CLT – European Experience

Idea & Development
Technology & Applications

Prof. G. Schickhofer
Institute of Timber Engineering and Wood Technology
Graz University of Technology

Presentation in the frame of the
CLT Forum 2013 in KOCHI

Kochi, 22nd October 2013

- Introduction
- Idea & Development
- Technology & Production
- Applications

- **Introduction**
- Idea & Development
- Technology & Production
- Applications

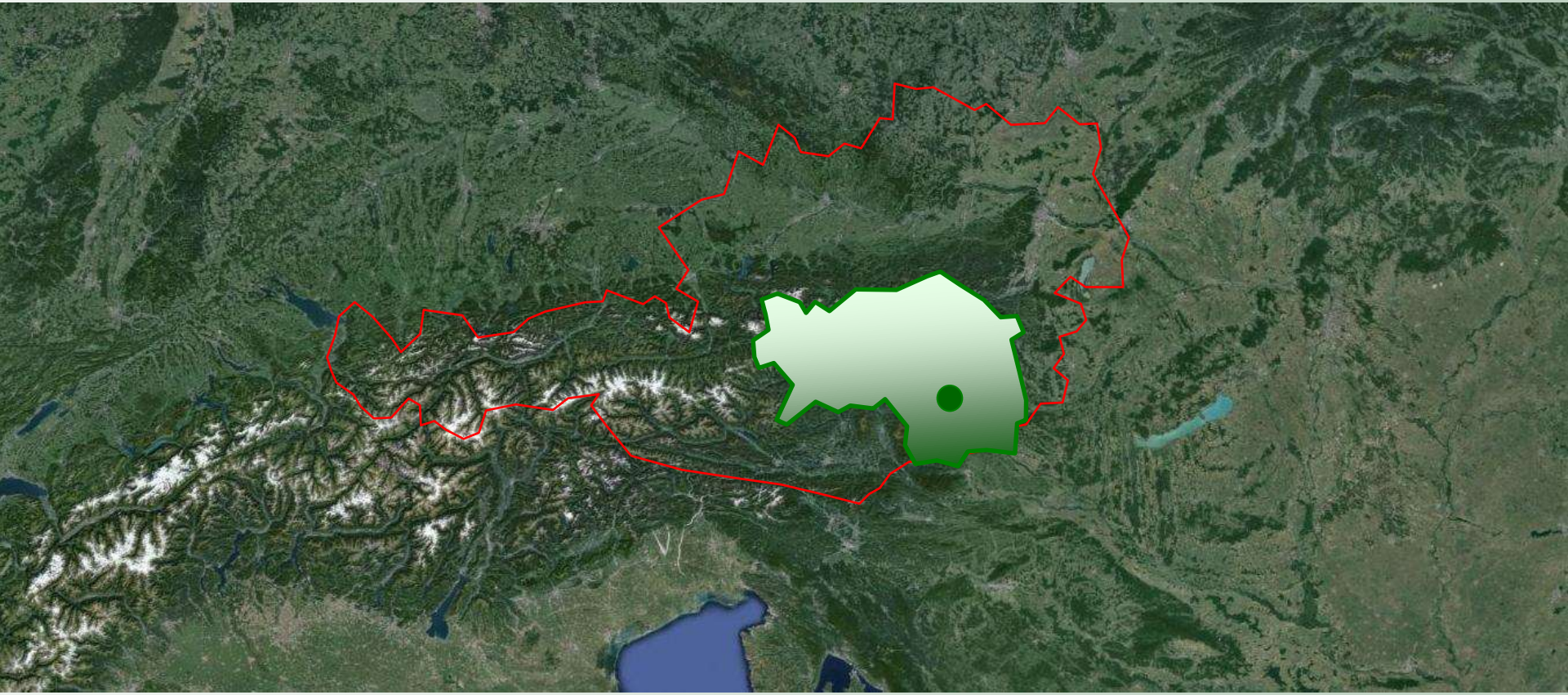
GRAZ UNIVERSITY OF TECHNOLOGY

Austria / Europe

AUSTRIA - 8.5 mio. inhabitants - Capitol: Vienna - 9 provinces
48% forest vegetation

GRAZ UNIVERSITY OF TECHNOLOGY

Styria / Austria



Styria - 1.2 mio. inhabitants - capitol: Graz - 13 districts
61% forest vegetation

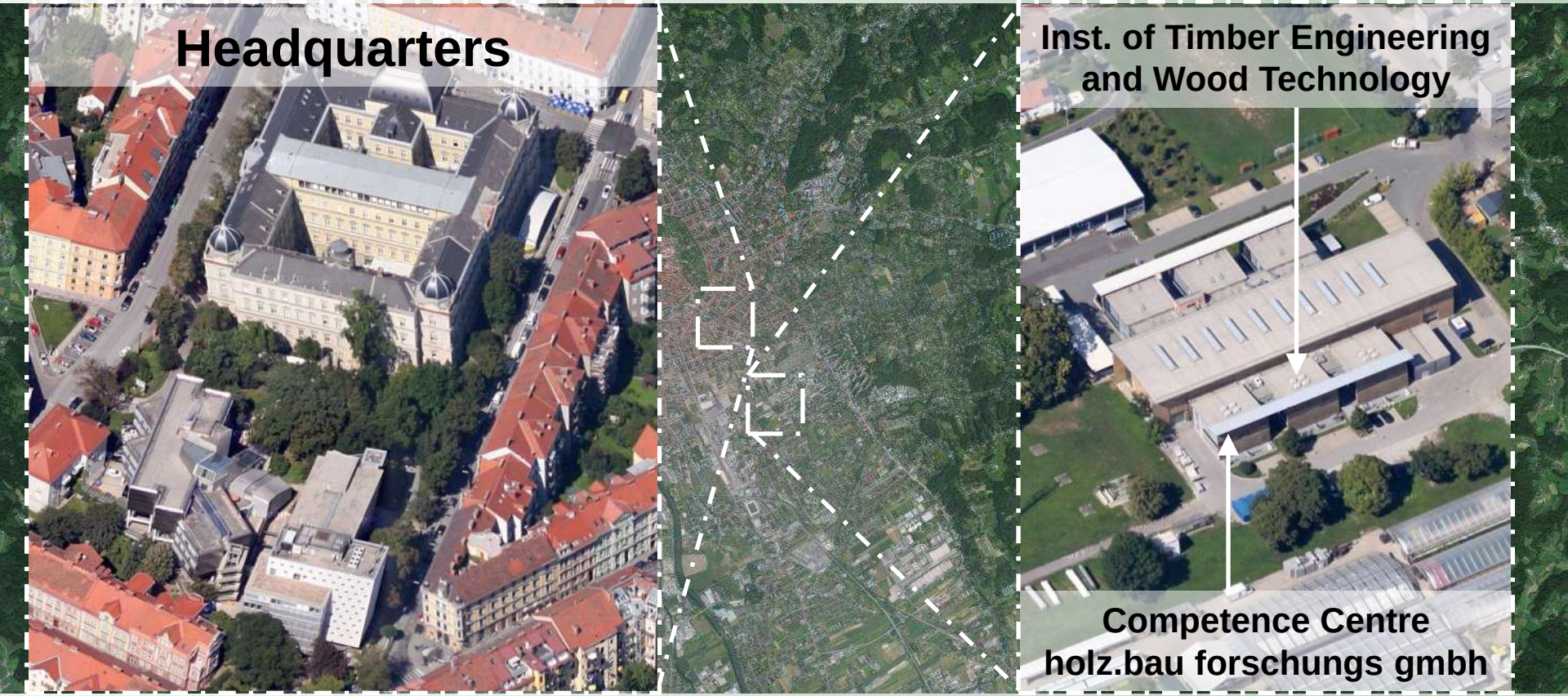
GRAZ UNIVERSITY OF TECHNOLOGY

Graz / Styria

Graz - 0.3 mio. inhabitants

GRAZ UNIVERSITY OF TECHNOLOGY

Graz / Styria



CAMPUS “ALTE TECHNIK”

CAMPUS “INFFELDGASSE”

GRAZ UNIVERSITY OF TECHNOLOGY

Graz / Styria

7 faculties | 12,323 students | staff 2,269 (2012)
budget: **€ 170 Mill.** (1/3 3rd party budget)

Faculty of Civil Engineering Sciences

17 institutes | about 1.400 students (2012)

Institute of Timber Engineering and Wood Technology

1991: Chair for Timber Engineering

10|2004: **Institute Timber Engineering and Wood Technology**

Scientific staff: **4.8 FTE** | 3rd party-budget: **€ 270,000** (2012)

Competence Centre holz.bau forschungs gmbh

12|2002 **Competence Centre holz.bau forschungs gmbh**

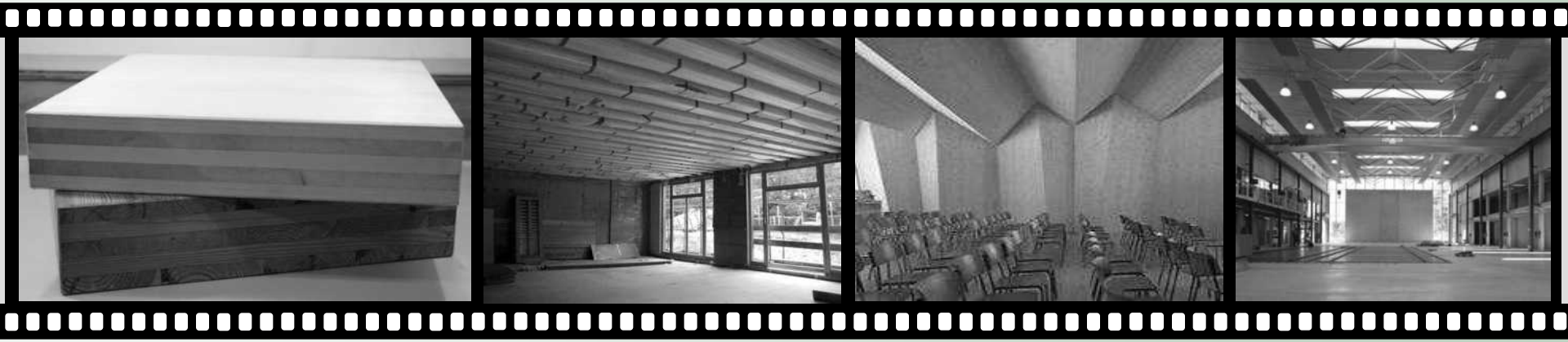
11|2012 3rd acceptance of a 4-year-funded programme: COMET-Project "**focus_sts**"

Scientific staff: **7.2 FTE** | budget: **€ 940,000** (2013)

AREA 1

SOLID TIMBER SOLUTIONS AND COMPONENTS (STSC)

1.1 High performance CLT Timber hybrids for large span elements



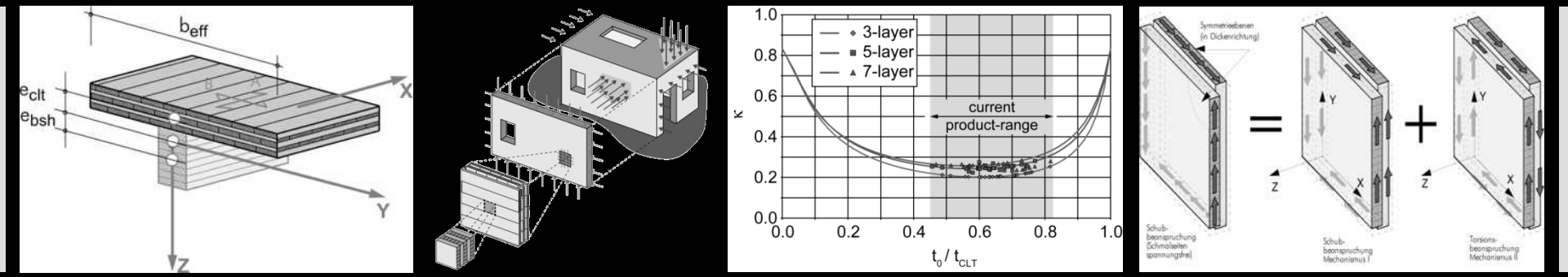
1.2 Optimised CLT ceilings and standardised, target-oriented leading details

AREA 2

ADVANCED PRODCUTION, MODELLING AND DESIGN (APMD)

2.1 Determination of characteristic strength and stiffness values of CLT-elements

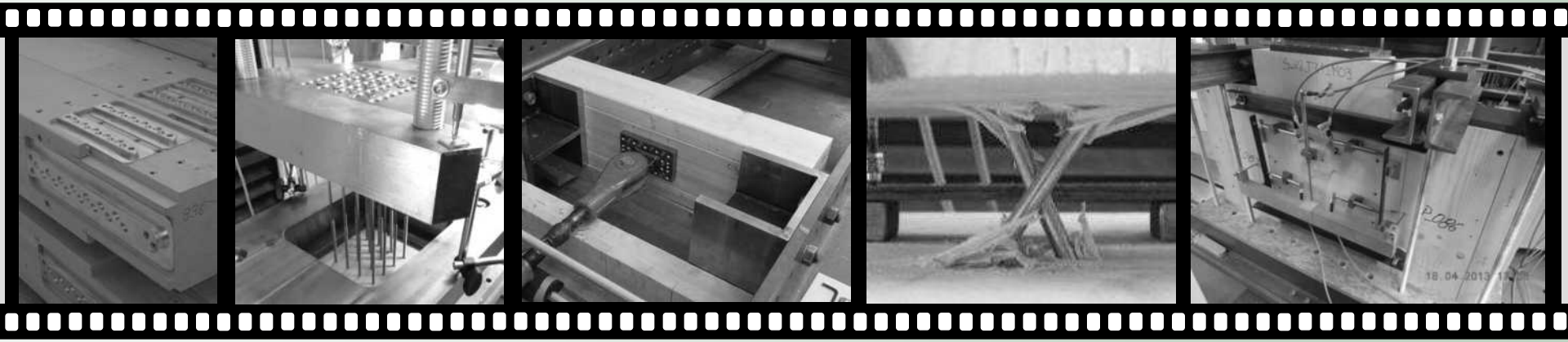
2.2 Development of load bearing models for CLT elements



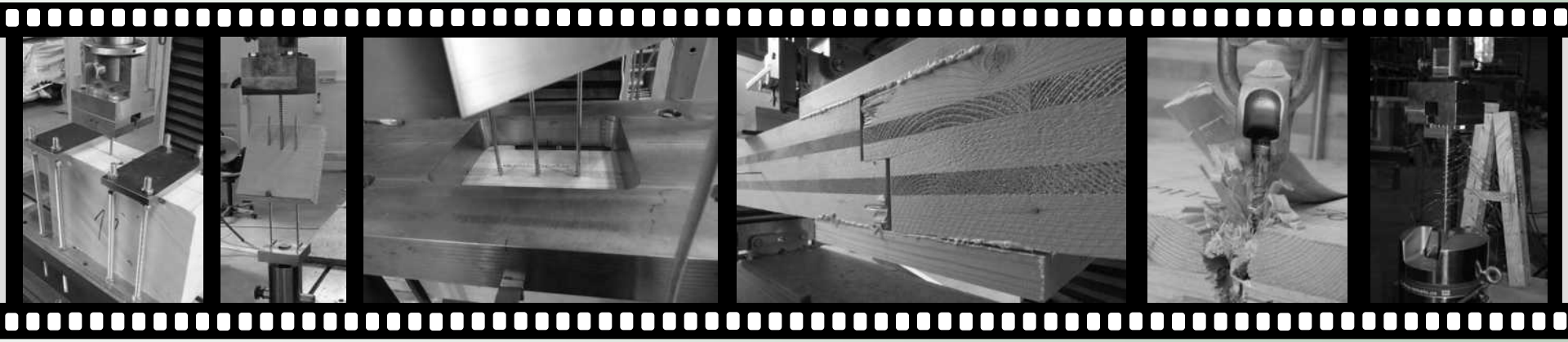
AREA 3

SCREWING, GLUING AND SYSTEM CONNECTIONS (SGSC)

3.1 Axial and transversal loaded joints and system connectors



3.2 Screwing and gluing technology for STC system with CLT



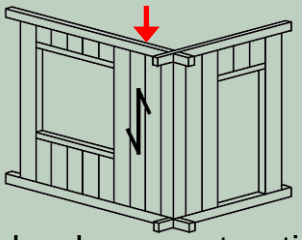
- Introduction
- **Idea & Development**
- Technology & Production
- Applications

Solid Timber Construction (STC) – INNOVATION based on TRADITION

load transfer

tradition

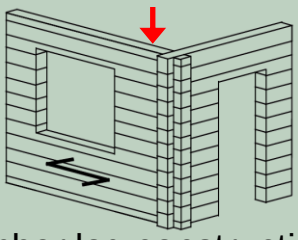
bar-like
(parallel to grain)



timber bar construction
(especially in Scandinavia)

stave church

bar-like
(perp. to grain)

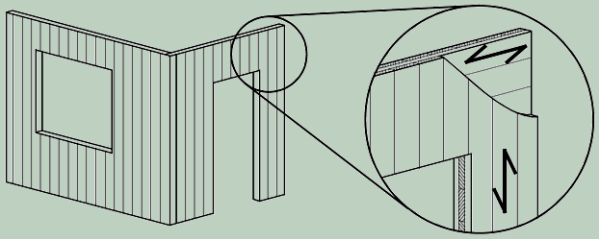


timber log construction
(especially in Alpine Space)

chalet

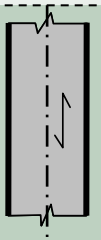
innovation

slab-like
(interaction of "parallel" and "perp." to grain)



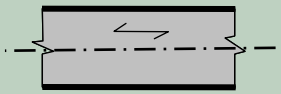
Solid Timber Construction with CLT

detached house Jeitler



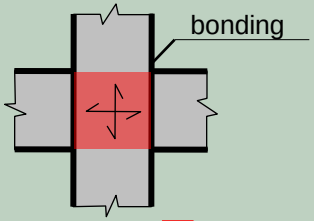
vertical

+



horizontal

=

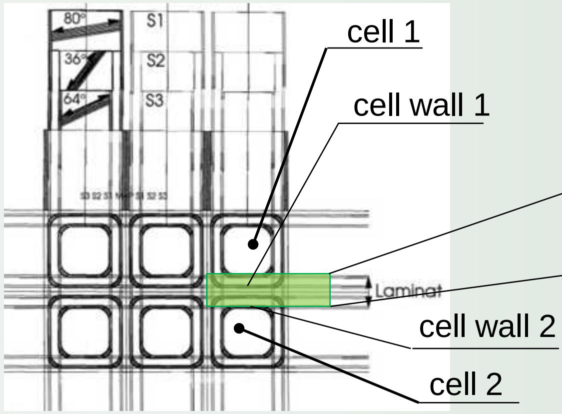


Cross Laminated Timber (CLT)
[rigidly connected]

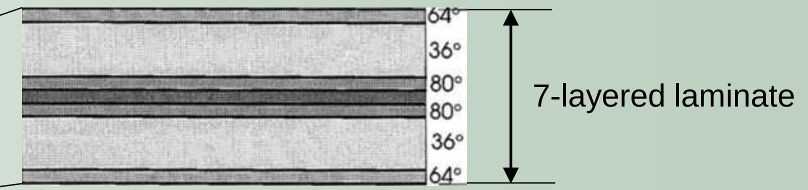
Analogies between Wood and Fibre-Plastic Composites

Scientific Activities [doctoral thesis] | 1989 ÷ 1994

lay-up of the load carrying system of a wood cell…



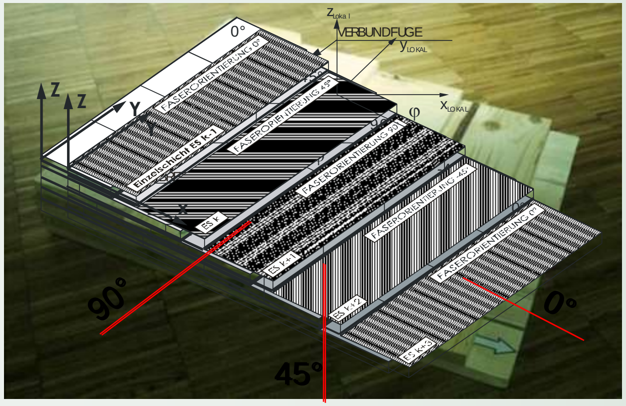
… is similar to the lay-up of fibre plastic composites



ANALOGY

analysis is based on the
`**C**lassical **L**aminate **T**heory´ **(CLT)**
[see also A.P. Schniewind | J.D. Barrett (1969)]

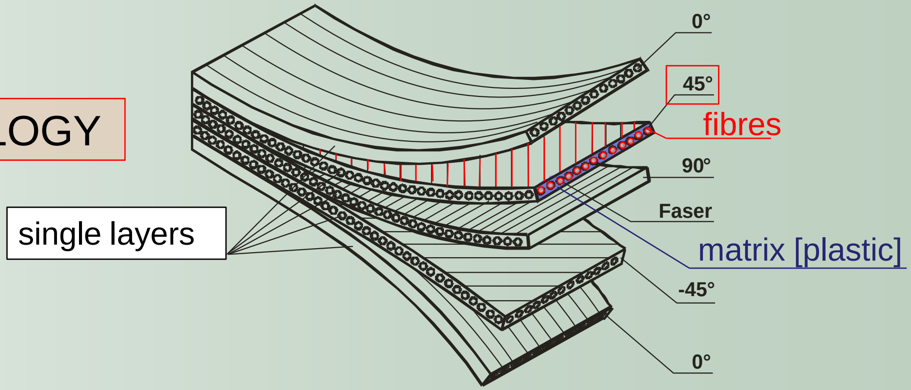
plywood (veneers) | CLT (1994) e.g. 5-layered panel



wood fibres + matrix
(lignin + adhesive between the layers)

ANALOGY

fibre plastic composites e.g. 5-layered panel

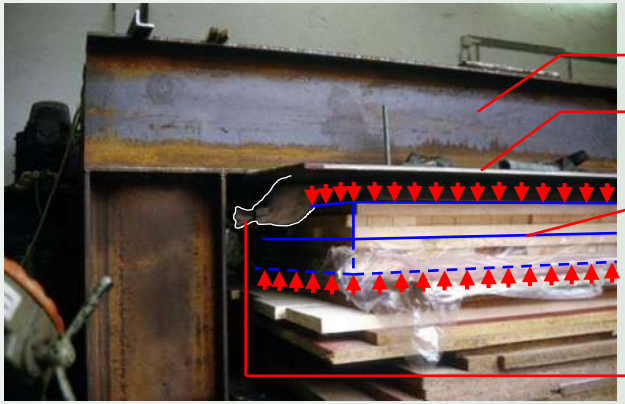


glas-, aramid-, carbon fibres + matrix [plastic]

Product Development

Project between 1995 and 1998

tryout press … and … one of the first CLT panels produced by KLH | Austria, 1996 …



… 15 years later – 2011|2012 – KLH Massivholz GmbH is the world largest CLT producer

www.klh.at | Katsch/Mur | Austria

Product Development

Approvals and Standardisation

1st STEP
National approvals

Austria

France

Germany

Russia

Spain

2nd STEP
ETAs


ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

Member of EOTA

European technical approval ETA-06/0138

English translation, the original version is in German

Handelsbezeichnung *Trade name*	KLH-Massivholzplatten *KLH solid wood slabs*
Zulassungsinhaber *Holder of approval*	KLH Massivholz GmbH 8842 Katsch an der Mur 202 Österreich
Zulassungsgegenstand und Verwendungszweck *Generic type and use of construction product*	Massive plattenförmige Holzbauelemente für tragende Bauteile in Bauwerken *Solid wood slab element to be used as structural elements in buildings*
Geltungsdauer vom *Validity from* bis zum *to*	01.07.2011 30.06.2016
Herstellwerk *Manufacturing plant*	KLH Massivholz GmbH 8842 Katsch an der Mur 202 Österreich
Diese Europäische technische Zulassung umfasst *This European technical approval contains*	17 Seiten einschließlich 6 Anhängen *17 Pages including 6 Annexes*
Diese Europäische technische Zulassung verlängert *This European technical approval extends*	ETA-06/0138 mit Geltungsdauer vom 27.07.2006 bis zum 26.07.2011 *ETA-06/0138 with validity from 27.07.2006 to 26.07.2011*

EOTA

European Organisation for Technical Approvals
Europäische Organisation für Technische Zulassungen
Organisation Européenne pour l'Agrément technique

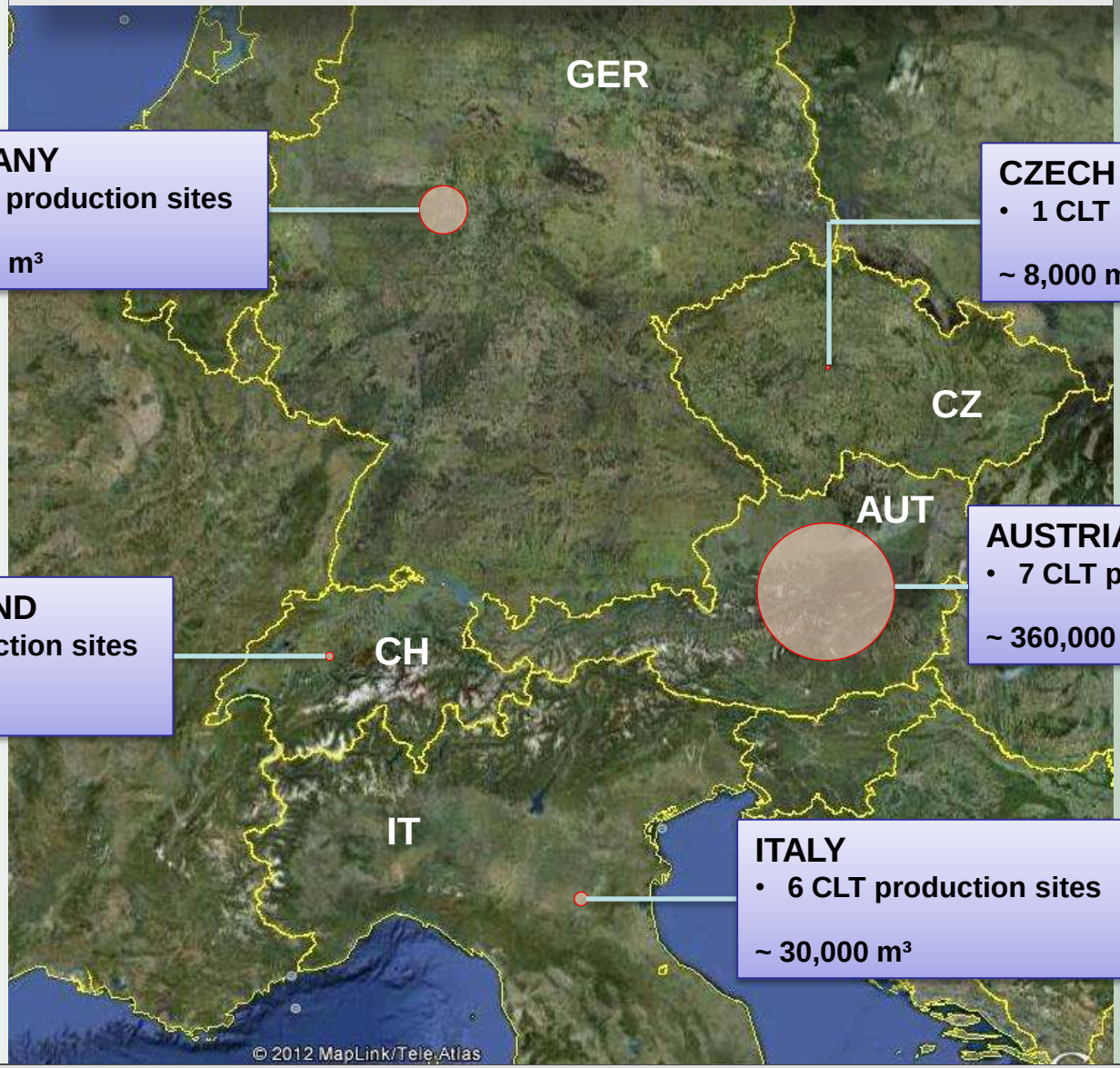
3rd STEP
Standardisation

ISO 165

prEN 16351

EN 1995

Central Europe
Production 2011 ~ 450.000 m³



GERMANY
- 8 CLT production sites

~ 90,000 m³

CZECH REPUBLIC
- 1 CLT production site

~ 8,000 m³

AUSTRIA
- 7 CLT production sites

~ 360,000 m³

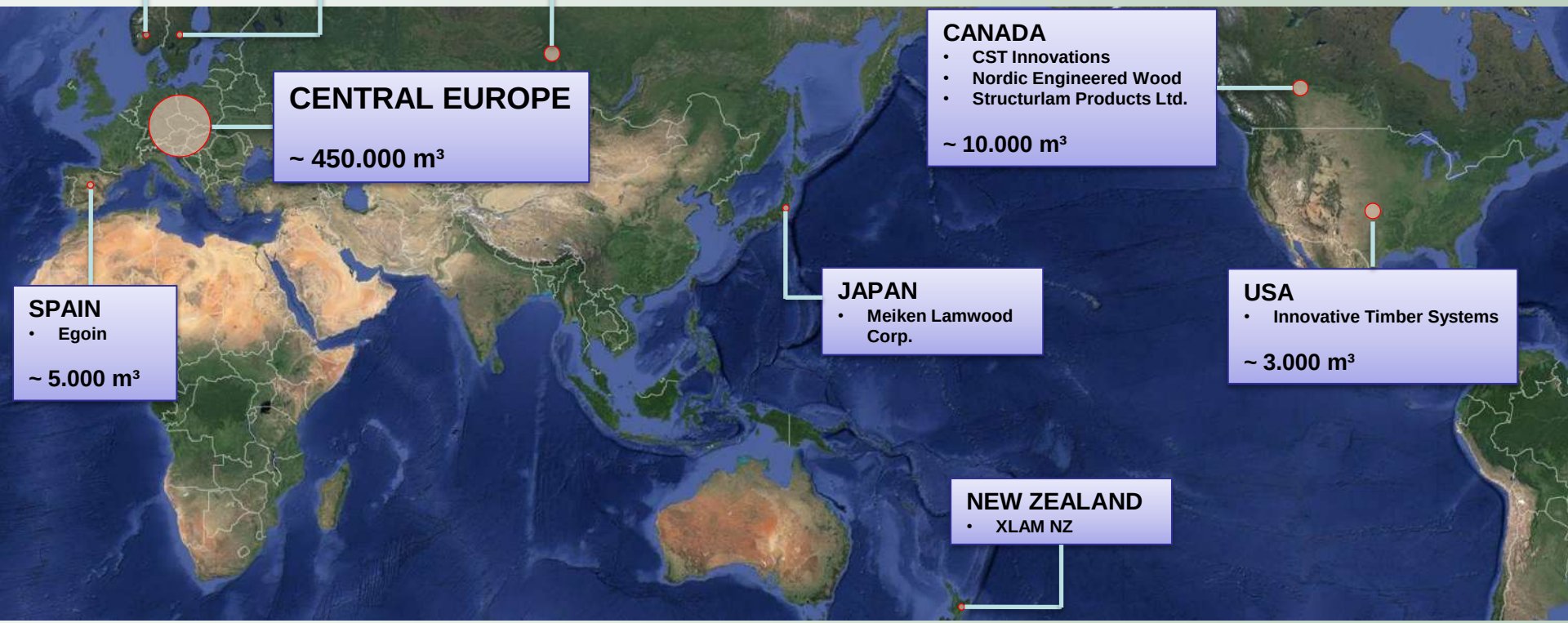
SWITZERLAND
- 2 CLT production sites

~ 18,000 m³

ITALY
- 6 CLT production sites

~ 30,000 m³

Worldwide
Production 2011 ~ 475.000 m³

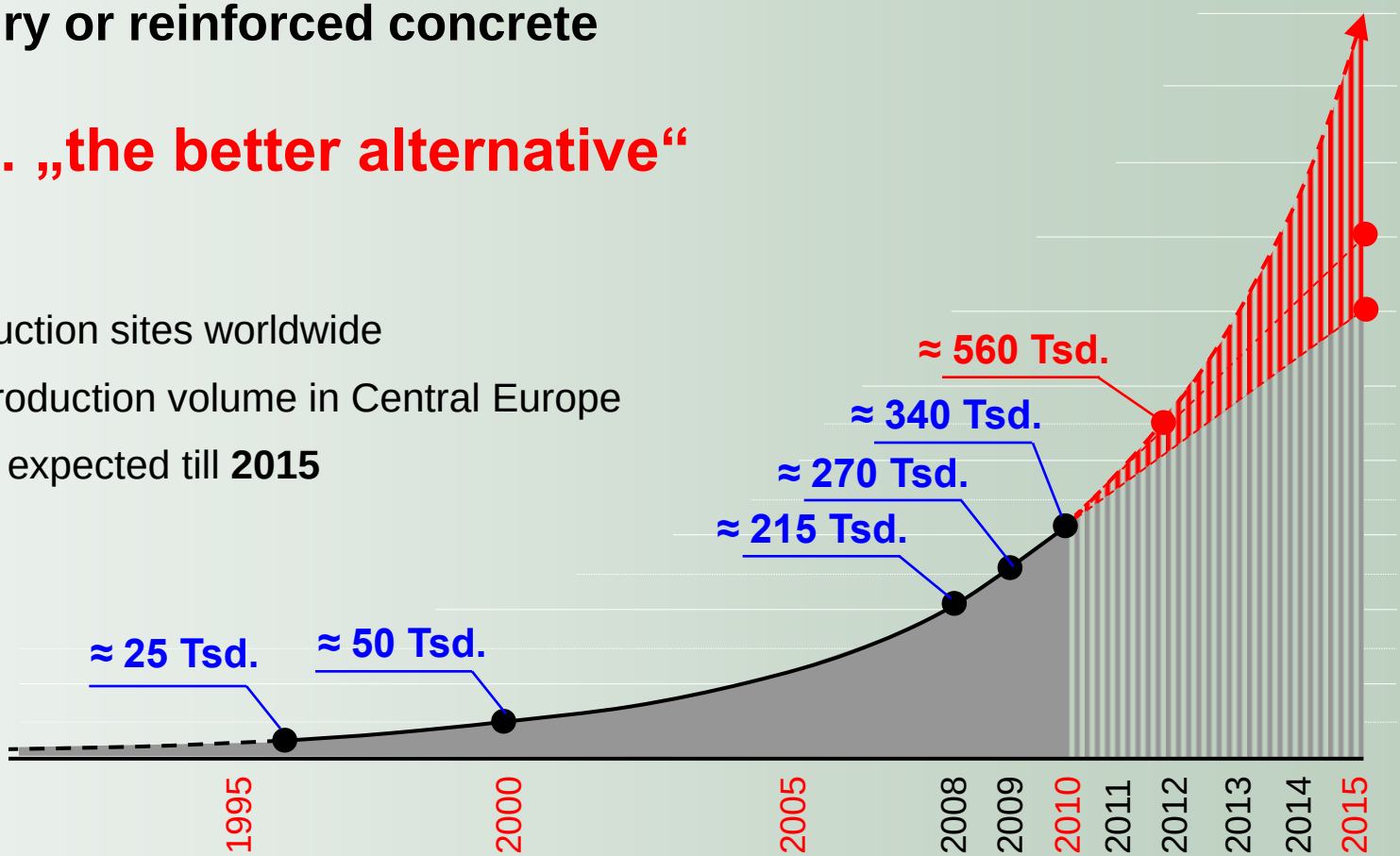


Re-organisation | shifting market shares → ~~concrete~~ | CLT

- **CLT is not competing with current | past timber engineering**
- **… but substitutes mineral based building products like masonry or reinforced concrete**

→ CLT, … „the better alternative“

- > 35 production sites worldwide
- 95 % of production volume in Central Europe
- **1 Mio. m³** expected till **2015**



- Introduction
- Idea & Development
- **Technology & Production**
- Applications

Cross Laminated Timber (CLT) composed as …

FLEXIBLE composite

- **ring-shank nails** (e.g. MHM-wall elements | Z-9.1-602)
- **metal brackets**, **screws**, …
- **hardwood dowels** (e.g. THOMA-Holz 100 | Z-9.1-574)
- **hardwood screws** (e.g. Rombach Bauholz+Abbund GmbH | ETA-11/0338)

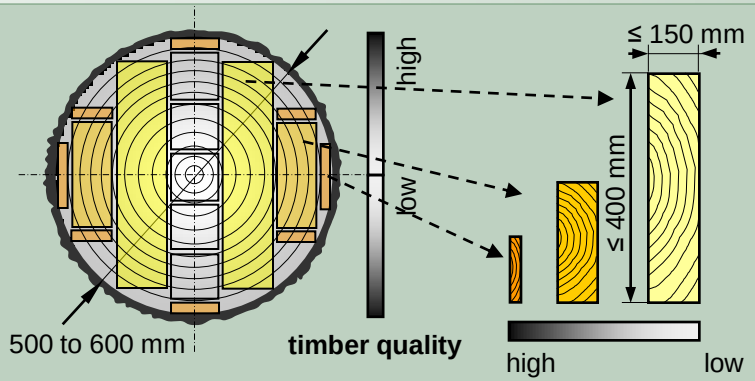
RIGID composite

- by surface bonding enabled by
  - **hydraulic / pneumatic / vacuum press facilities** (→ pressure “globally”)
  - **screws, brackets or nails** (→ pressure „locally“)

FOCUS: CLT as rigid composite product !

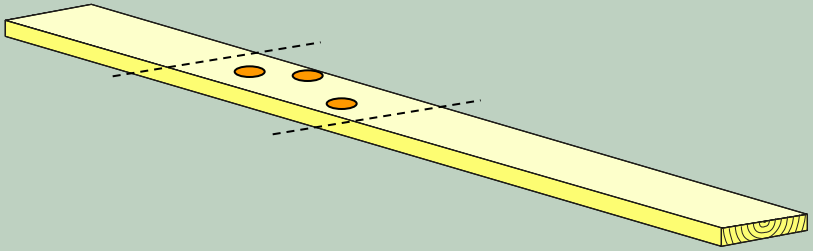
STEPs intermediate products | steps in production

STEP I
log



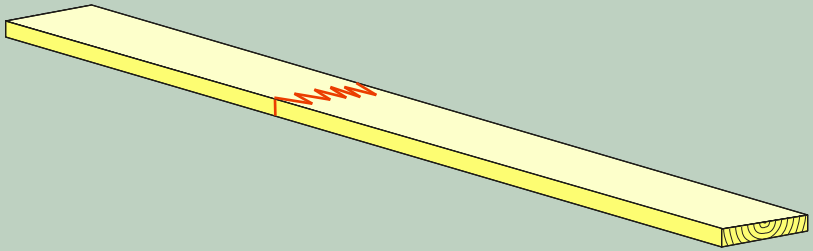
breakdown

STEP II
board



classification / grading
trimming

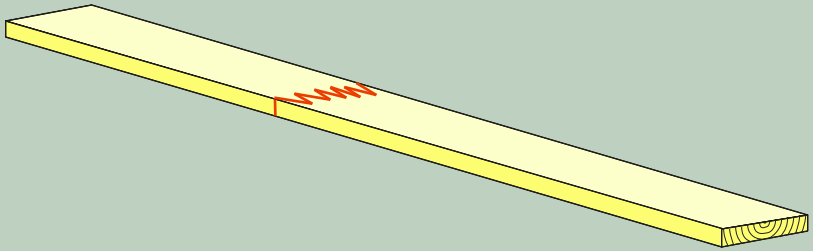
STEP III
finger jointed lamella



finger jointing

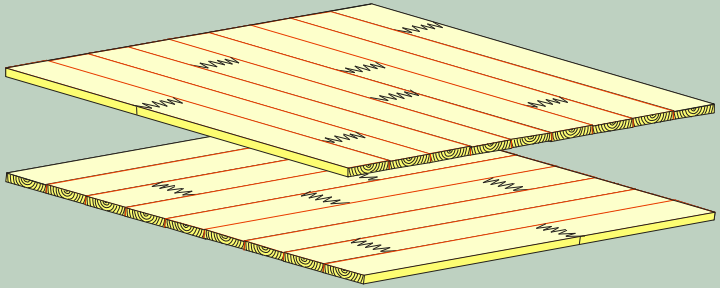
STEPs intermediate products | steps in production

STEP III
finger jointed lamella



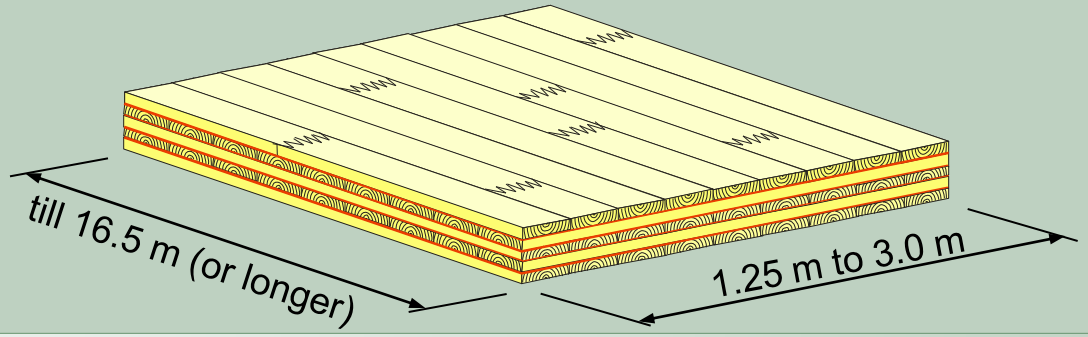
finger jointing

intermediate STEP
single-layer panel



edge bonding

STEP IV
cross laminated timber (CLT)



surface bonding

Requirements on the BASE MATERIAL (boards) …

- **strength / stiffness graded** C24 (C16) acc. to **EN 338** (bending !)

  ➔ classification acc. tensile properties, e.g. **T14 E11.0**, recommended !

  ➔ **stiffness grading +** compliance criteria to fulfil **minimum requirements on strength** (e.g. proof loading) recommended !

- **dimensions**
  - t_B = (12 to 45) mm; **standard layers: t_B = (20, 30, 40) mm**
  - w_B = (40 to 300) mm; **w_B / t_B ≥ 4**; **$w_{B,ref}$ = 150 mm** recommended!
  - edges prismatic or with profiling → shadow gaps

Requirements on the BASE MATERIAL (boards) …

- **species** mainly softwoods; primary Norway spruce; **u = (12 ± 2) %**

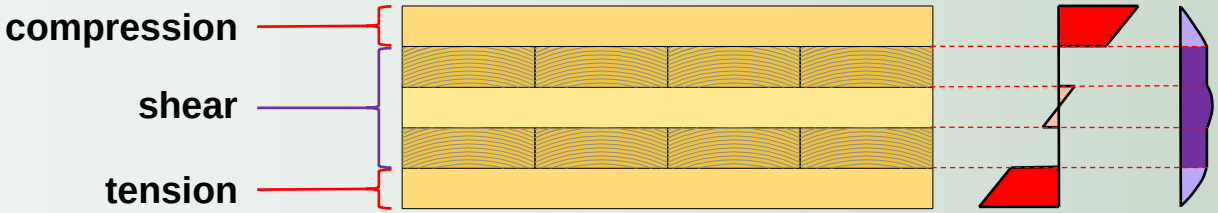
➔ **use or combination with other species (e.g. hardwoods) for optimising e.g.**

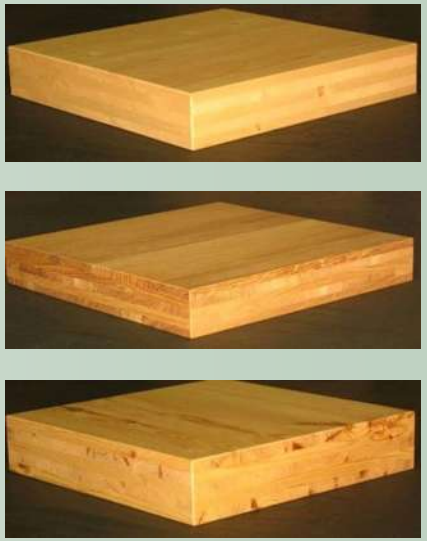
  - bending strength / stiffness
  - rolling shear modulus and strength

} e.g. birch, ash, eucalyptus, …

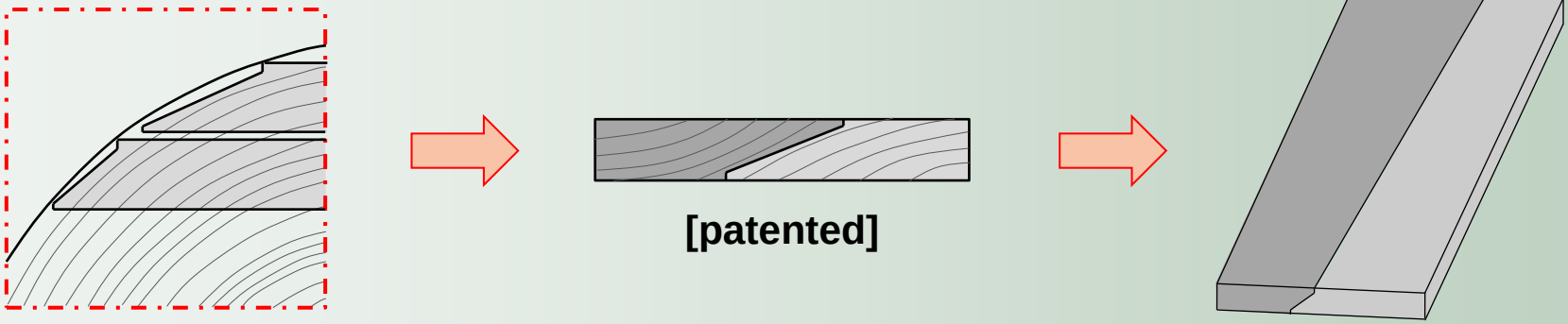
Requirements on the BASE MATERIAL (boards) …

- **optimisation of cross section by:**
  - applying different strength classes of one material
  - applying different species





- **further optimisation:**
  - applying of new cutting patterns



Requirements on FINGER JOINTS …

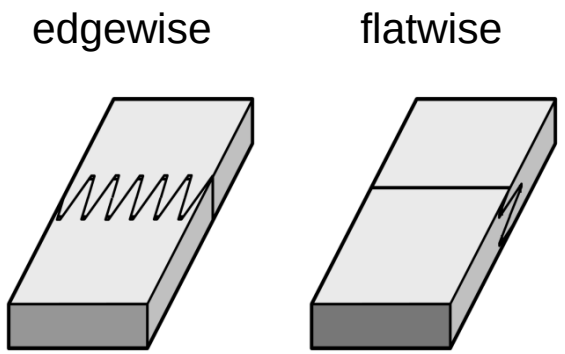
- economical approach for joining graded board segments longitudinally !
- position of finger joints …
  - **edgewise** (common in GLT)
  - **flatwise** (higher appearance quality)
- production & FPC regulations **EN 385**, **DIN 1052**, **prEN 16351**
- common adhesives: **1K-PUR (90% of CLT producers) | MUF (10%)**

- **minimum requirements on strength** related to the base material

proposal

$$f_{t,0,FJ,05} \geq \zeta_{05} \cdot f_{t,0,B,05}$$

$\zeta_{05} \geq 1.40$	for CV[$f_{t,0,B}$] = (35 ± 5) %
$\zeta_{05} \geq 1.20$	for CV[$f_{t,0,B}$] = (25 ± 5) %



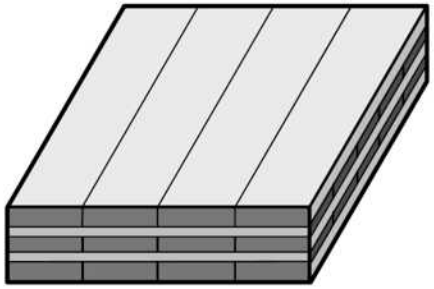
LAYUP of CLT

- **symmetrical !** → if additional layers, **counteracting layers** recommended
- a layer can be of …
  - **single (finger jointed) boards** / lamellas with / without **relieves**
  - **single-layer panels** of boards or **EWP**s

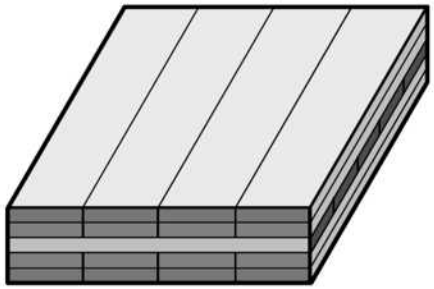
→ **double or triple layers** possible → resistance in bending, fire, …

→ **mechanical properties of the layer** shall be defined by the lowest quality of the used base material !

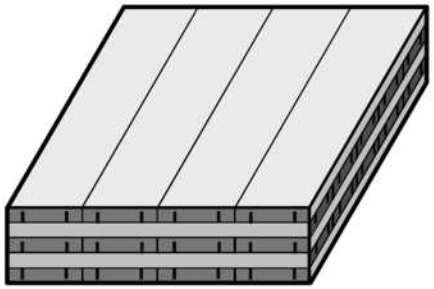
common layup



double outer layers



stress relieves



Gaps between boards

- currently **top layers ≤ 2(3) mm**; **core layers ≤ 4(6) mm**
- some approvals allow gaps **≤ 10 mm!**

- **gaps** have a negative influence on …
  - **mechanical behaviour**, e. g. rolling shear
  - **building physics**, e. g. fire design, airborne sound, air tightness
  - **joining technique**, i. e. pin-shaped fasteners
  - **appearance** quality

➔ **AIM: minimising gaps !**

Single-layer panels vs. single lamellas: PROS & CONS

PROS of single-layer panels

- gaps minimised
- lower requirements
  - $w_P/t_P \geq 4$ even when $w_B/t_P < 4$
  - surface bonding pressure
- building physics, joining technique, appearance

CONS of single-layer panels

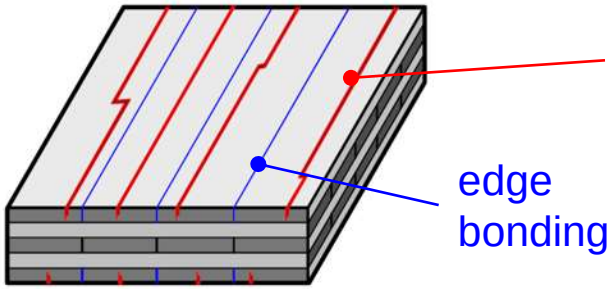
- **swelling / shrinkage !**

  → irregular pattern of cracks (appearance !)
  - reduced properties in building physics
  - relativization of $w_B/t_P < 4$

➔ **smaller gaps with thinner top layers !**

edge bonded top layers

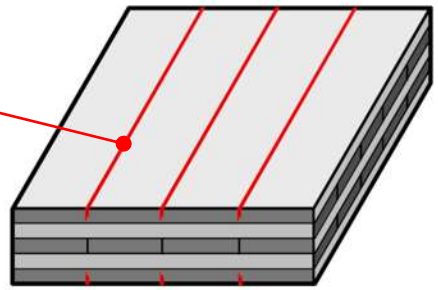
risk of irregular pattern of cracks



gaps

top layers without edge bonding

regular pattern of (shadow) cracks



Single-layer panels: several possibilities

edge bonding of boards / lamellas

- **strength / stiffness graded base material** continuously joined to endless plates by edge bonding; $\mathbf{w_B / t_P \geq 4}$
- homogenisation of physical properties → **system effects**

single-layer panels acc. to EN 13986

- $\mathbf{w_P / t_P \geq 4}$; no specific requirements on the base material
  → adequate quality assurance for **classification / grading of the panels** required!
- no additional homogenisation effects; single-layer panels already homogenised!

axial splitting of glulam

- $\mathbf{w_P / t_P \geq 4}$; splitting of **homogeneous glulam**
- strength grading performed on base material for glulam invalid !
  → adequate quality assurance for **classification / grading of the panels** required!
- no additional homogenisation effects; single-layer panels already homogenised!

Excursus: requirements on bonding pressure

➔ theoretically no bonding pressure required !

minimum requirements depending on …

- **surface quality** of adherends
  → flatness, roughness, warp, twist, …
  → **thickness tolerances ➔ ≤ (± 0.1 mm) recommended !**
- **adhesive system**
  → swelling (e.g. PUR) vs. shrinking adhesives (e.g. MUF)
  → „close contact“ (e.g. 1K-PUR) vs. gap-filling“ adhesives (e.g. MUF, 2K-PUR)
- **adhesive application system**: line-wise application common !
  → complete wetting required !
- **stiffness of adherends** against deflection (longitudinal & transverse) and torsion

Excursus: requirements on bonding pressure

upper limits determined by the timber species

- **crushing of adherend's surfaces**
  → reduces penetration and resistances, e.g. in shear

Conclusions for Norway spruce

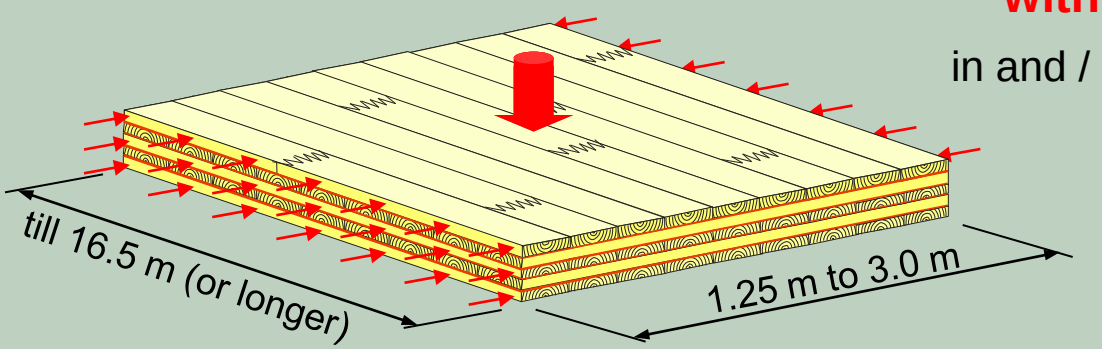
→ recommended to limit internal pressure to ≤ 1.0 N/mm²
(Baumann & Marian, 1961)

→ damage of cell structure and decrease in shear strength
at ≥ 0.40 N/mm² (radially) and ≥ 1.0 N/mm² (tangentially)
(Wassipaul, 1982)

→ p ≤ (0.4 ÷ 0.6) N/mm² recommended !

Possibilities for surface bonding …

- **continuously by press facilities**
  - hydraulic (pneumatic) press (0.10 to 1.00) N/mm²
  - vacuum press (0.05 to 0.10) N/mm²
- **discontinuously by pin-shaped fasteners**
  - pressing with screws, nails or brackets (0.01 to 0.20) N/mm²

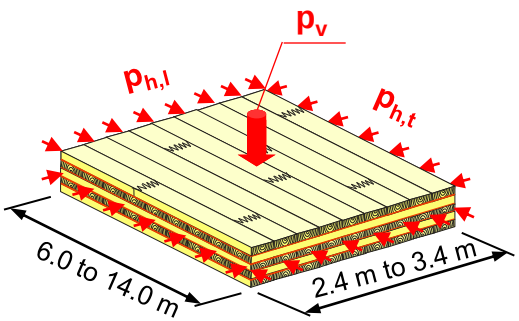


with / without transverse pressure

in and / or across the direction of production

Examples of hydraulic press facilities …

		MINDA "CLT press" (G)	**Kallesoe** "CLT press" (DK)
CLT dimensions		l = (**6.0 to 18.0**) m w = (**2.1 to 3.5**) m t = (**70 to 400**) mm	l = (**4.0 to 20.0**) m w = (**2.2 to 3.2**) m t = (**60 to 400**) mm
type of press system		hydraulic, continuous	hydraulic, discontinuous high frequency press
bonding pressure	vertical, $\mathbf{p_v}$	(**0.4 to 0.6** (0.8)) N/mm²	**≤ 1.0** N/mm²
	horizontal transverse, $\mathbf{p_{h,t}}$	10 kN/m	available
	horizontal lengthwise, $\mathbf{p_{h,l}}$	45 kN	available



© Minda Industrieanlagen GmbH

© Kallesoe Maschinery A/S

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

Further CLT-press producers …

SPRINGER (AT) | LEISSE (G) | LEDINEK (SLO) | WEINIG GROUP (G) | WOODTEC Fankhauser (vacuum press) (CH) | SORMEC (IT) | …

Latest developments …

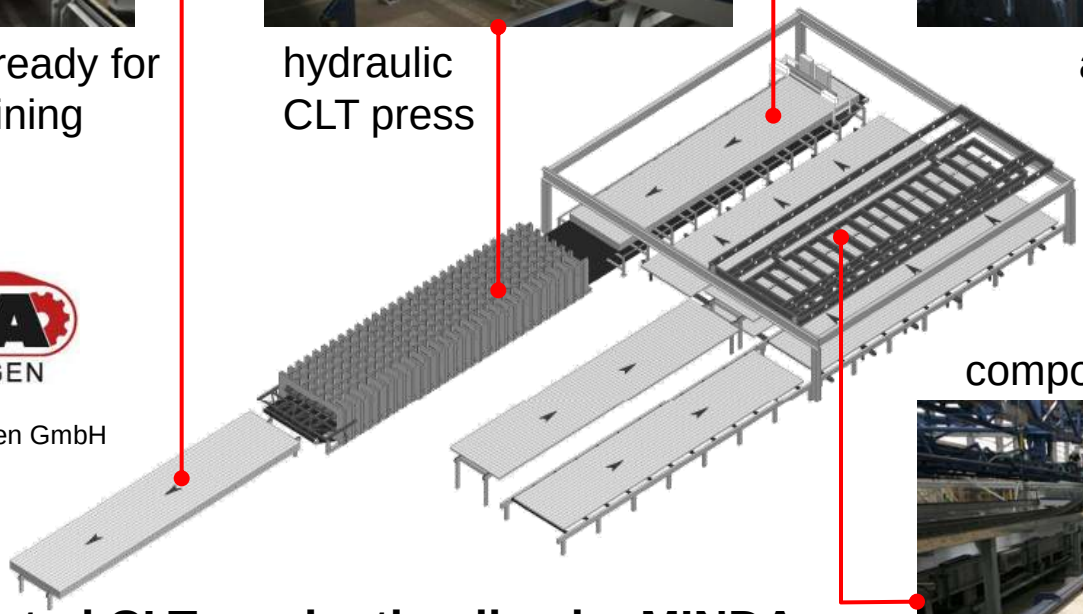
- **modular production lines**, e.g. MINDA
  - BASIC 1 hydraulic press & manual feeding 2 to 3 press cycles / shift
  - STEP I 1 hydraulic press & automated feeding 5 to 6 press cycles / shift
  - STEP II 2 hydraulic press & automated feeding 10 to 12 press cycles / shift
- **flexible production lines**
  - CLT composed of loose boards / lamellas
  - CLT composed of single-layer panels
  - CLT including door & window openings

  } adapted adhesive application system; discretely adapted surface pressure
- **high frequency CLT press**

CLT element ready for cutting and joining

hydraulic CLT press

adhesive application next layer stand-by



MINDA INDUSTRIEANLAGEN

cross layers composing & compressing

fully automated CLT production line by MINDA

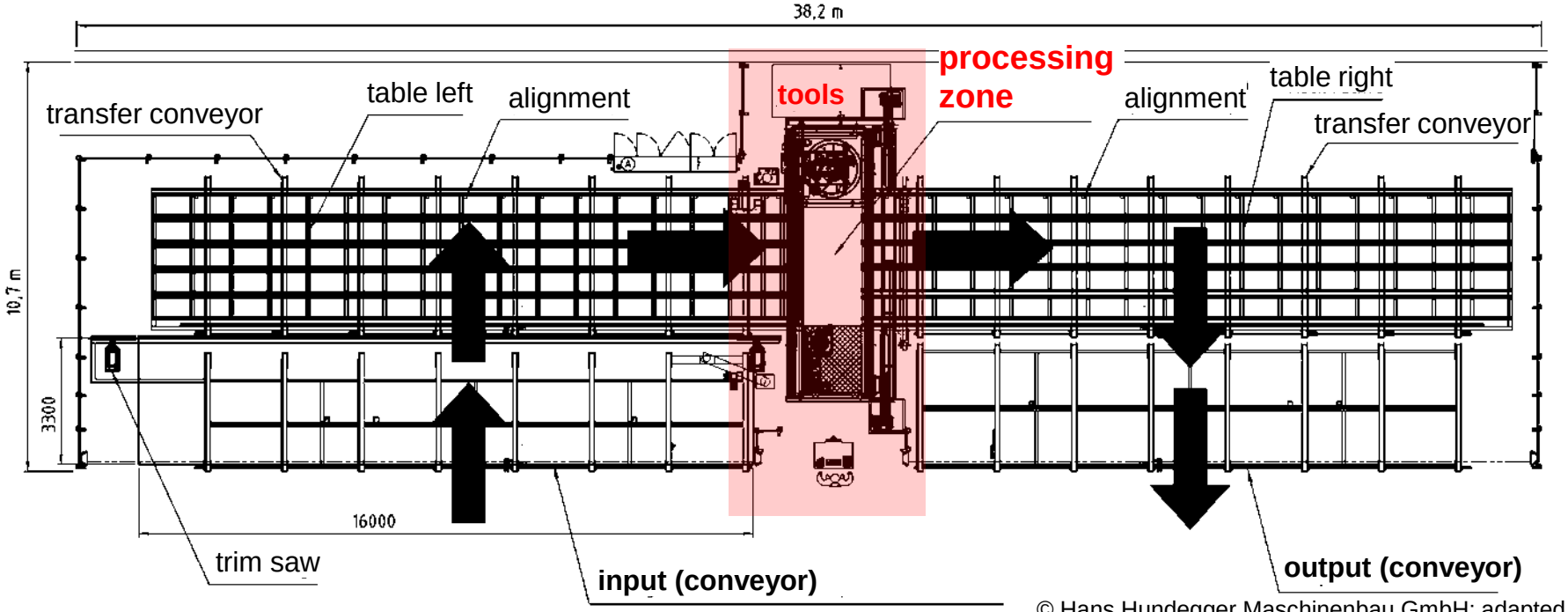
- CLT production of single lamellas
- ≤ 14 press cycles / shift; 1K-PUR (Purbond)
- ≈ 20 TSD m³ / shift / year

Schickhofer G (2011) Presentation, Zurich, Switzerland, 25th October 2011; adapted

CNC cutting and joining ➔ customising !

→ cutting | trimming | joining | milling (e.g. for connection technique)

portal processing centre „PBA-drive“ | Hans Hundegger Maschinenbau GmbH



- **“throughfeed processing” on all surfaces and edges**
- element dimensions: **l = (2.5 to 16.0) m | w = (0.625 to 4.0) m | t ≤ 350 mm**

processing zone

„PBA-drive“

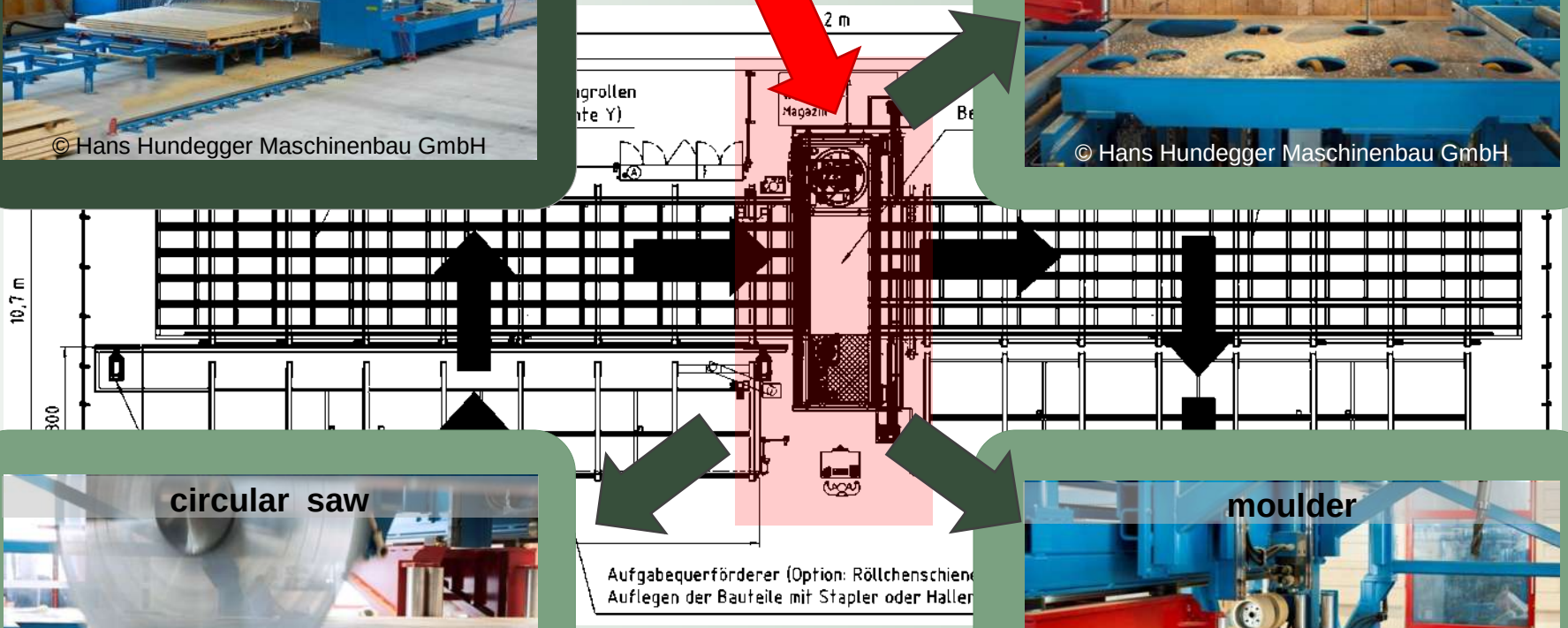
Hans Hundegger Maschinenbau GmbH

portal processing centre

© Hans Hundegger Maschinenbau GmbH

chain saw

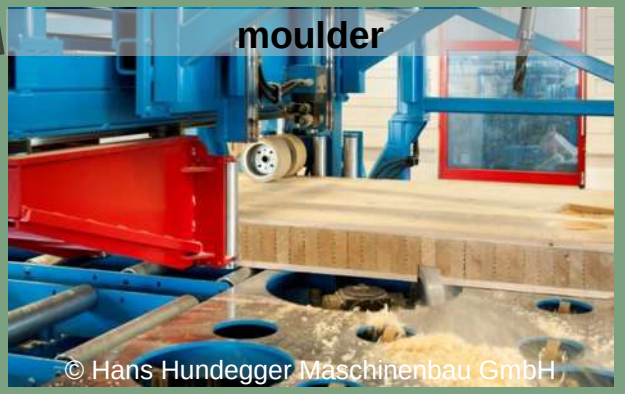
© Hans Hundegger Maschinenbau GmbH



circular saw

© Hans Hundegger Maschinenbau GmbH

moulder



© Hans Hundegger Maschinenbau GmbH

Hundegger
Innovationen für den Holzbau

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

- Introduction
- Idea & Development
- Technology & Production
- **Applications**

Solid **T**imber **C**onstruction **(STC) ...**

- ... is a building technique using elements out of **C**ross **L**aminated **T**imber (**CLT**) for structural walls and ceilings in supernatural buildings
- ... enables **industrialisation** of timber constructions
- ... a **reason** why timber is coming **back to town**:

not only ...

Vienna (AT) - 6F

© schluder architektur ZT GmbH

London (UK) - 8F

© Pirmin Jung

Milano (IT) - 9F

© TEKNE

Solid **T**imber **C**onstruction **(STC) ...**

- ... is a building technique using elements out of **C**ross **L**aminated **T**imber (**CLT**) for structural walls and ceilings in supernatural buildings
- ... enables **industrialisation** of timber constructions
- ... a **reason** why timber is coming **back to town**:

... but also

St. Loup (FR)

© Milo Keller

Graz (AT)

Graz (AT)

© Paul Ott

Solid **T**imber **C**onstruction **(STC) ...**

- ... currently leads to **competitions to maximize dimensions**
- aspects like
  - wider in application
  - longer in period of use
  - higher in quality
- should not be forgotten when thinking in **comparatives** and **superlatives**

→ improving the **efficiency** of building with CLT

→ thinking and acting **interdisciplinary**

... to guarantee **high quality** and **durability**

Social housing Wittenbauerstraße | Graz

general FACTS

- Housing
  - 2 buildings
  - 3 storeys
  - 22 flats in STC (60 ÷ 90 m²)
- Dimensions
  - 2,600 m² total area
  - 1,600 m² living area
  - € 3.3 million (STC ~ 20%)

  → € 2,000 per m² living area

Social housing Wittenbauerstraße | Graz

general FACTS

- 560 m³ CLT elements used for
  - walls (210 m³ | 5 layers)
  - floors (280 m³ | 5 layers)
  - roofs (70 m³ | 5 layers)

  → **0.21 m³ CLT / m² total area**

  → **0.35 m³ CLT / m² living area**

  → **25.0 m³ CLT / flat**
- project duration: 20 months
- **STC** assembly: 1 month (5%)

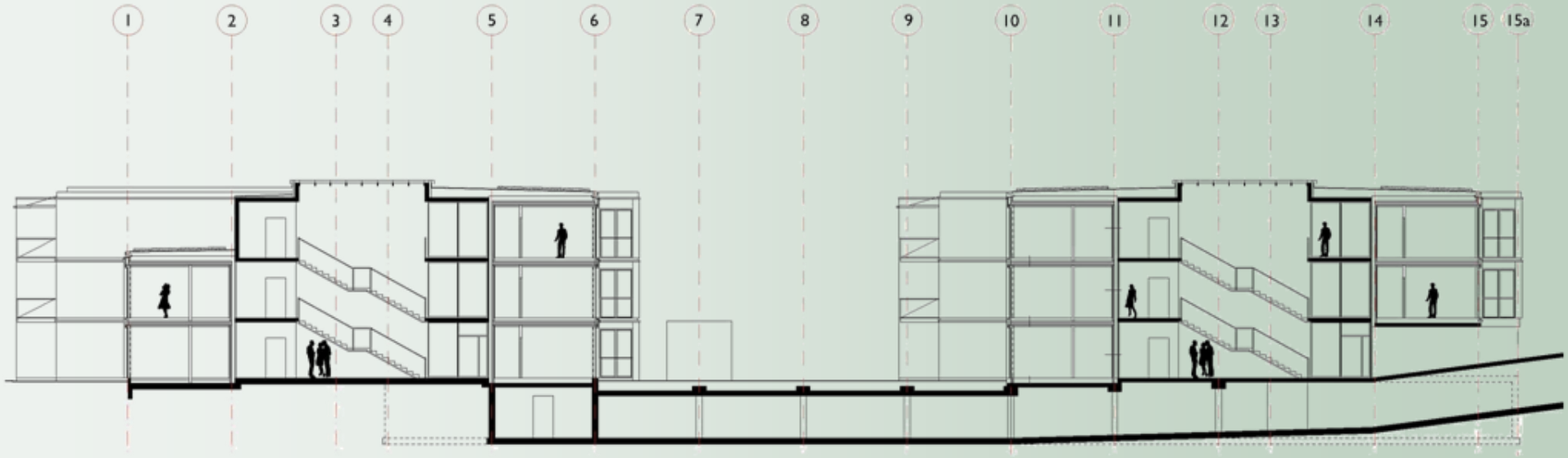
Social housing Wittenbauerstraße | Graz

using hardwood for CLT production

- walls of 1 flat out of **birch-CLT**
- ruled by
  “approval on individual basis”
  → material tests of boards and finished lay-ups
  → delamination tests on spot core samples
  → long-time monitoring

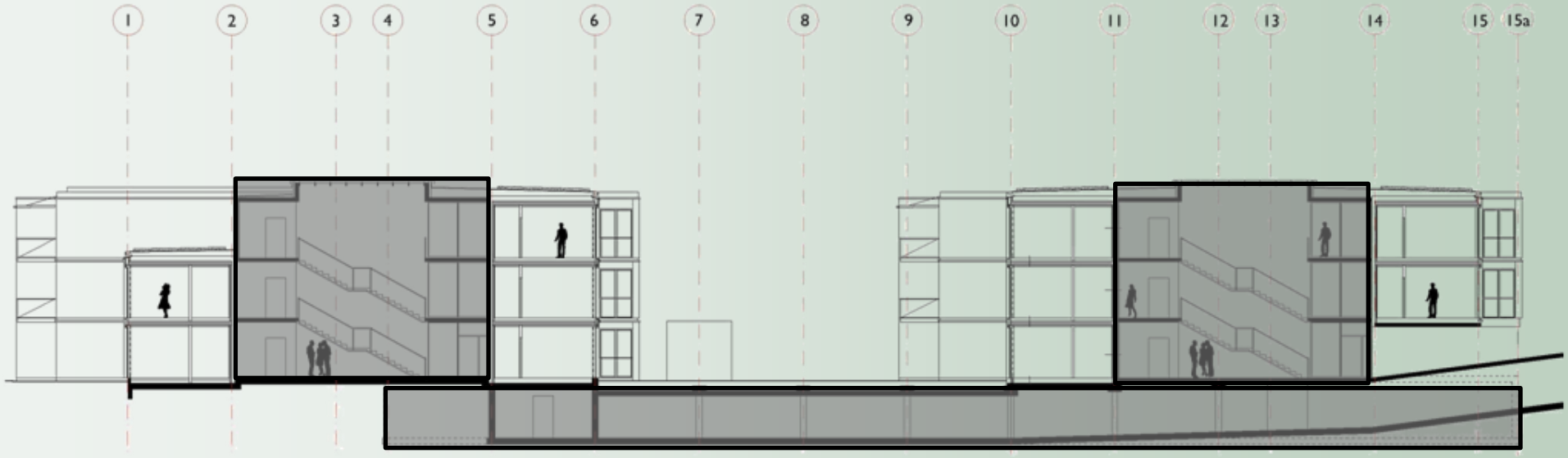
Social housing Wittenbauerstraße | Graz

principles of the structural system



Social housing Wittenbauerstraße | Graz

principles of the structural system



© Peter Zinganel

inner core | underground parking

Social housing Wittenbauerstraße | Graz

principles of the structural system

© Peter Zinganel

inner core | underground parking

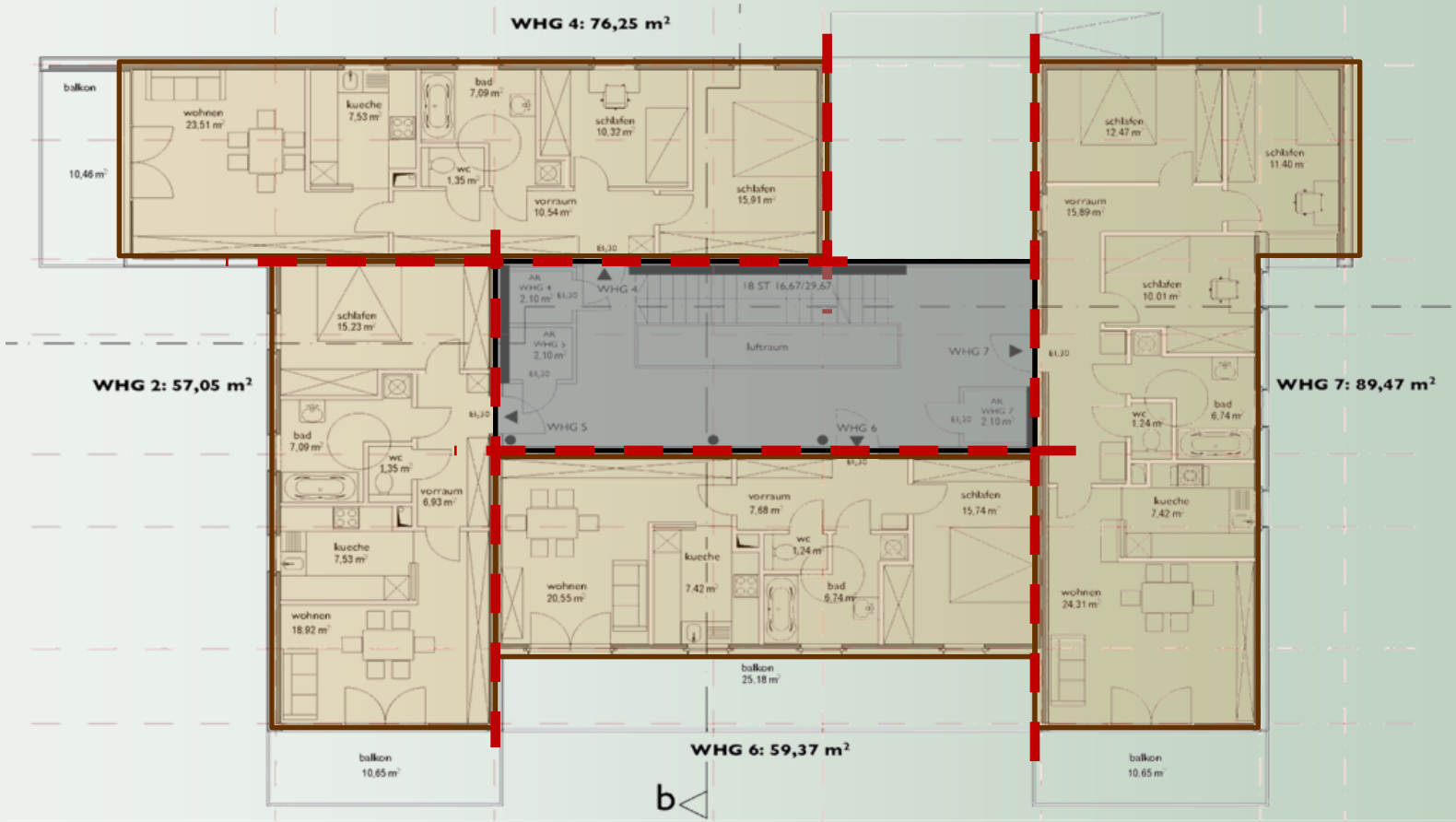
flats in STC

Social housing Wittenbauerstraße | Graz

principles of the structural system

Social housing Wittenbauerstraße | Graz

principles of the structural system

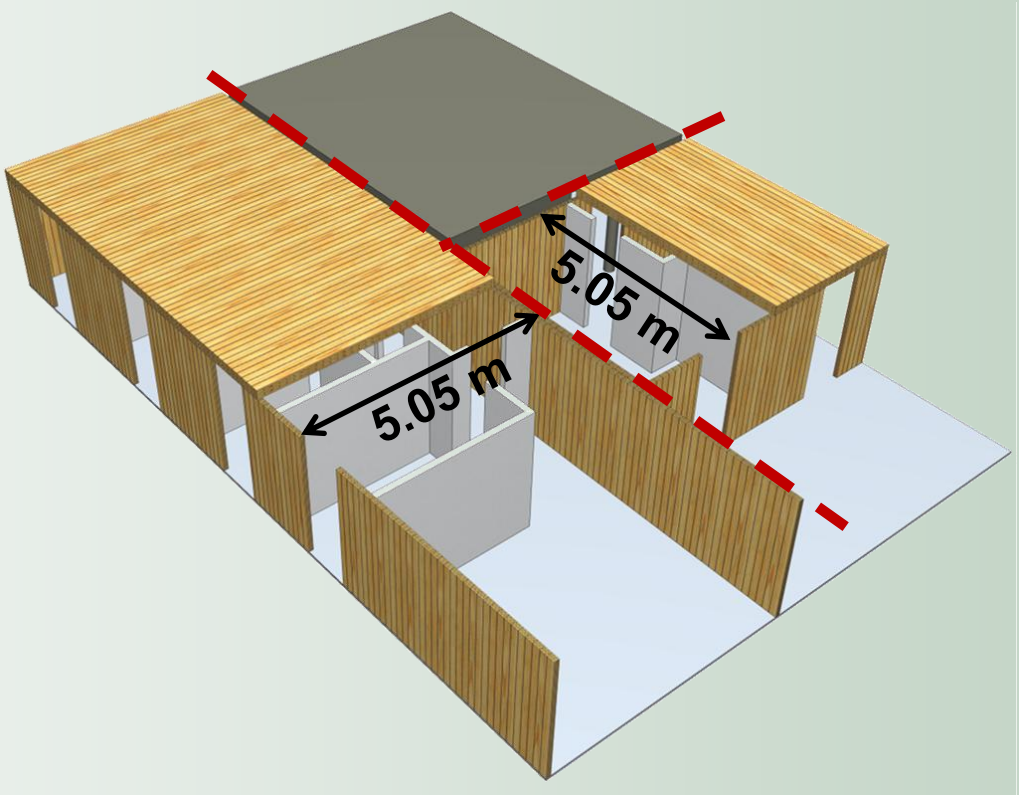


Social housing Wittenbauerstraße | Graz

principles of the structural system

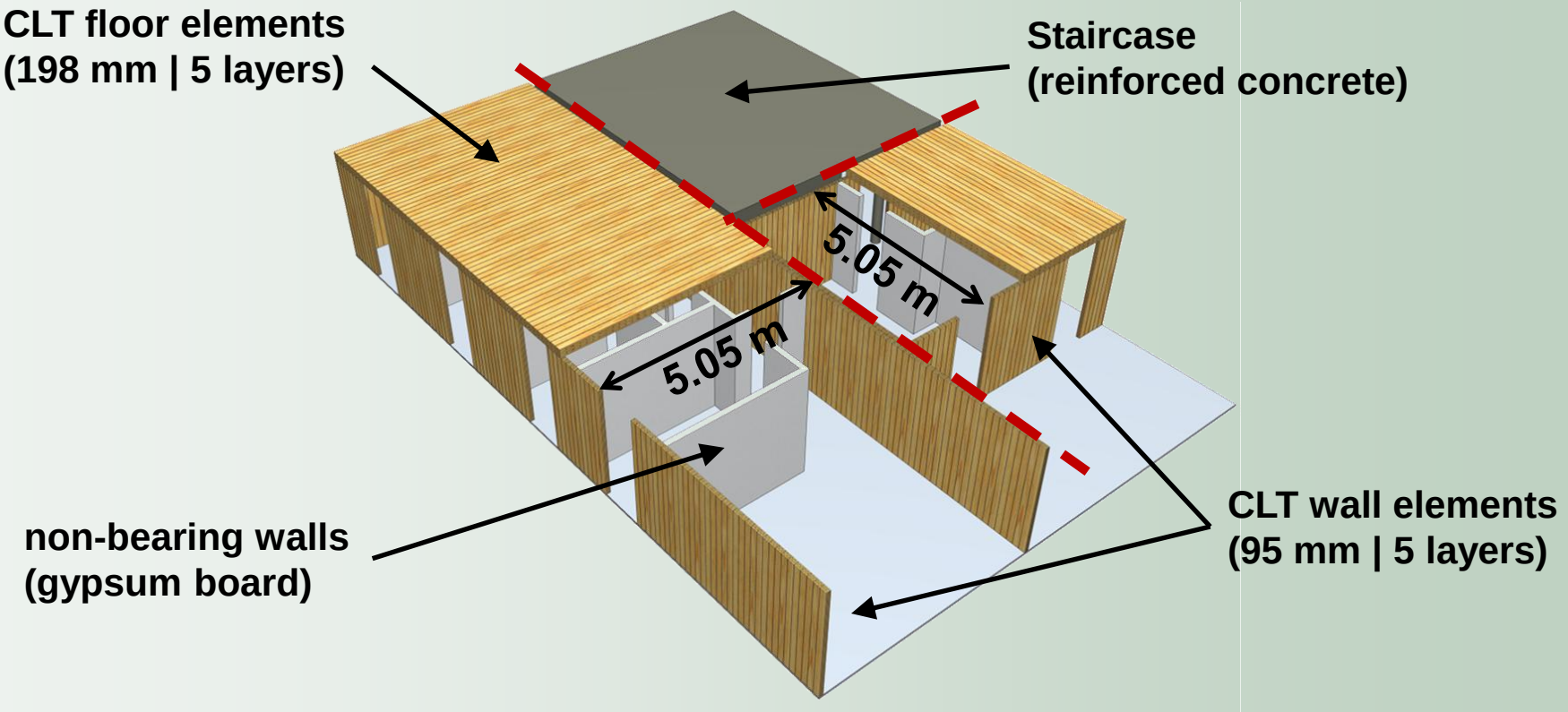
Social housing Wittenbauerstraße | Graz

principles of the structural system



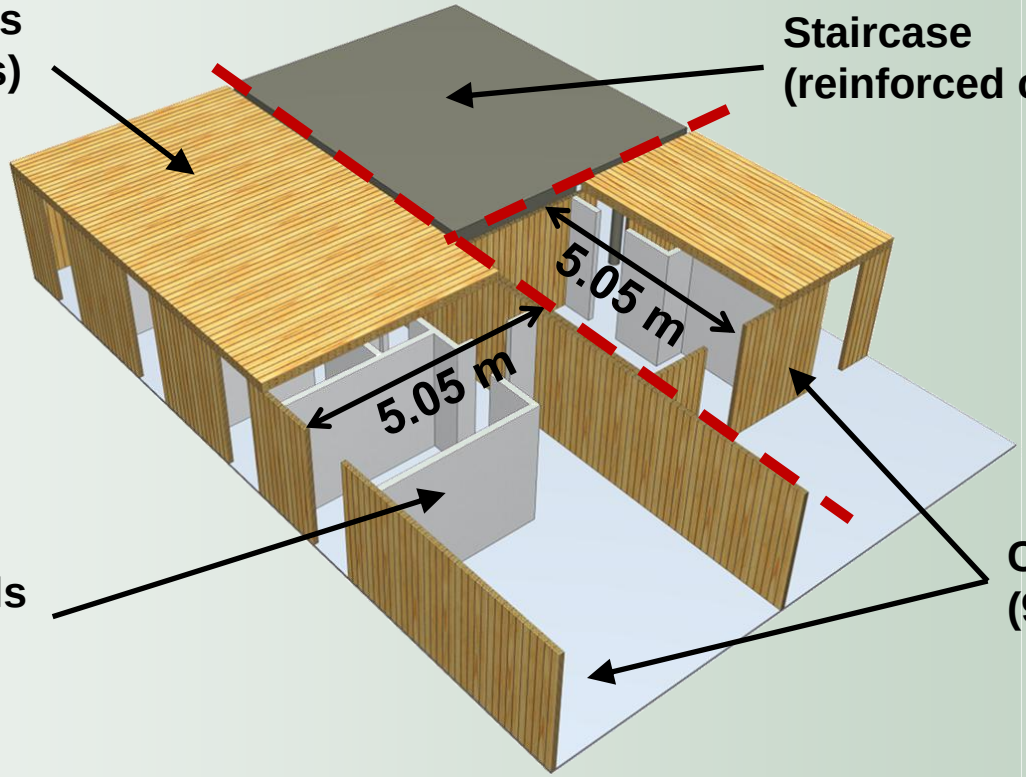
Social housing Wittenbauerstraße | Graz

principles of the structural system



Social housing Wittenbauerstraße | Graz

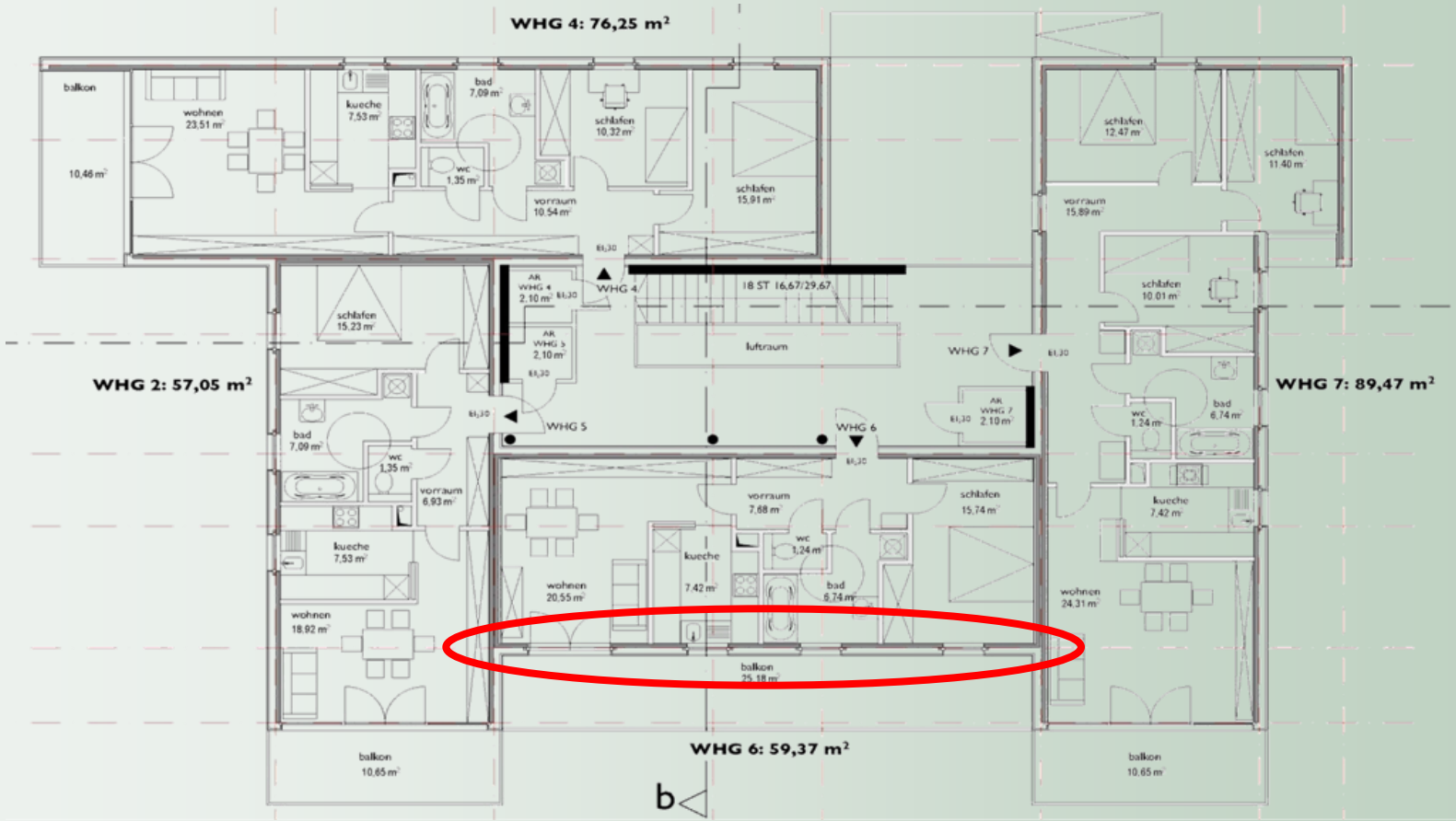
principles of the structural system



→ **uniform** and **economical** span widths simplify structural design and assembly

Social housing Wittenbauerstraße | Graz

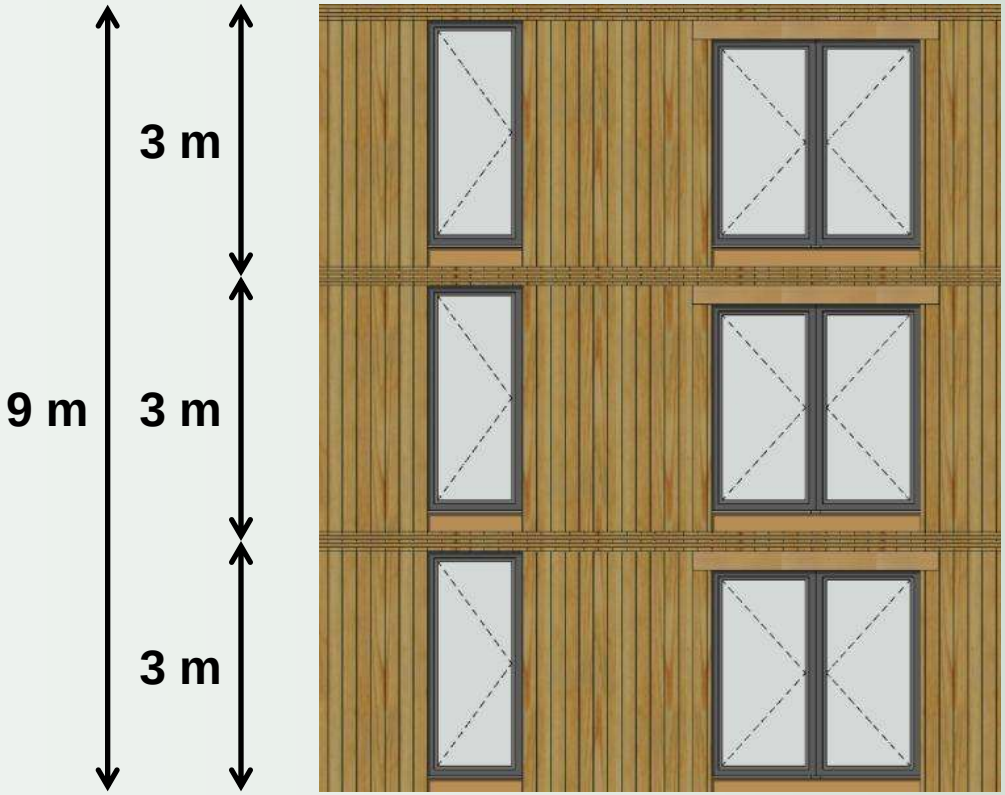
principles of the structural system



© Peter Zinganel

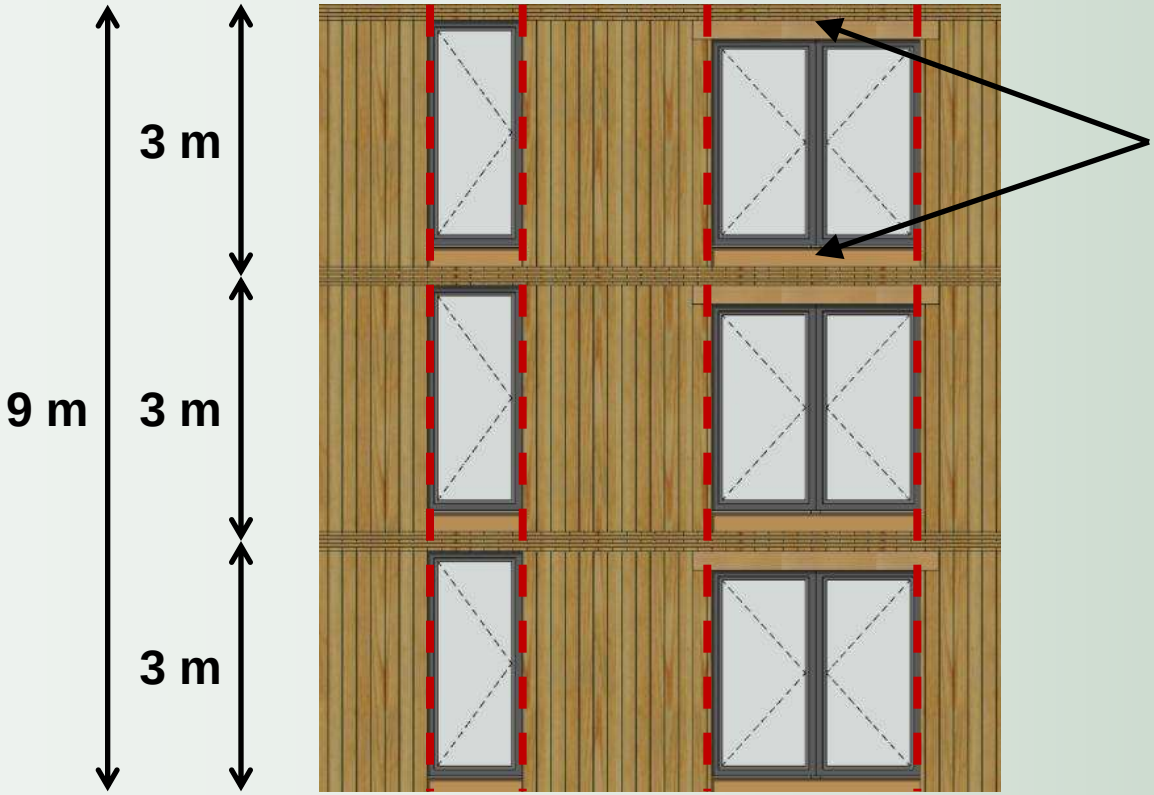
Social housing Wittenbauerstraße | Graz

principles of the structural system



Social housing Wittenbauerstraße | Graz

principles of the structural system

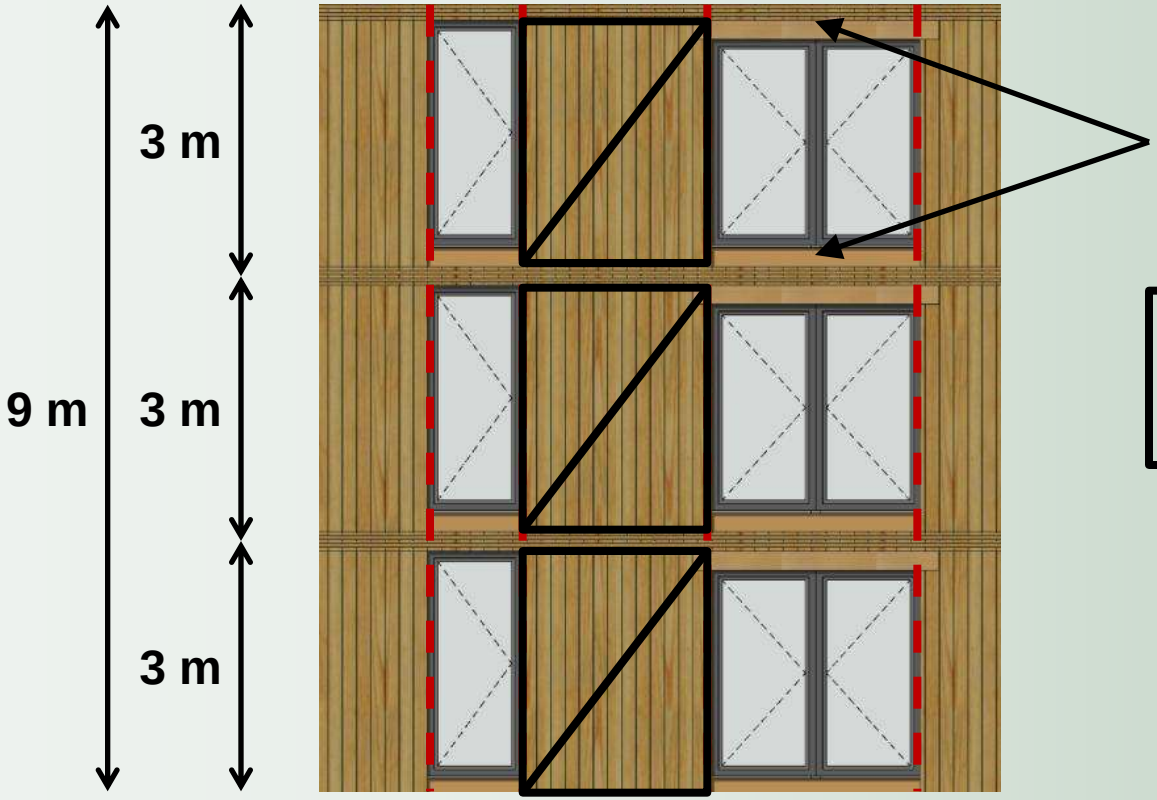


secondary components:

- pre-fabricated
- supporting beams if necessary

Social housing Wittenbauerstraße | Graz

principles of the structural system



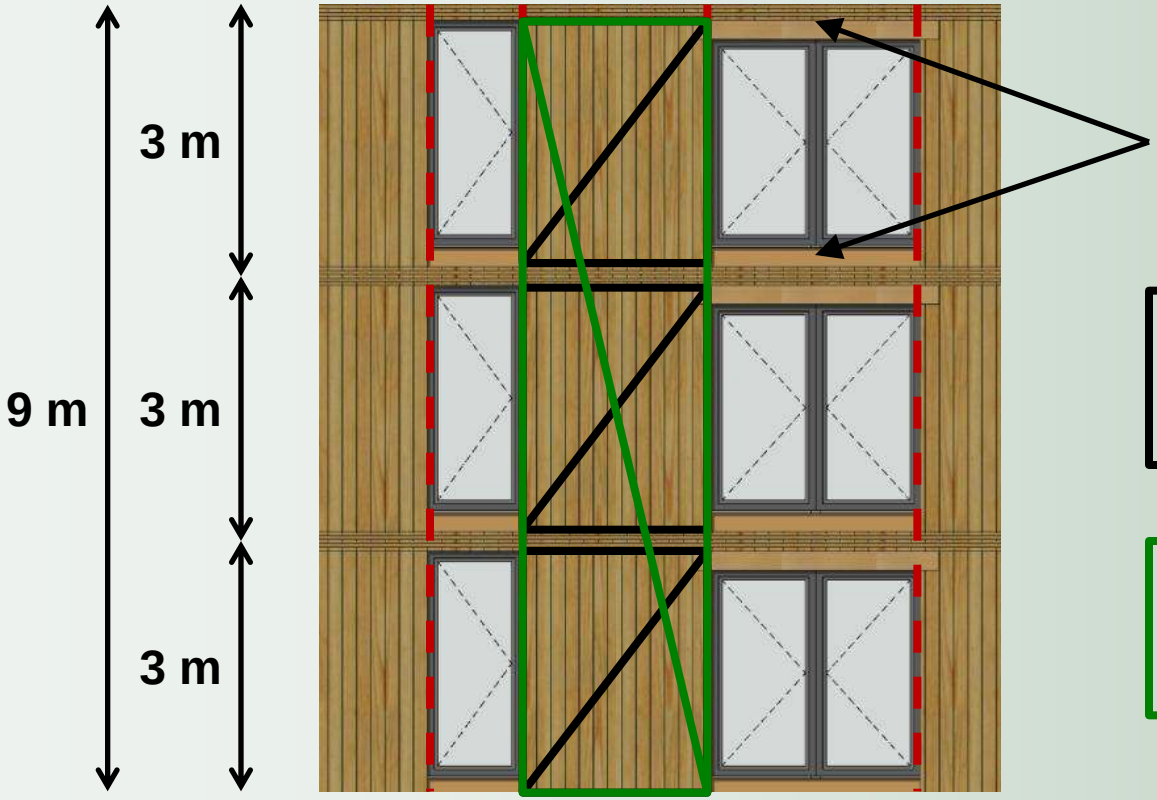
secondary components:

- pre-fabricated
- supporting beams if necessary

Var 1:
room-high CLT wall elements instead of large cutouts

Social housing Wittenbauerstraße | Graz

principles of the structural system



secondary components:

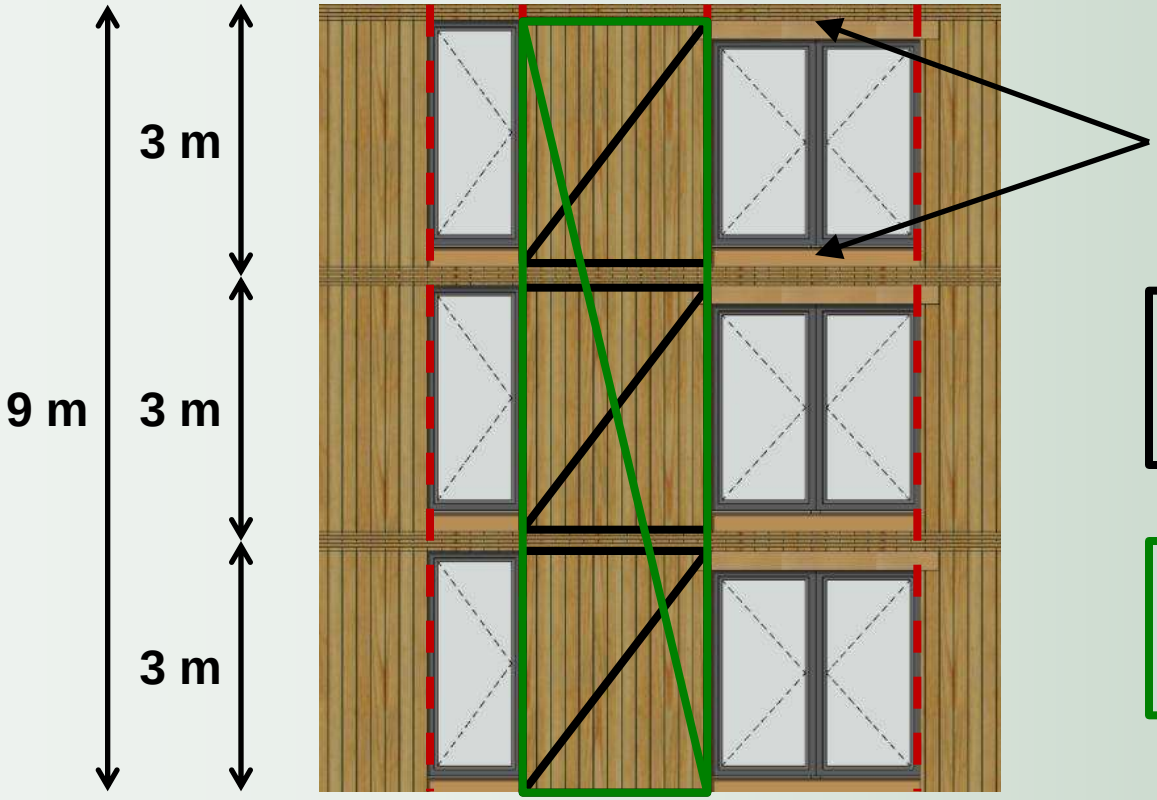
- pre-fabricated
- supporting beams if necessary

Var 1:
room-high CLT wall elements instead of large cutouts

Var 2:
continuous CLT elements over the whole height of the building

Social housing Wittenbauerstraße | Graz

principles of the structural system



secondary components:
- pre-fabricated
- supporting beams if necessary

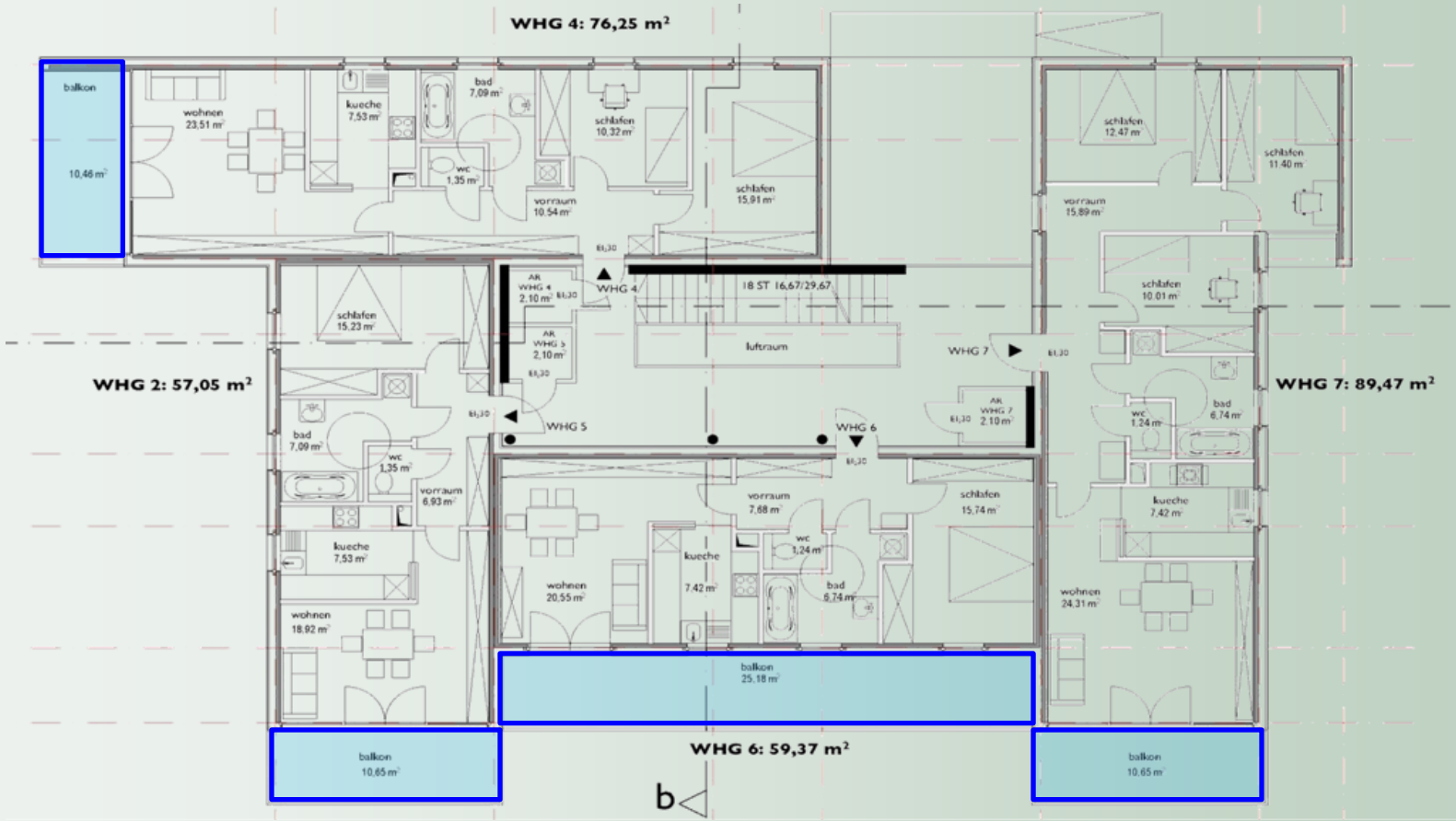
Var 1:
room-high CLT wall elements instead of large cutouts

Var 2:
continuous CLT elements over the whole height of the building

→ **continuously** situated **full storey walls** avoid **waste of CLT** and simplify **fastener design**

Social housing Wittenbauerstraße | Graz

principles of the structural system



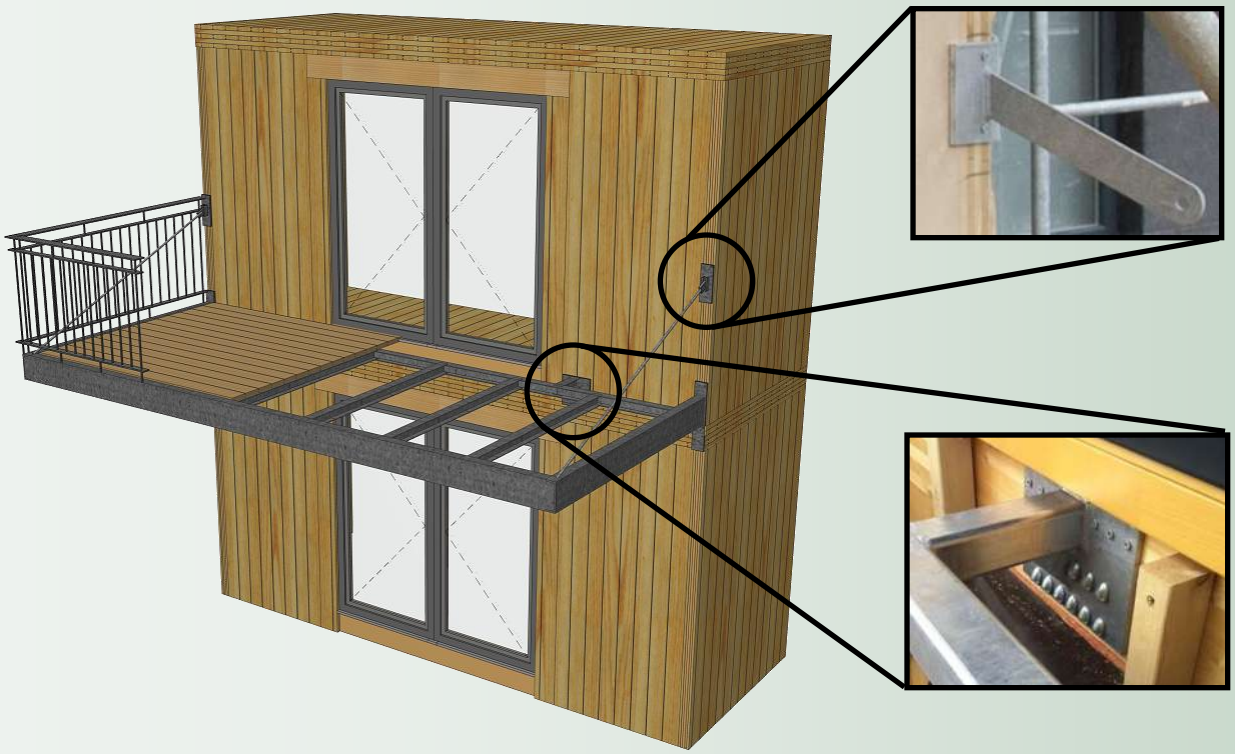
© Peter Zinganel

Social housing Wittenbauerstraße | Graz

principles of the structural system

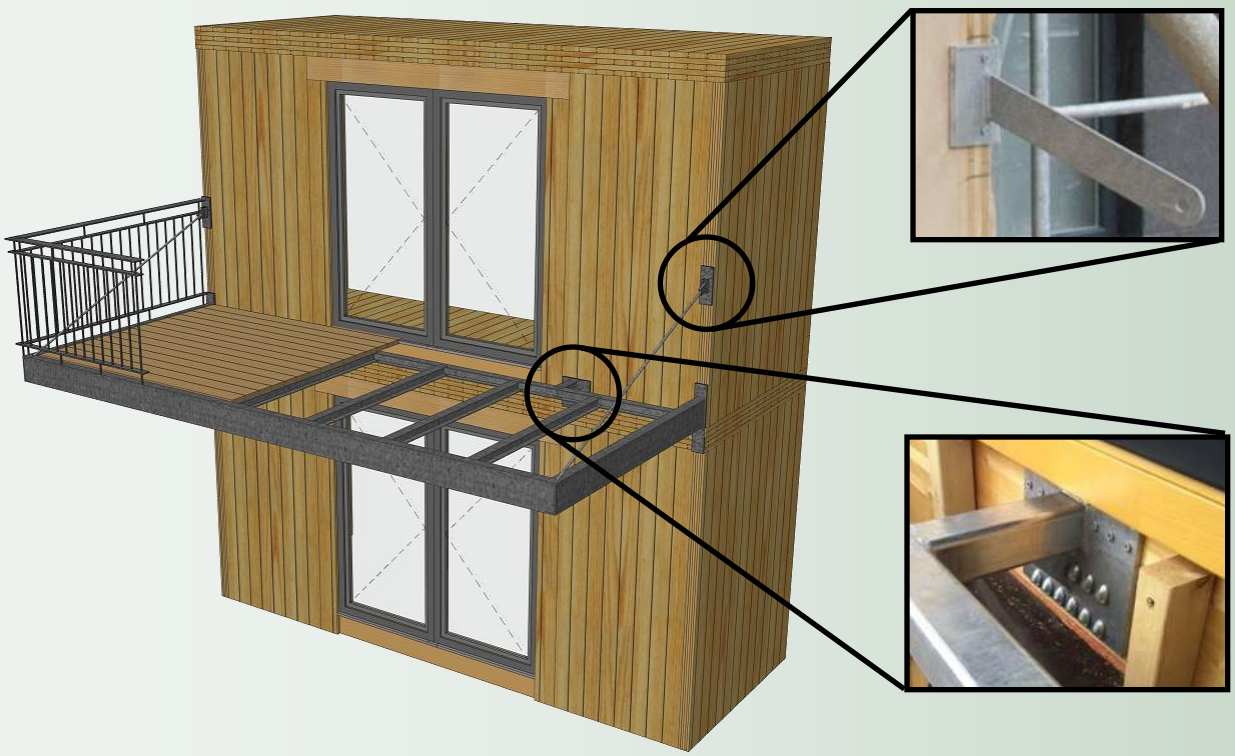
Social housing Wittenbauerstraße | Graz

principles of the structural system



Social housing Wittenbauerstraße | Graz

principles of the structural system

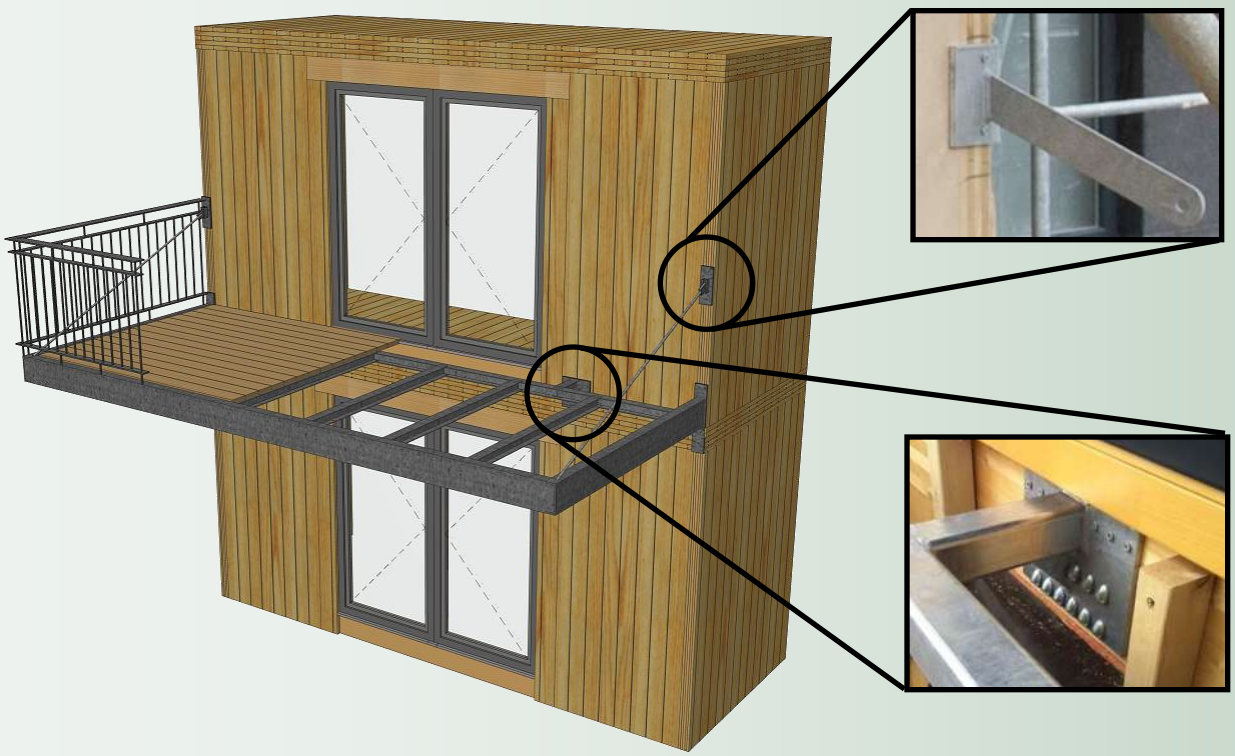


balcony as part of primary structure (cantilever system):

- different life cycles
- thermal bridges
- moisture and air transfer

Social housing Wittenbauerstraße | Graz

principles of the structural system



balcony as part of primary structure (cantilever system):

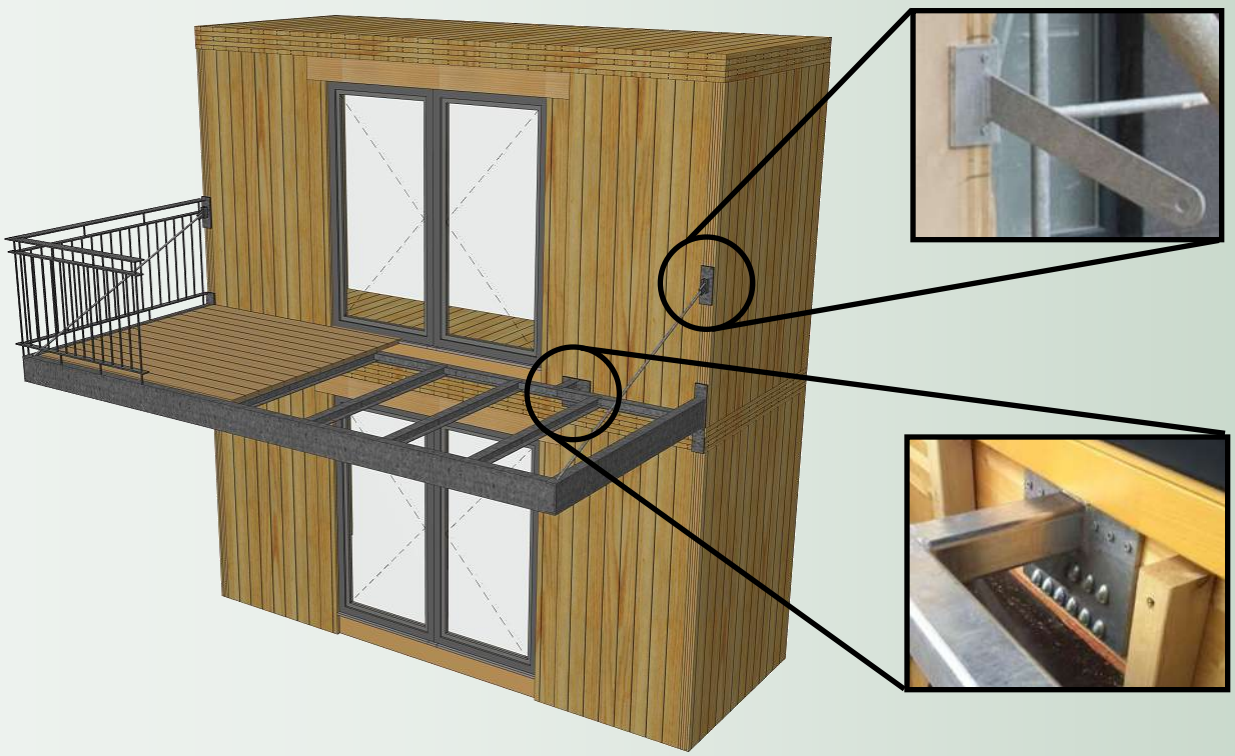
- different life cycles
- thermal bridges
- moisture and air transfer

balcony as secondary construction:

- pre-fabricated and fast to assemble
- no height compensation necessary
- easily to replace

Social housing Wittenbauerstraße | Graz

principles of the structural system



balcony as part of primary structure (cantilever system):

- different life cycles
- thermal bridges
- moisture and air transfer

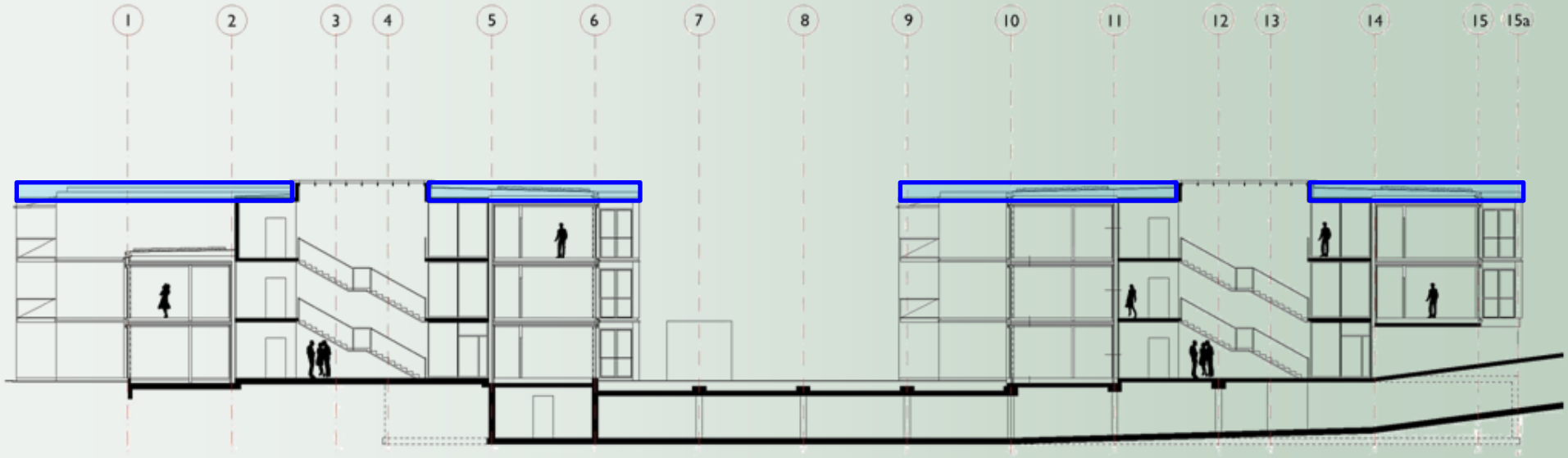
balcony as secondary construction:

- pre-fabricated and fast to assemble
- no height compensation necessary
- easily to replace

→ components with **different life cycles** should be structurally disconnected

Social housing Wittenbauerstraße | Graz

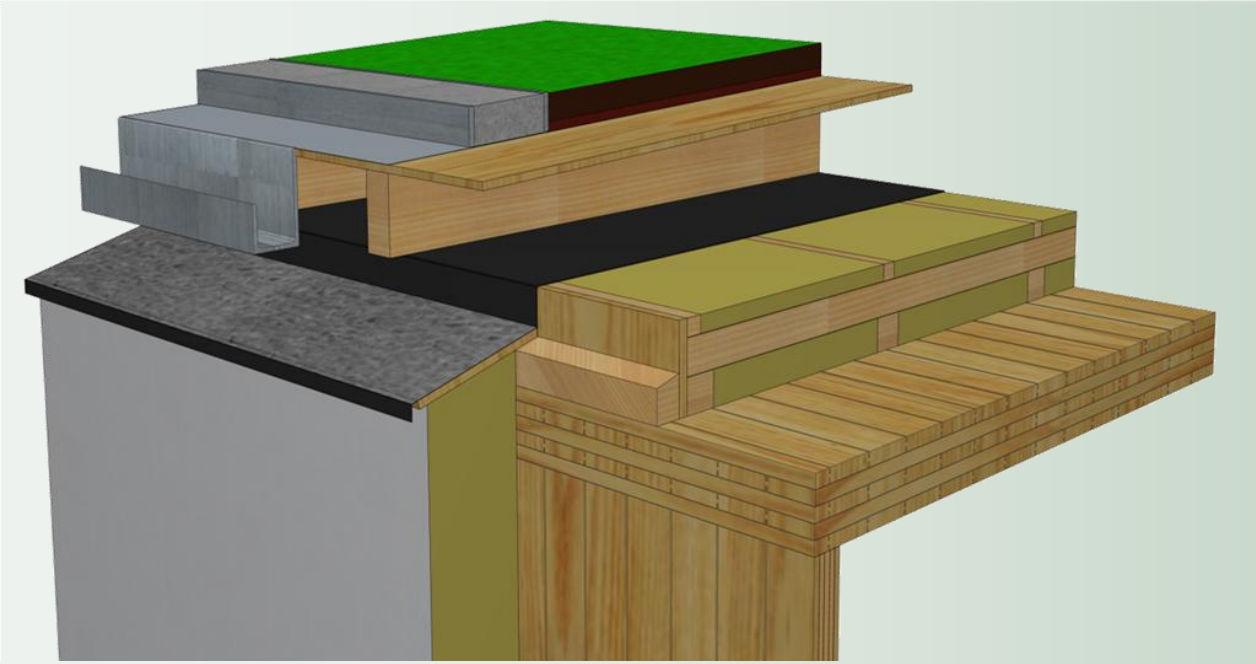
essential constructive aspects



© Peter Zinganel

Social housing Wittenbauerstraße | Graz

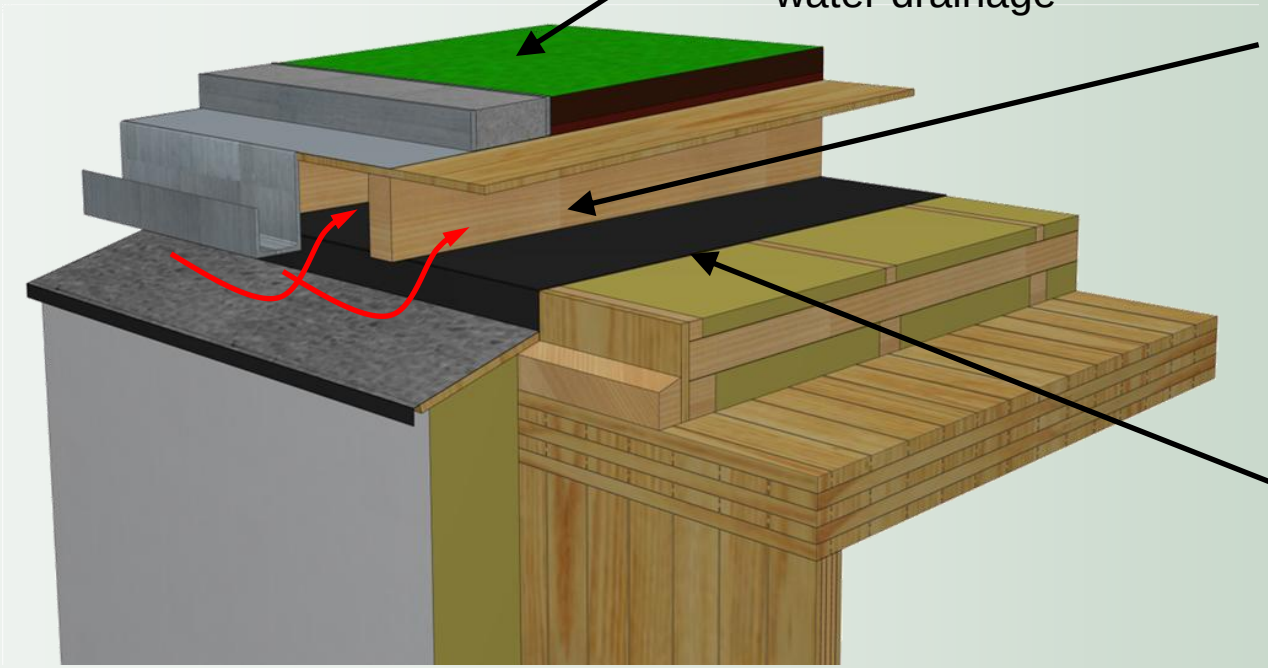
essential constructive aspects



Social housing Wittenbauerstraße | Graz

essential constructive aspects

layer of vegetation:
- green roof function
- water drainage



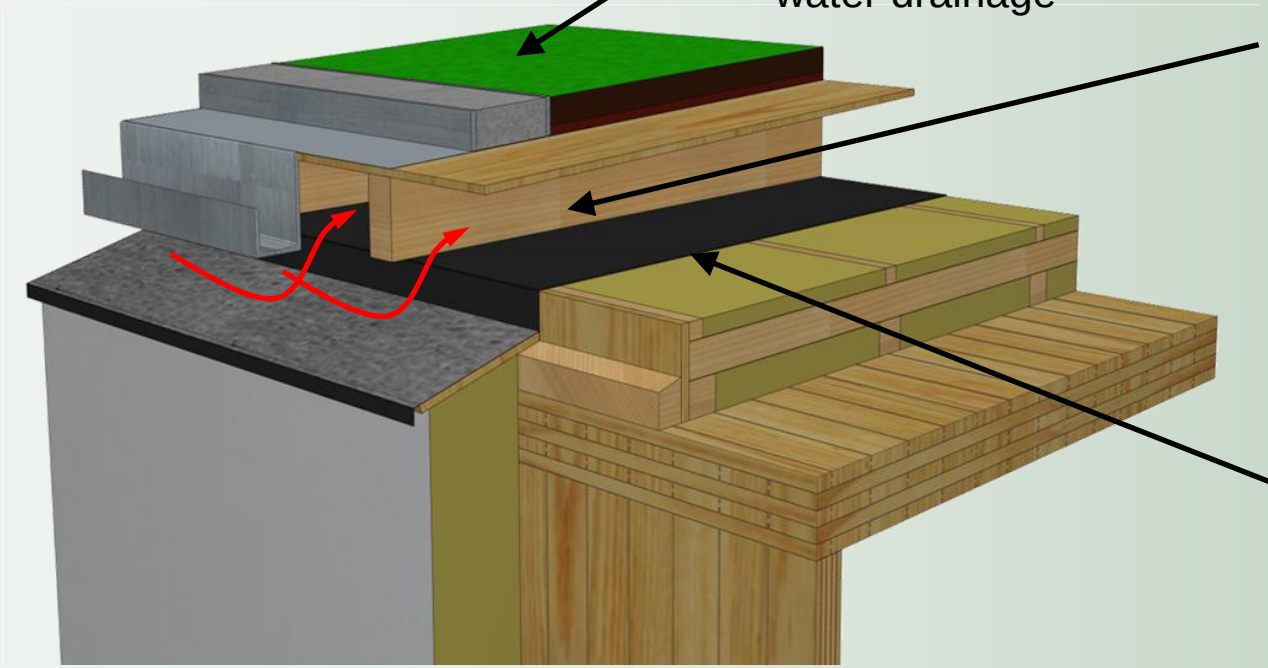
ventilation zone:
- protects against overheating
- secondary construction can dry out
- should have accessible height

second insulation layer:
- additional protection against moisture ingress
- should be positioned inclined

Social housing Wittenbauerstraße | Graz

essential constructive aspects

layer of vegetation:
- green roof function
- water drainage

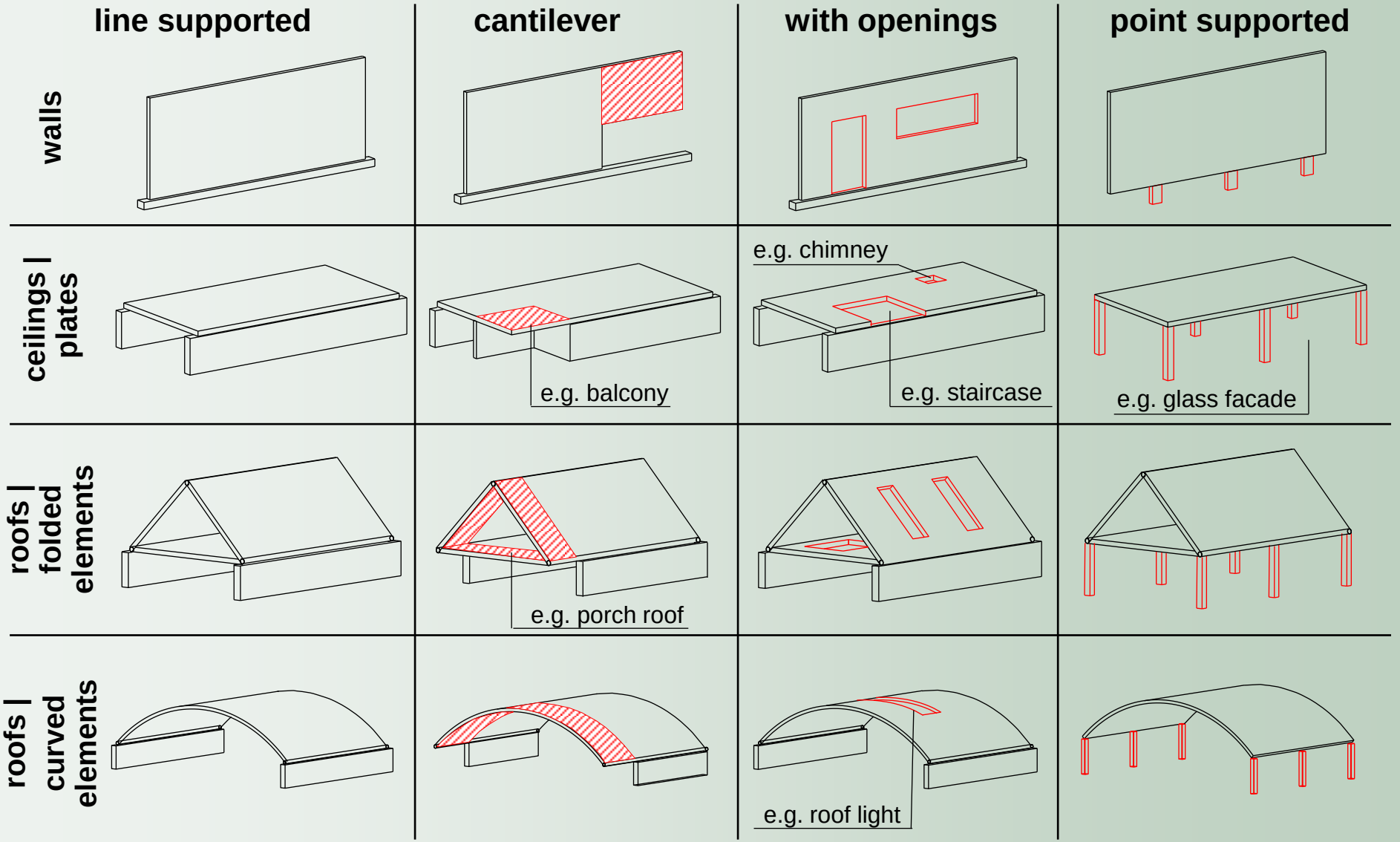


ventilation zone:
- protects against overheating
- secondary construction can dry out
- should have accessible height

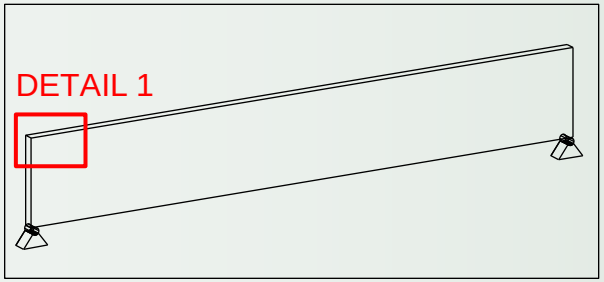
second insulation layer:
- additional protection against moisture ingress
- should be positioned inclined

→ vulnerable building zones should be easy to **maintain**, **control** and **repair**

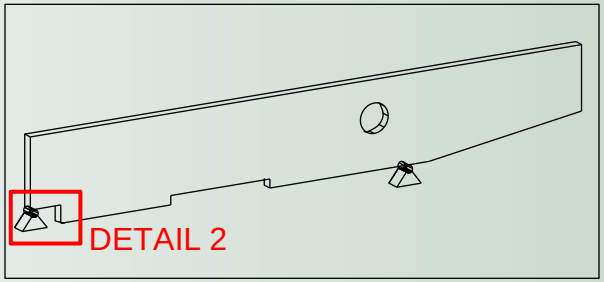
Use of CLT as 2D Elements



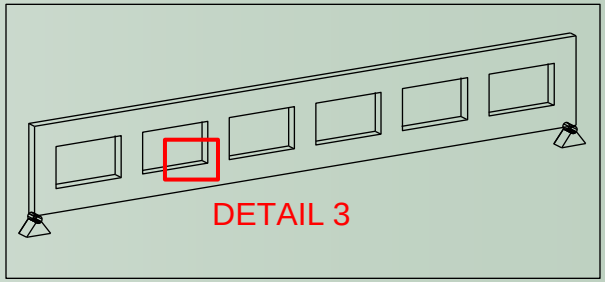
Use of CLT as 1D Elements



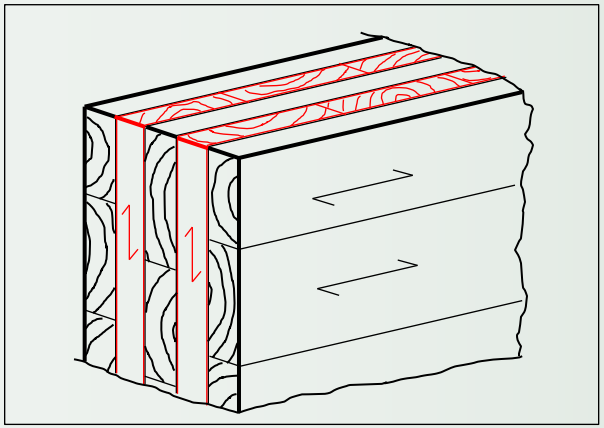
beam
without openings



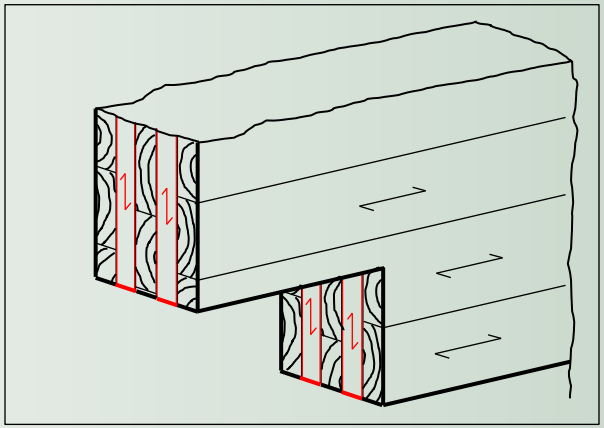
tapered beam with notched support
and openings



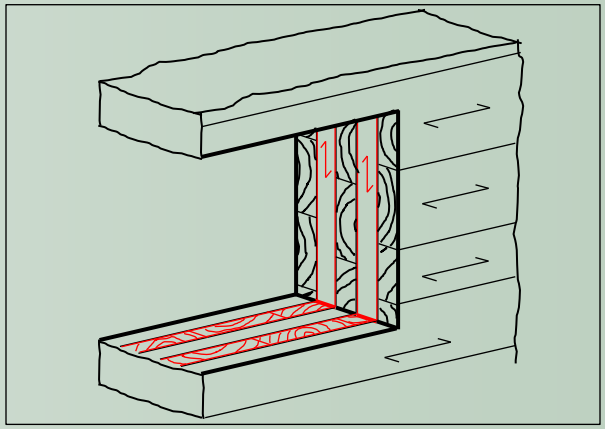
beam as `Vierendeel system´



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)

→ Research activities are needed!

Residential Buildings

Hartberg (AUT) | 2008
CLT by KLH

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

Eichgraben (AUT) | 2008
CLT by Stora EnsoTimber

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

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

Kindergarten

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

Innsbruck (AUT) | 2008
CLT by Binderholz Bausysteme

Augsburg (GER) | 2013
CLT by KLH

Office Buildings

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

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

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

THANKS FOR ATTENTION!

Contact

Univ.-Prof. Dipl.-Ing. Dr.techn. Gerhard Schickhofer
Institute of Timber Engineering and Wood Technology
Graz University of Technology
Inffeldgasse 24/I
A-8010 Graz
gerhard.schickhofer@tugraz.at
P: +43 316 873 4600