analysis of Flexibly Jointed Laminated Timber Plates. 1st Congress of the Croatian Society of Mechanics, Pula, Croatia

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

residential housing
Aichach (DE | 1995):

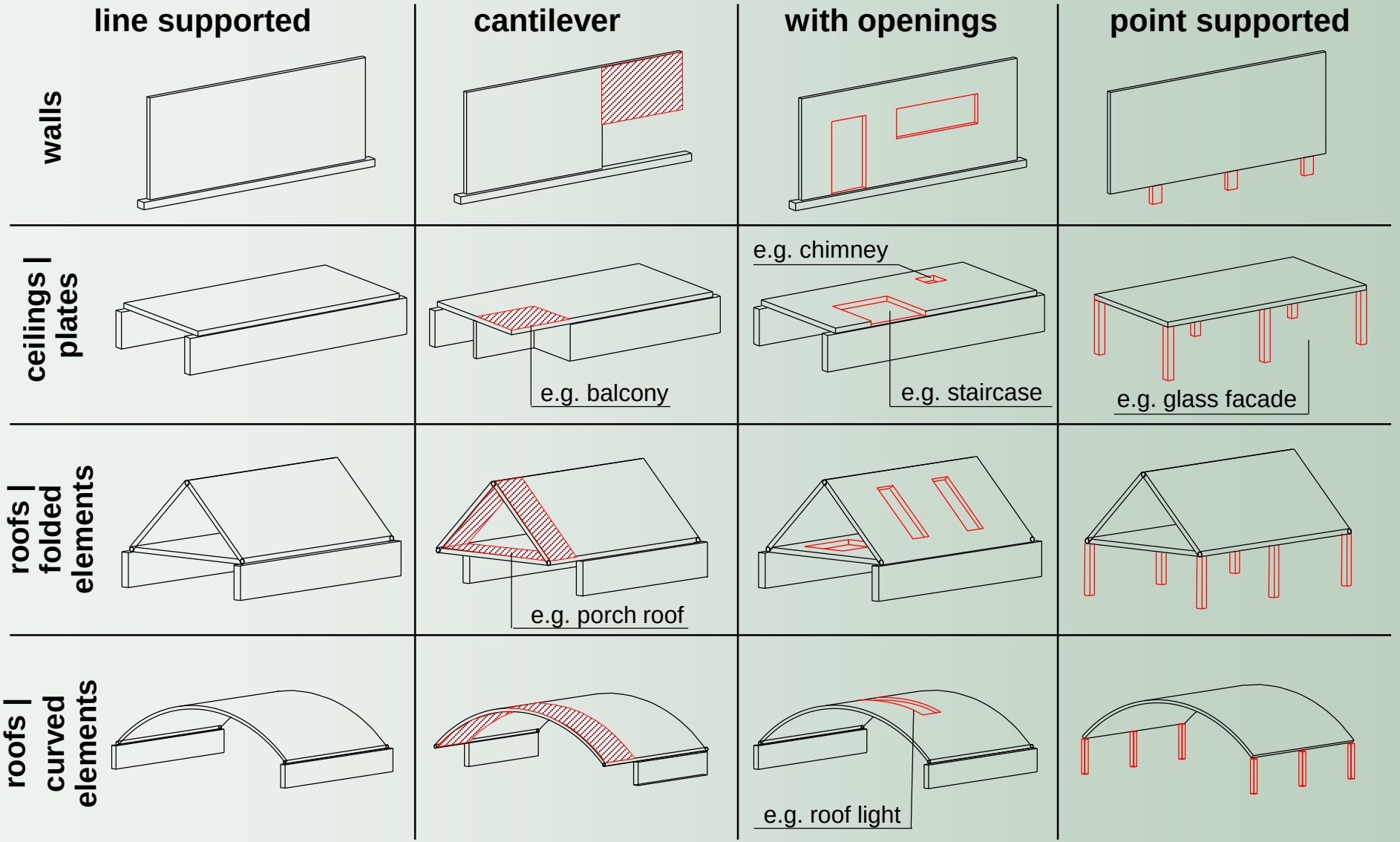
- first multi-storey timber building in solid timber construction with CLT **(„Dickholz“)**
- production and execution by Merk Holzbau GmbH & Co. (**K. Moser**)

Sources: © Bauen mit Holz 11/95

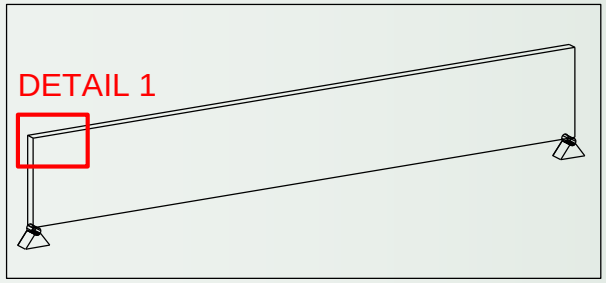


CLT elements

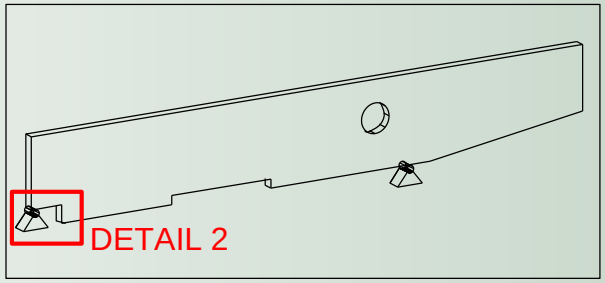
Use of CLT as 2D Elements



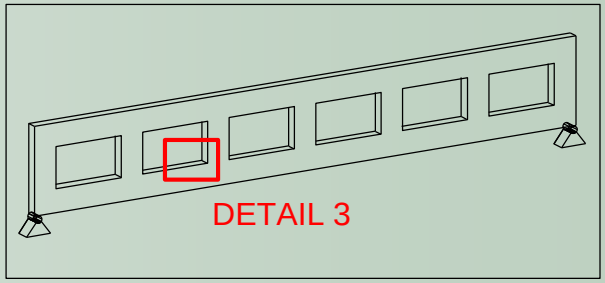
Use of CLT as 1D Elements



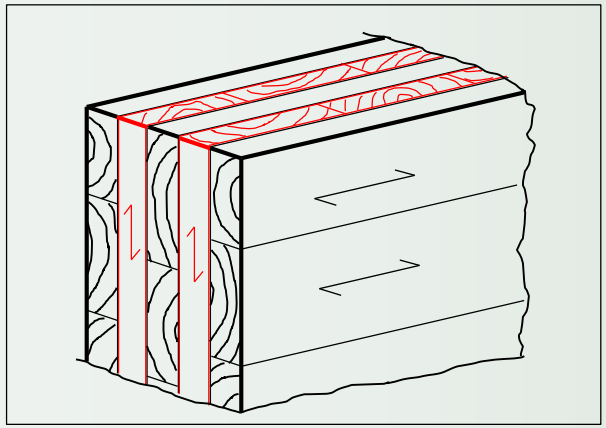
beam
without openings



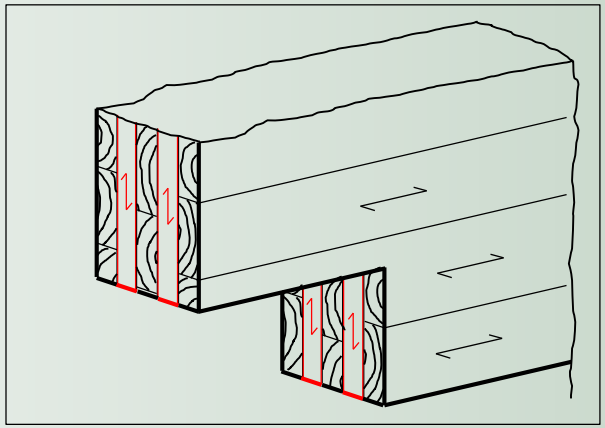
tapered beam with notched support
and openings



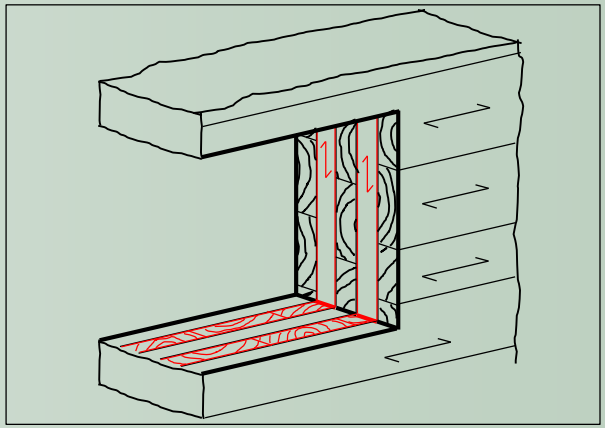
beam as `Vierendeel system´



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



detail 2:
notched support



detail 3:
opening

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

Residential Buildings

© Pictures: holz.bau forschungs gmbh, Graz

Hartberg (AUT) | 2008
CLT by KLH

© Pictures: Paul Ott, Graz

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

© Pictures: Stora Enso Timber

Eichgraben (AUT) | 2008
CLT by Stora EnsoTimber

Multi-Storey Buildings

© Pictures: holz.bau forschungs gmbh, Graz

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

© Pictures: KLH

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

© Pictures: KLH

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

Multi-Storey Buildings

© Pictures: KLH

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

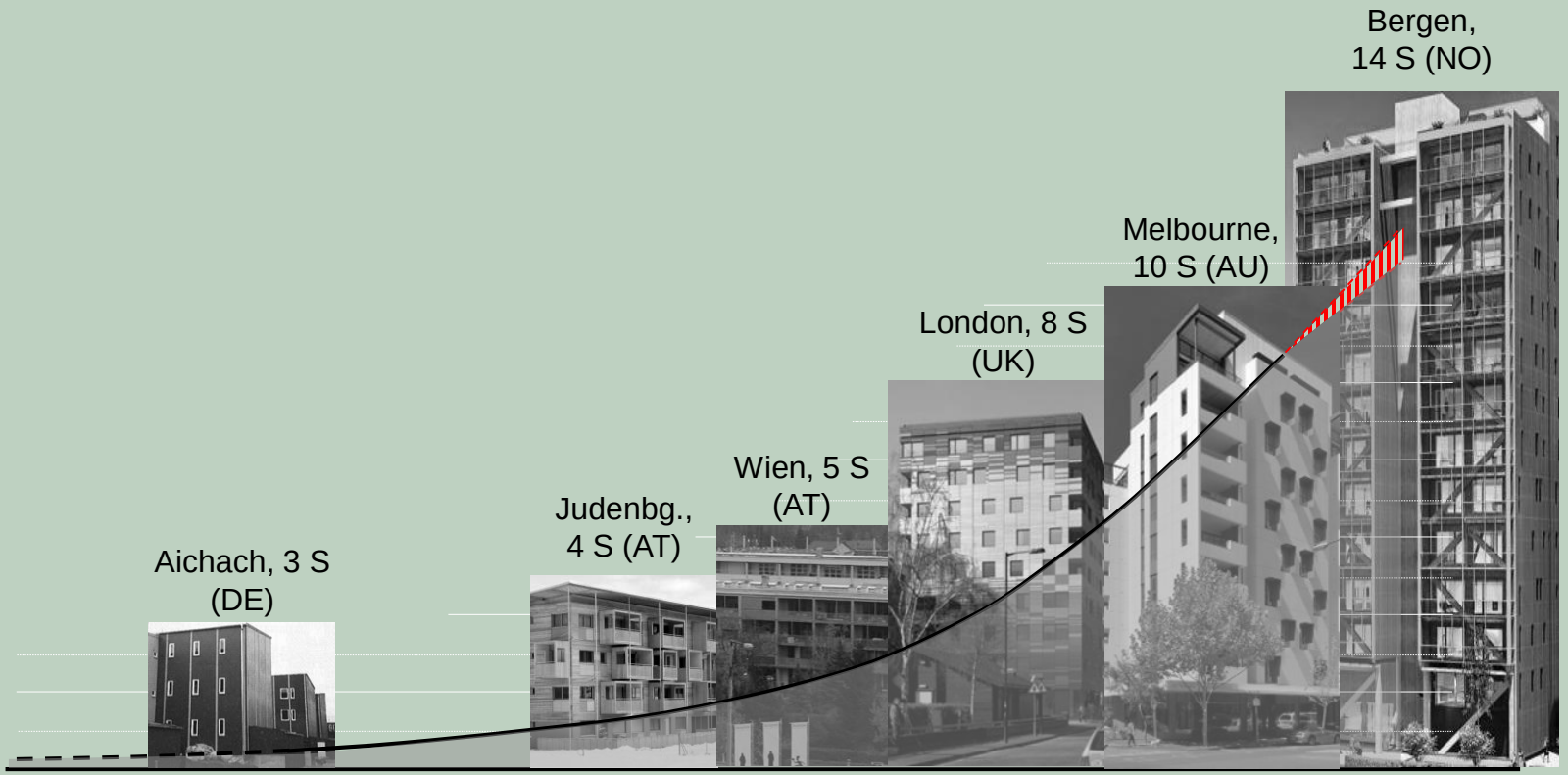
© Pictures: KLH

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

© Pictures: KLH

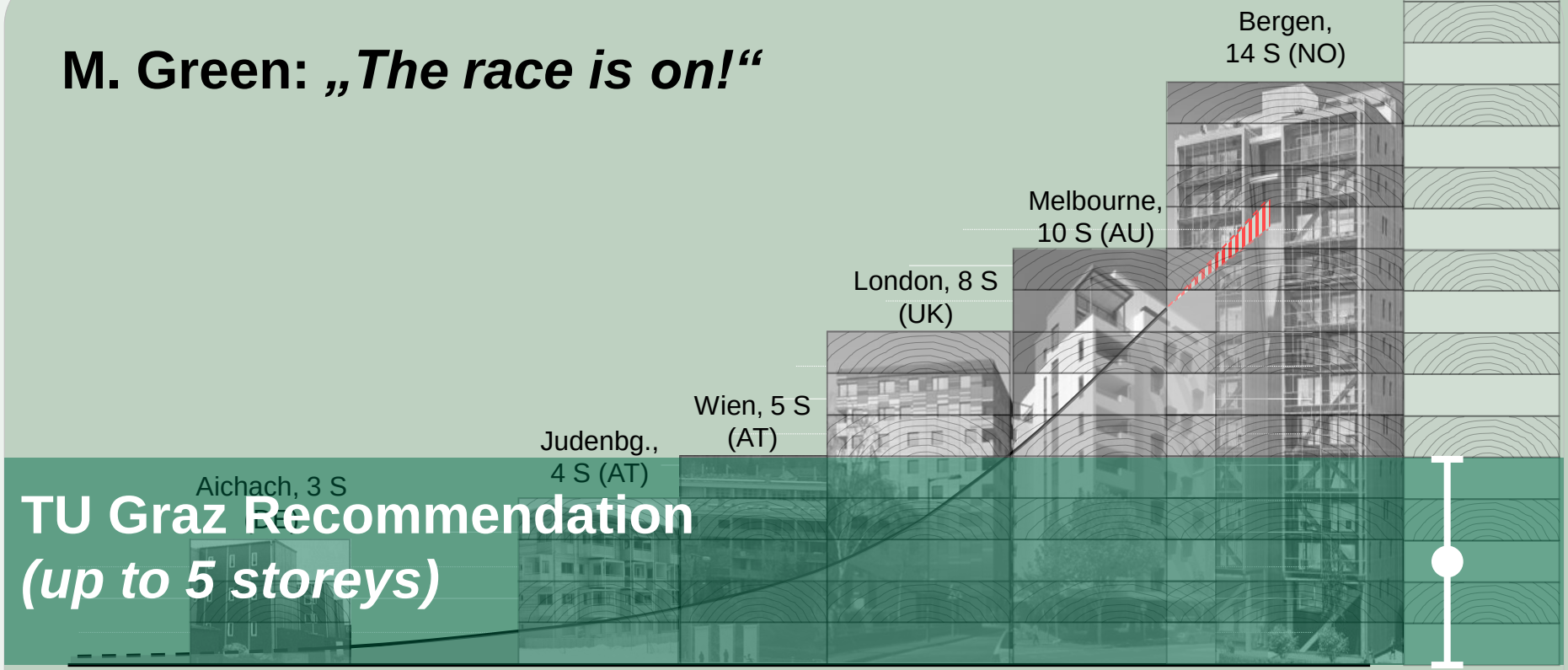
10-storey building
Melbourne (AUS) | 2012
CLT by KLH

Storey Development of the Last 20 Years



Storey Development of the Last 20 Years

M. Green: *„The race is on!“*



TU Graz Recommendation
(up to 5 storeys)

Kindergarten

© Pictures: Mayr-Melnhof Kaufmann

© Pictures: Binderholz Bausysteme GmbH

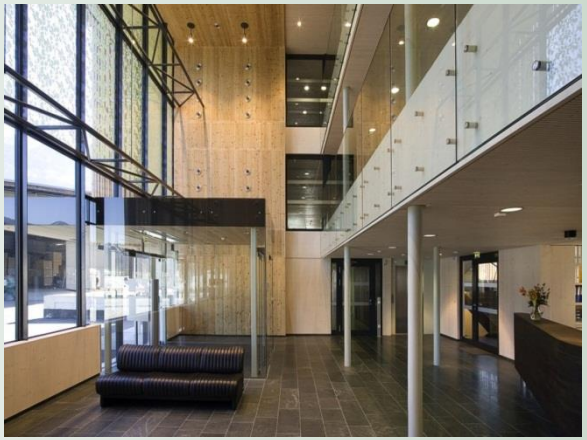
© Pictures: KLH

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

Innsbruck (AUT) | 2008
CLT by Binderholz Bausysteme

Augsburg (GER) | 2013
CLT by 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

© Pictures: KLH

Vennesla Library
Vennesla (NOR) | 2011
CLT by KLH

© Pictures: Mayr-Melnhof Kaufmann

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

© Pictures: holz.bau forschungs gmbh, Graz

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

Special Constructions

© Pictures: KLH and Stora Enso

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

© Pictures: Schillinger

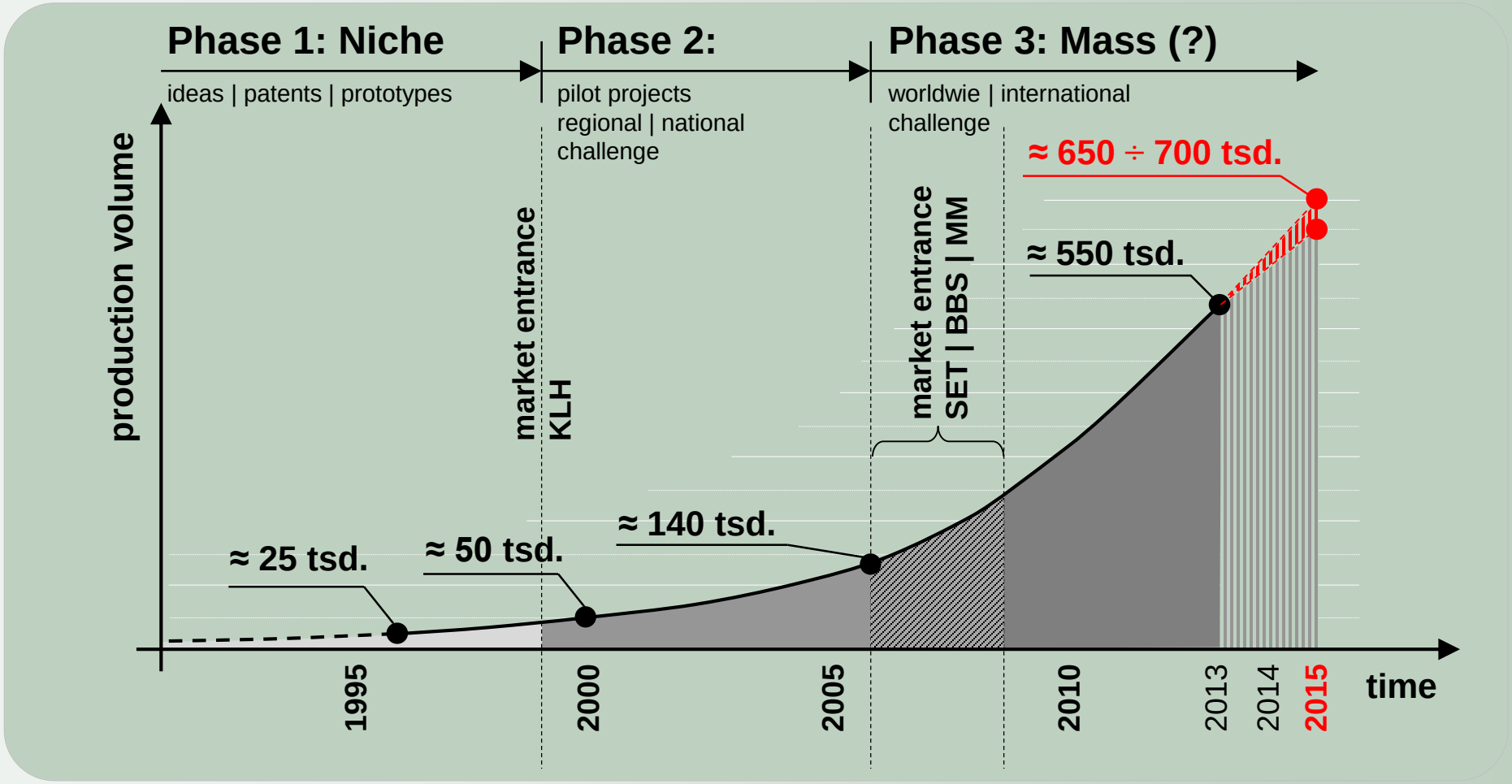
Monte Rosa
Valais (CH) | 2010
CLT by Schillinger

© Pictures: AHEC

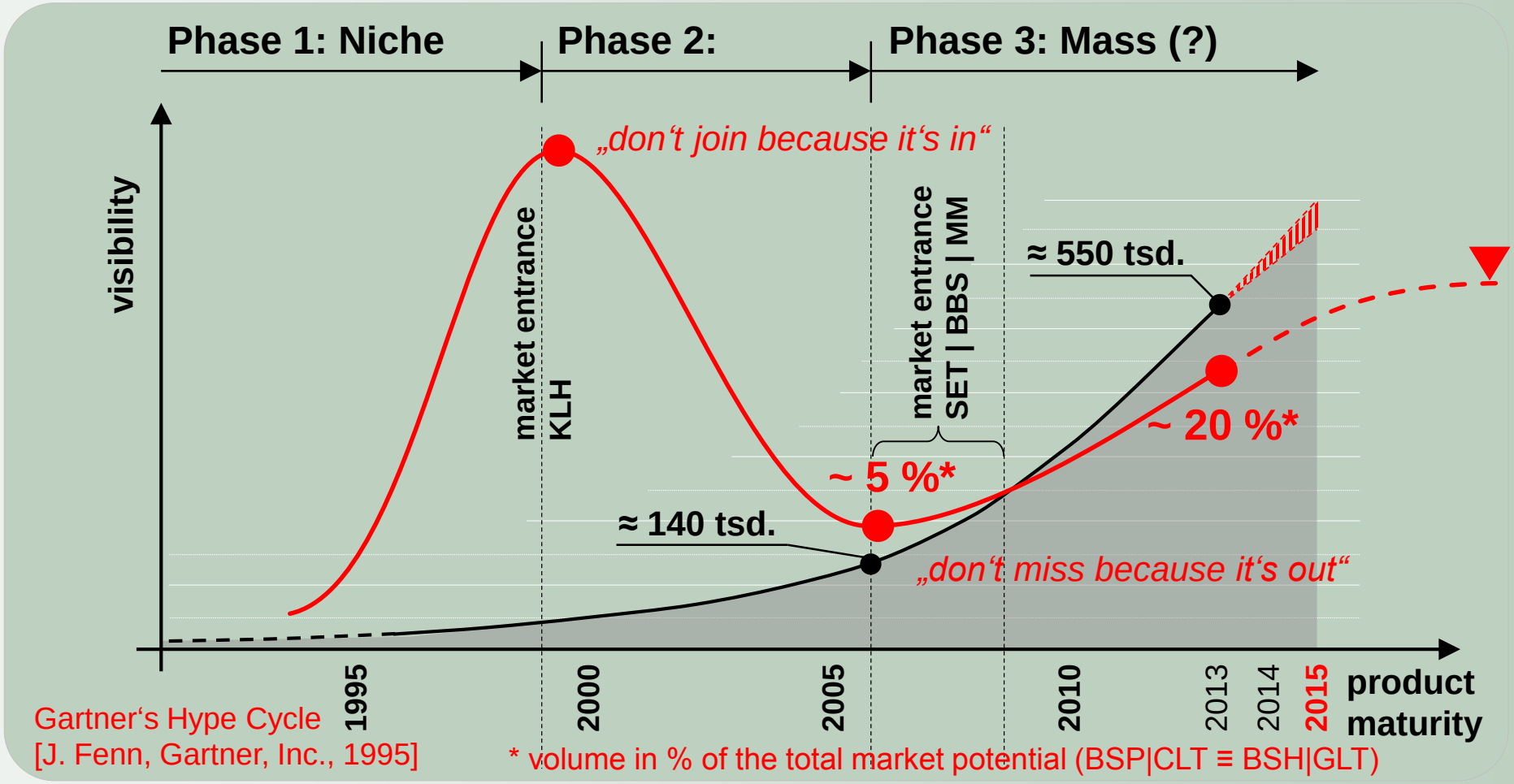
Endless Stair
London (GBR) | 2013
CLT by Imola Legno

- Introduction
- From Idea to Product
- From Product to Building Technique
- **Concluding Remarks**

Global Production of CLT | 1995-2015



Global Production of CLT | 1995-2015



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

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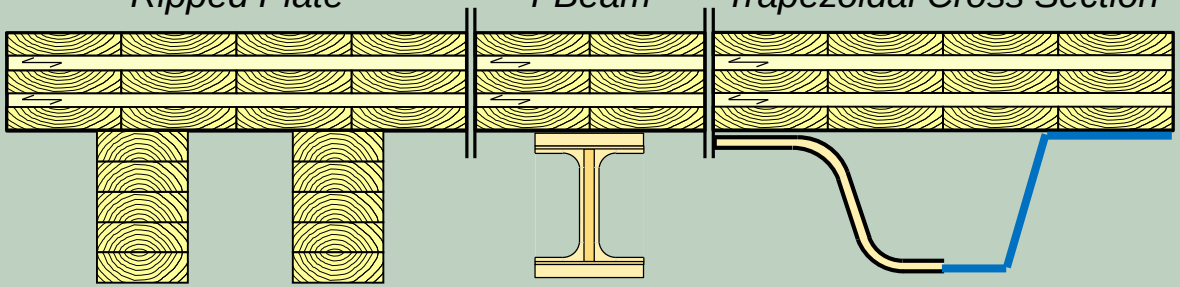
Constructing with Hybrids

CLT | GLT **CLT | UHPP/STEEL**

Ripped Plate *I-Beam* *Trapezoidal Cross Section*



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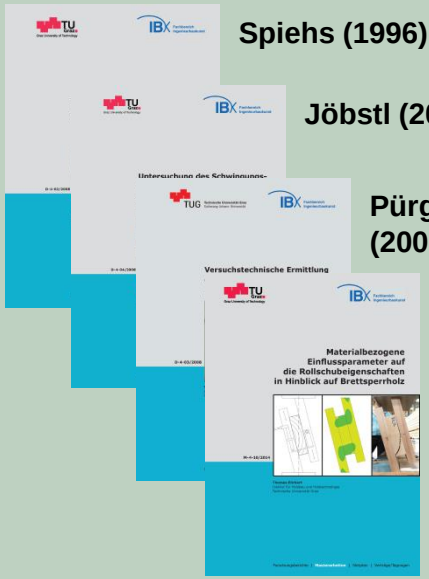
Constructing with Modules

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

Transfer at Graz University of Technology

Master Thesis | Diplomas

(selected)



Spiehs (1996)

Jöbstl (2002)

Pürgstaller (2008)

Ehrhart (2014)

Seminars | Conferences | Books

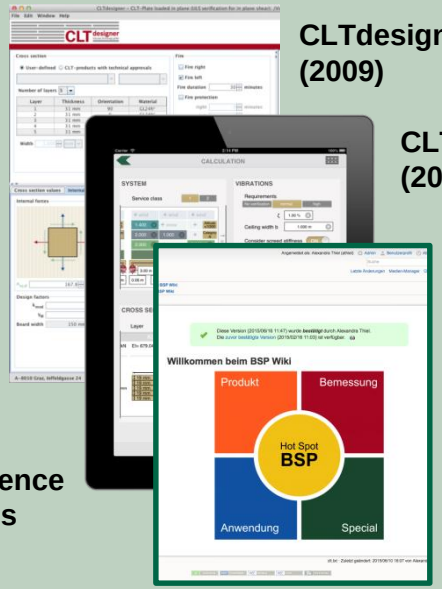
5. GraHFT'06

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) ≡ 1/3

THANKS FOR ATTENTION!

Contact

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Graz University of Technology
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Approvals and Standardisation

1st STEP
National Approvals

Austria

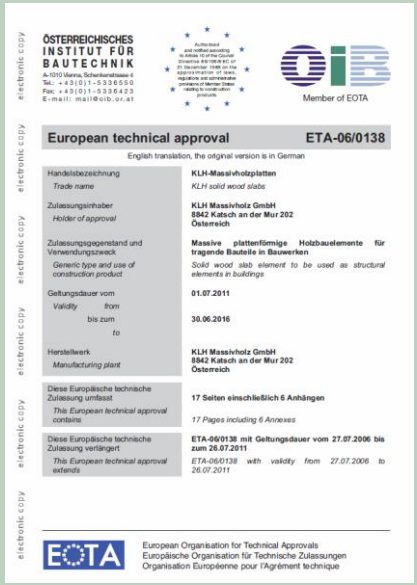
France

Germany

Russia

Spain

2nd STEP
ETAs



3rd STEP
Standardisation

ISO 165

prEN 16351

EN 1995