A **Status Report** from the **CLT** Hot Spot in **Europe | Austria**

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CLT Seminar
sola city Conference Center, Tokyo
March 21st 2017

- **INTRODUCTION**
  - TIMBER at Graz University of Technology – Teaching and R&D
  - Data & Facts about CLT
- **SELECTED SUB- AND PROJECTS**
  - "**CLT+GLT_ribbed plates**" for large spans
  - "**PREFAB_modules**" for densification
  - "**CLT_follows_form**" | house of bread
- **SUMMARY AND FUTURE PROSPECTS**

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Graz University of Technology
Styria / Austria

Styria – 13 districts – 1,2 mill. inhabitants | capitol: Graz
61% forest vegetation

Graz University of Technology

7 faculties | 13,800 students | 3,270 staff (2016/17)
budget: **€ 236 Mil.** (1/3 is 3rd party budget)

Faculty of Civil Engineering Sciences

15 institutes | about 1,500 students (2016/17)

Institute of Timber Engineering and Wood Technology

1991: Chair for Timber Engineering
10|2004: **Institute of Timber Engineering and Wood Technology**
Scientific staff: **8.0 FTE** | 3rd party budget: **€ 270,000** (2016)

source: TU Graz

Competence Centre holz.bau forschungs gmbh

12|2002: **Competence Centre holz.bau forschungs gmbh**
2013-2016: 4-year funded programme:
COMET-Project "**focus_sts**" [budget: € 3 millions]
Scientific staff: **8.3 FTE** | budget: **€ 810,000** (2016)

R&D topics regarding Timber Engineering and Wood Technology at TU Graz

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)

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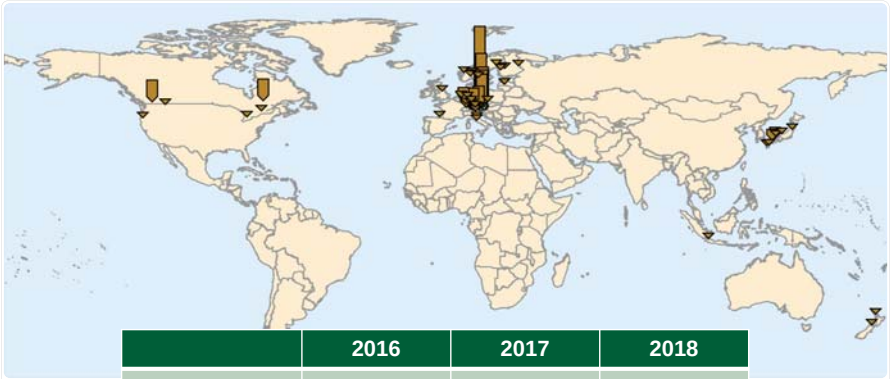
CLT plants



	2016	2017	2018
Europe	~ 29	~ 32	~ 37
NA, JP, AUS|NZ	~ 15	~ 16	~ 17
Total	**~ 44**	**~ 48**	**~ 54**

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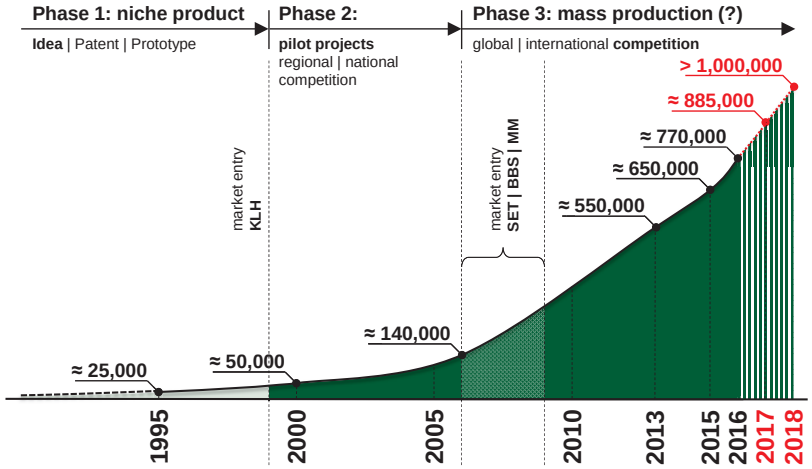
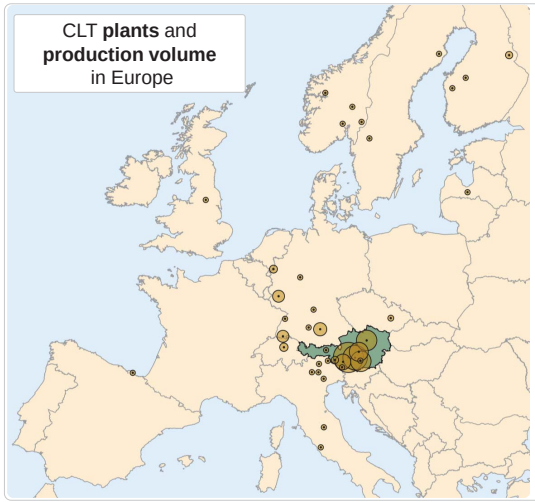
CLT production



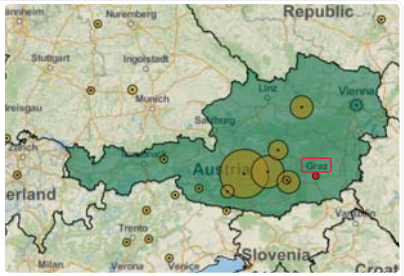
CLT production



- **CLT production** 2016
  - ~ 89 % in Europe
  - ~ 65 % in Austria
- **important** future **markets** in Europe
  - Scandinavia (SE,FI,NO)
  - United Kingdom
  - France

Hot Spot - Austria

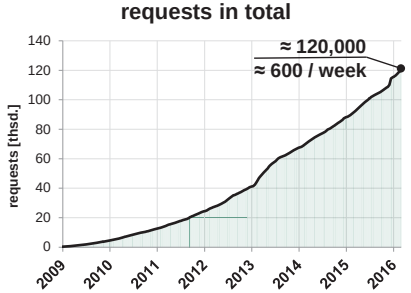
- CLT production 2016
  - ~ 65 % of total production in Austria
    ~ **500,000** m³/year

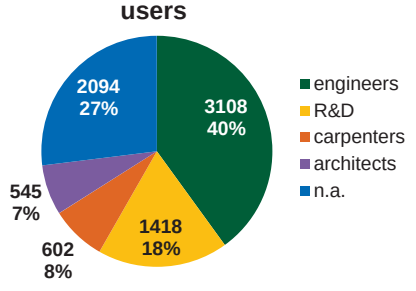


- reasons for the success in Austria
  - "**fast forward**" sawmill industry
  - efficient **forestry** and **timber industry**
  - **innovation-friendly** environment
  - strong tradition in **solid constructions** (concrete, bricks)
  - fast integration of new topics in **teaching** and **research**
  - application-oriented **R&D** at **universities**
  - tireless and constant cooperation between **architects** and **civil engineers**

www.cltdesigner.at

- **software** tool for the **design** of CLT
- **5** modules
  - plates
  - walls
  - compression perp.
  - load introduction into walls
  - ribbed CLT-plates
- **~ 7,800** users from **66** nations





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CLT+GLT_ribbed plates | large spans

Austrian pavilion in Venice

completed backyard of the pavilion, 1934

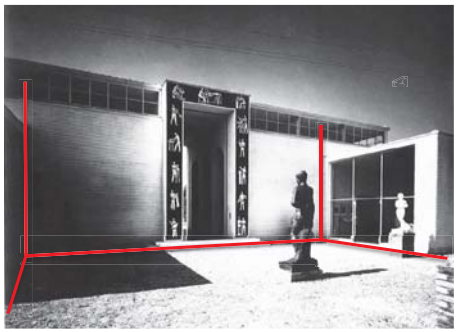


figure: adaption based on
„JOSEF HOFFMANN – 50 Jahre österreichischer Pavillon"

historical facts

- first intention to build the "Austria pavilion" in 1910
- the initiative was interrupted by the outbreak of the first world war
- Austria continued to exhibit in the central pavilion in 1920
- plans were drafted by architects **Josef Hoffmann** and **Robert Kramreiter** in 1933
- officially inaugurated in 1934

source: www.austrianpavilion.at

CLT+GLT_ribbed plates | large spans

Austrian pavilion in Venice

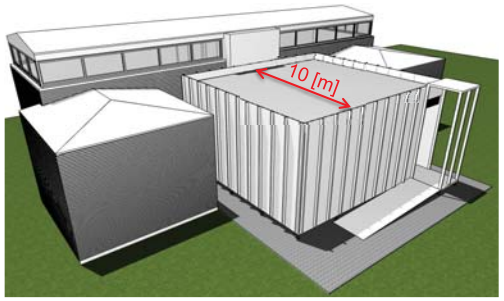
backyard of the pavilion – extension area

figure: adaption based on
www.labiennalevenezian.at

CLT+GLT_ribbed plates | large spans

extended pavilion in Venice *

Design of the extension for the **Biennale 2017 in Venice,**
based on the concept of **Arch. H. Eisenköck**, 2016



requirements of the architect

- flawless surface
  (no visible cracks or joints)
- inherently stable at unfavorable weather conditions
- easy transport of the elements
- simply to assemble and disassemble
- no connection to the existing building
- barrier-free entrance
- **span = 10 [m]**

CLT+GLT_ribbed plates | large spans

assembly steps

step 1: column base and bearing plates

step 2: CLT floor elements

step 3: ribbed wall elements and temporary securing

step 4: disassembling of securing

step 5: lift-in ribbed ceiling elements

step 6: entrance and ramp

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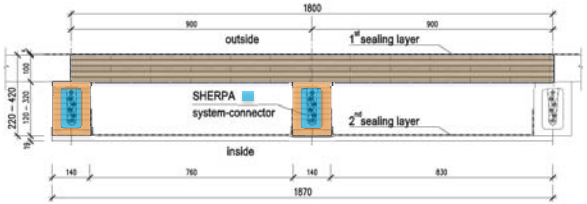
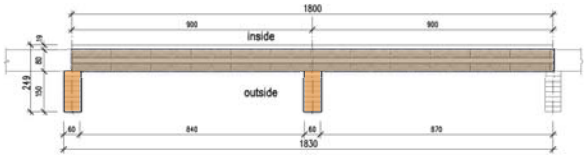
CLT+GLT_ribbed plates | large spans

ceiling element

values in [cm]



wall element



structure | layers:

- 1st sealing layer
- **CLT (20|20|20|20|20)**
- **GLT-rib** (cambered: 30 mm)
- 2nd sealing layer
- soffit (matt white colour)

- planking (matt white colour)
- **CLT (30|20|30)**
- **GLT-rib**
- paint finish (matt white colour)

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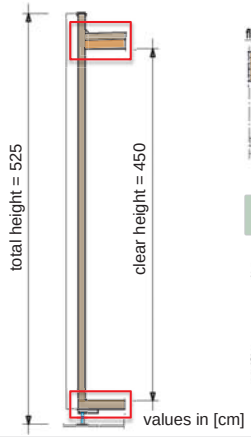
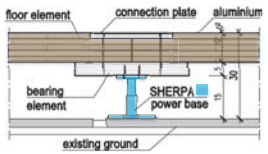
CLT+GLT_ribbed plates | large spans

cross-section

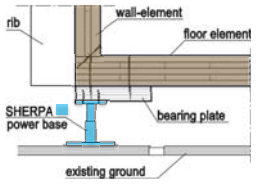


values in [cm]

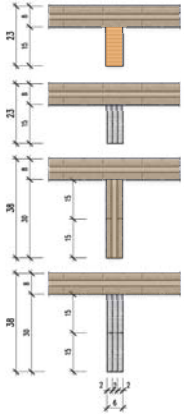
middle floor element



edge floor element



variation of rib-design



GLT

TRIO

CLT

double TRIO

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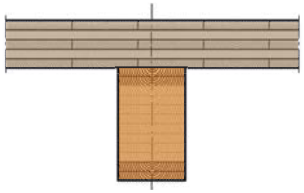
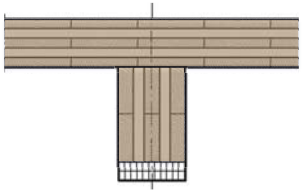
CLT+GLT_ribbed plates | large spans

benefits of CLT + GLT-RBP

- enables large span elements
- **adjustable bending stiffness** due to geometry
- further **improvement with high strength lamellas** at lower edge possible → combined GLT | LVL
- **CLT+CLT_ribbed plate** for **ribs with openings** (inherent reinforcement)



combined GLT



high strength lamella on CLT-rib

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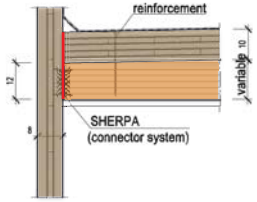
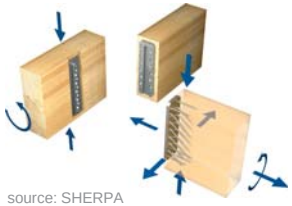
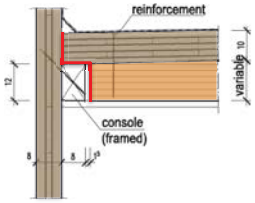
RBP with SHERPA





source: SHERPA

notched RBP



benefits

- ordinary support conditions
  - **no cutouts** for ribs
  - ordinary building physics
- **space for** indoor **installation**
  - **less height** of the floor construction

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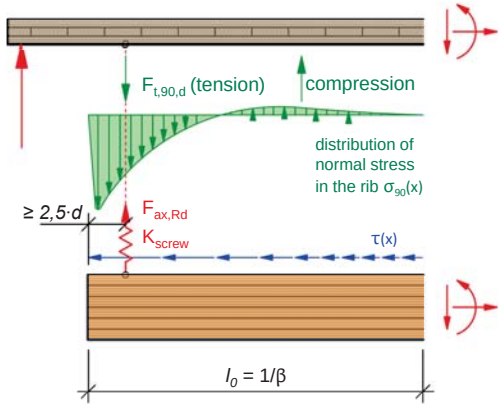
mechanical model for the interface



- perpendicular stresses, caused by the notch die away within a short distance l_0 to the notch
- sum of **tensile stress** perpendicular to the grain **must be secured with reinforcement**
- position of **reinforcement** as **close** as possible **to end grain** (within first 10 cm)

$$F_{t,90,d} \leq F_{ax,Rd}$$

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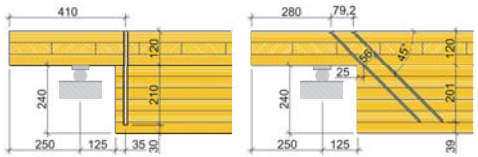
CLT+GLT_ribbed plates | large spans

verification of mechanical model



- 3- and 4-point-bending-tests:
  - different spans
  - **small** and **large** scale specimens
  - variation of **distance** between **support and notch**
  - **different** types of **reinforcement**

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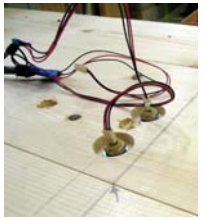
CLT+GLT_ribbed plates | large spans

verification of mechanical model

- measurements at notch:
  - vertical and horizontal displacement between GLT-rib and CLT-plate
  - force within the reinforcement at the level of the glue joint


displacement transducers


measurement screws


measurement screws


screws with load cells

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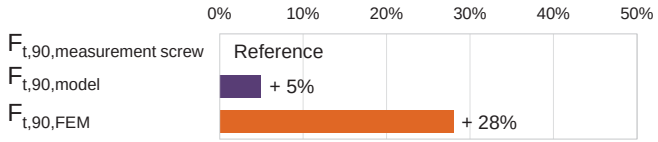
verification of mechanical model

comparison of test results with analytic solution and FEM-calculation:

- **mean deviation** (four samples of small specimens)



- analytic solution in **good accordance** with measurements and FEM-calculation
- **conservative** overestimation of $F_{t,90}$
- verification with large scale specimen in progress

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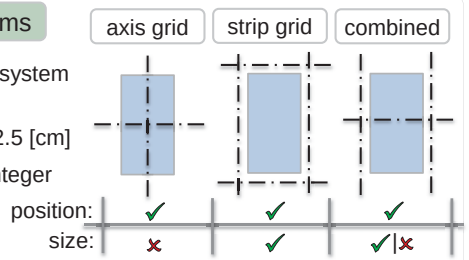
PREFAB_modules

basic module and construction systems

- **basic size** for geometric classification system
- unit of measurement:
  1 [M] ≙ e. g. 100, 900 [mm] or 62.5, 12.5 [cm]
- all component measures must be an integer multiple of the basic module **n x [M]**
- basis for planning, production and assembly

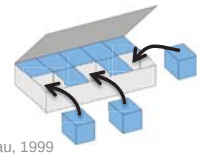
source: G. Staib, Elemente und Systeme, 2008



source: Neufert, Entwurfslehre 2015

closed

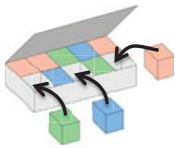
- **inflexible** system
- no exchange with different systems



source: H. Landsberg, Holzsysteme für den Hochbau, 1999

open

- **flexible** system
- exchange with different subsystems



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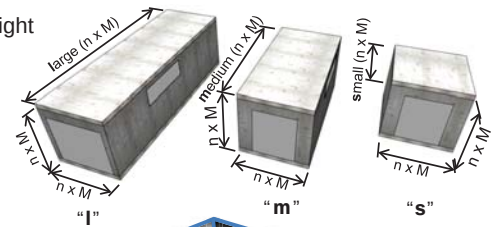
PREFAB_modules

dimensions of modules

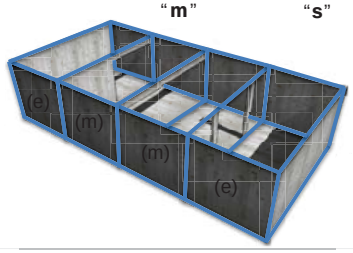
n x M = **n**umber x **m**odule

- standardised width, length and height
- but possible steps in length
  - **small** = "s"
  - **medium** = "m"
  - **large** = "l"



types of modules

- types according to their **position**
  - edge module (e)
  - middle module (m)



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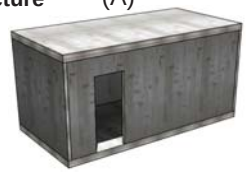
PREFAB_modules

types of modules

- types according to their **structure**
  - closed on all sides (A)
  - open on one side (B)
  - open on two sides (C)
  - open on three sides (D)
  - open on all sides (E)



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PREFAB_modules for retirement homes

retirement home “Hallein”

source: Kaufmann Bausysteme | architect: sps-architekten zt gmbH, 2013

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PREFAB_modules for retirement homes

retirement home “Hallein”

- 140 modules **(completely equipped)**
- dimension: 4 x 8 [m] (w/l)
- **only vertically routed pipelines**
- every single module has its own shaft for building services

- apartment module
- horizontal access
- vertical access
- reception room
- common room module

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PREFAB_modules for retirement homes

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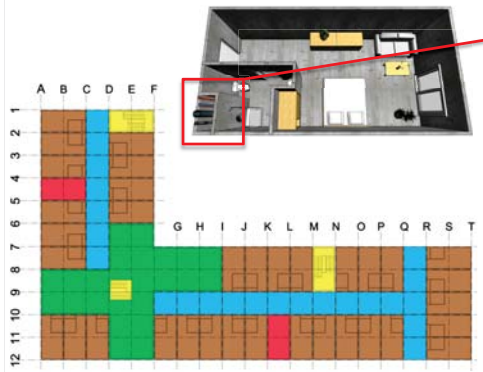

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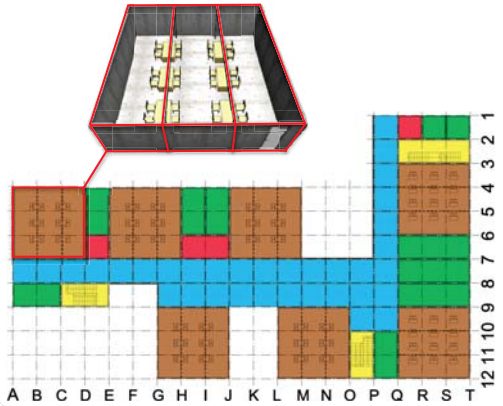
PREFAB_modules for day-care centers and schools

European School Frankfurt

source: Kaufmann Bausysteme | architect: nkbak Nicole K. Berganski & A. Krawczyk, 2015

PREFAB_modules for day-care centers and schools

European School Frankfurt



- 90 modules **(completely equipped)**
- dimension: 3 x 9 [m] (w/l)
- one classroom consists of three modules
- building services are integrated in sanitary modules
- **only vertically routed pipes**

PREFAB_modules for temporary events

modules for the olympic village of the winter olympics in Turin 2006

source: F. de Monte

source: F. de Monte

- complete **prefabrication** at the plant
- **assembling** and **fixing** on the construction site

PREFAB_modules for temporary events

modules for the olympic village of the winter olympics in Turin 2006

source: F. de Monte

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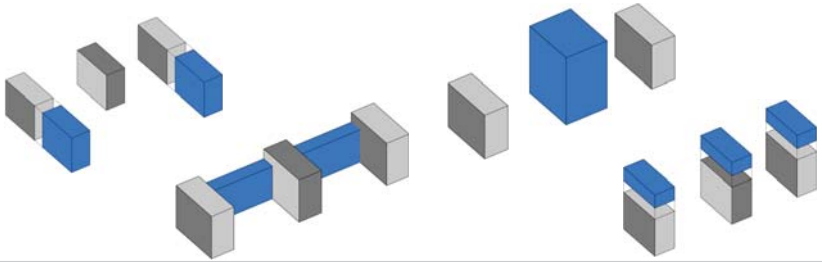
- assembling: module by module and storey by storey
- benefits: **clean construction site**, **rapid and dry** construction method and **easy to disassemble** for possible changes of use

PREFAB_modules for smart city densification

4 methods of urban densification

- horizontal extension to the existing buildings
- **closing gaps and vacant lots between buildings**
- dismantling existing and reconstructing new buildings
- **adding stories on the rooftops of the existing buildings (“roof stacking”)**



PREFAB_modules for smart city densification

closing gaps and vacant lots between buildings

source: G. Schickhofer, Tokyo 2016

source: G. Schickhofer, Tokyo 2016

PREFAB_modules for smart city densification

closing gaps and vacant lots between buildings

source: G. Schickhofer, Tokyo 2016

source: G. Schickhofer, Tokyo 2016

PREFAB_modules for smart city densification

closing gaps and vacant lots between buildings

- building with modules implies **sustainable buildings** as well as **clean construction sites**

PREFAB_modules for smart city densification

adding stories on the rooftops of the existing buildings

source: G. Schickhofer, Graz
architect: Arch. D. Koch, 2009

source: G. Schickhofer, Graz
architect: Arch. D. Koch, 2009

- roof stacking can be a very **efficient** and **attractive** method for redensification

PREFAB_modules for smart city densification

adding stories on the rooftops of the existing buildings

source: G. Schickhofer, Graz
architect: Arch. D. Koch, 2009

source: G. Schickhofer, Graz
architect: Arch. D. Koch, 2009

- modules can **easily** be **intergraded** into existing buildings

"CLT_follows_form" | house of bread

house of bread II

customers' request

architects' idea

engineers' plan

statics/design

production

assembly

product

museum concerning the history of bread

Source: kornspitz.com

“CLT_follows_form” | house of bread

house of bread II

- customers’ request
- **architects’ idea**
- engineers’ plan
- statics/design
- production
- assembly
- product

COOPHIMMELB(L)AU
(Wolf D. Prix & Partner)

Source: coop-himmelblau.at

G. Schickhofer, G. Flatscher, K. Ganster, R. Sieder, S. Zimmer
Institute of Timber Engineering and Wood Technology, Graz University of Technology

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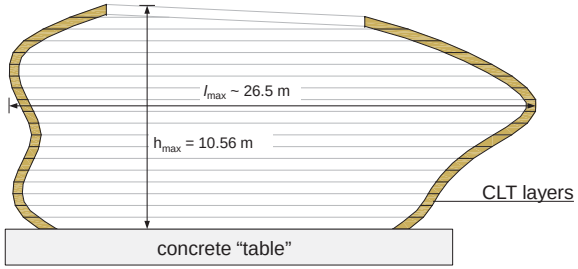
- composition in layers of CLT
- joining single layers with screw-press gluing
- reinforcement with self-tapping screws



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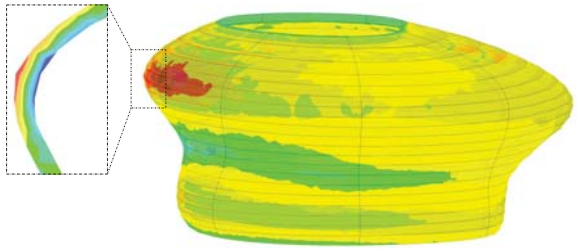
- simplified model applying beam statics
  (Wernly + Wischenbart + Partner Ziviltechniker GMBH)
- validation by 3D-volume FE analysis
  (Institute of Timber Engineering and Wood Technology, TU Graz)



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“CLT_follows_form” | house of bread

house of bread II

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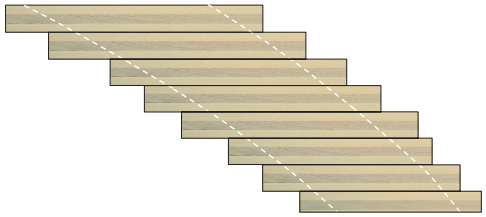
architects’ idea
engineers’ plan
statics/design
production
assembly
product

- **CLT raw material: 600 m³**
  - 3-, 5-, 7-layered CLT elements



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“CLT_follows_form” | house of bread

house of bread II

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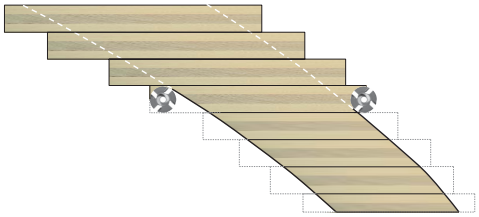
- **CLT raw material: 600 m³**
- **milling**



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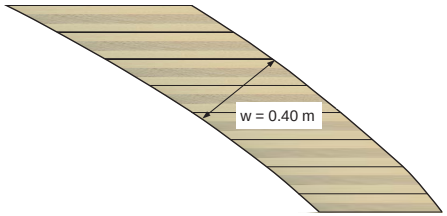
- **CLT raw material: 600 m³**
- **milling**
- **CLT final structure: 400 m³**
  - 80 “rings” → total height 10.56 m



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“CLT_follows_form” | house of bread

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- **applying adhesive**
- **applying CLT element(s)**
- **introduce secondary screws**
- **introduce primary (load-carrying) screws**

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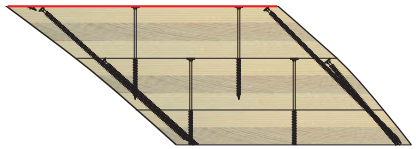
product

- **applying adhesive**
- **applying CLT element(s)**
- **introduce secondary screws**
- **introduce primary (load-carrying) screws**

→ **totally applied screws ~ 120,000 (!)**



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“CLT_follows_form” | house of bread

house of bread II

customers’ request
architects’ idea
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production
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product

Source: Wernly + Wischenbart + Partner Ziviltechniker GMBH, 2016

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“CLT_follows_form” | house of bread

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customers’ request
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Source: O. Wolf, 2017

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“CLT_follows_form” | house of bread

house of bread II

- customers’ request
- architects’ idea
- engineers’ plan
- statics/design
- production
- assembly
- **product**

Source: O. Wolf, 2017

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“CLT_follows_form” | house of bread

house of bread II

- customers’ request
- architects’ idea
- engineers’ plan
- statics/design
- production
- assembly
- **product**

Source: O. Wolf, 2017

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“CLT_follows_form” | house of bread

house of bread II

- customers’ request
- architects’ idea
- engineers’ plan
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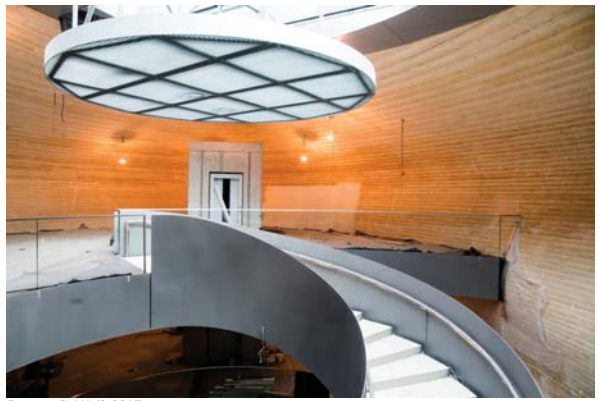
- production
- assembly
- **product**



Source: O. Wolf, 2017

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“CLT_follows_form” | house of bread

house of bread II

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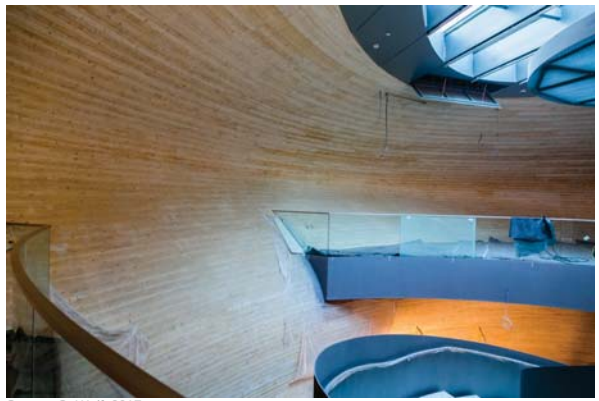


Source: O. Wolf, 2017

- INTRODUCTION
  - TIMBER at Graz University of Technology – Teaching and R&D
  - Data & Facts about CLT
- SELECTED SUB- AND PROJECTS
  - "**CLT+GLT_ribbed plates**" for large spans
  - "**PREFAB_modules**" for densification
  - "**CLT_follows_form**" | house of bread
- **SUMMARY AND FUTURE PROSPECTS**

CLT_systems and solutions advanced applications

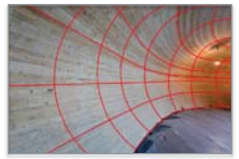
application possibilities

- "**CLT** enables **1D-** and **2D-elements** as well as **3D-modules** and even **free-form surfaces**

1D-element: beam or column

2D-element: wall or ceiling

3D-module



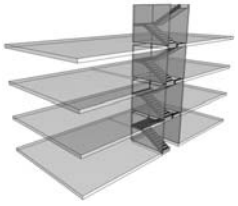
free-form surface

PREFAB_modules

future prospects

- **prefabrication** and **modularization** will play an **important** role **for CLT**
  - prefabricated modules for habitation, building services and development reduces assembly time and flaws during constructions on-site

habitation module



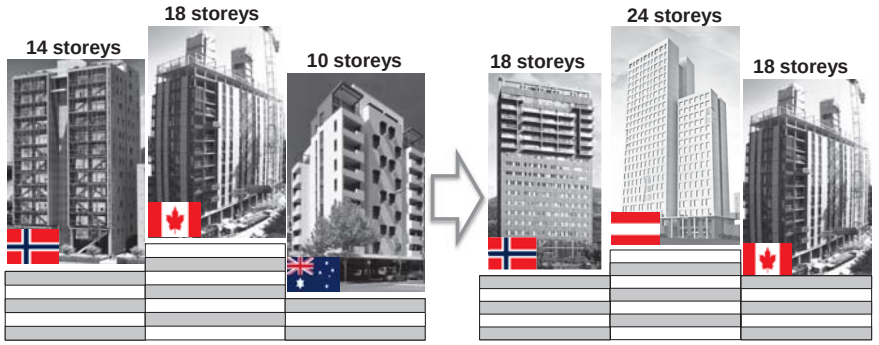
access module

module for building services

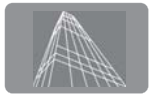
CLT storey development

M. Green: "The race is on!"*

* Green, M. „*Why we should build wooden skyscrapers*" TED2013



2016 outlook 2018



CLT storey development

statements regarding “storey race”

- sole focus on maximising the number of storeys or building heights ignores the necessity of thinking and acting interdisciplinary
- such competitions miss any foresight and follow the principle of **“Johnny head-in-the-air”**
- **CLT is a building product** and NOT a building system
- NOTE: a building system...
  - ... is more than the sum of its products!
  - ... comprises adequate combinations of building products to building structures being able to fulfil all requirements without increasing the risk of structural damage
- “superlatives” should be thought with **focus on application diversity** and **quality** instead of the number of storeys

Thank you for your attention!

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