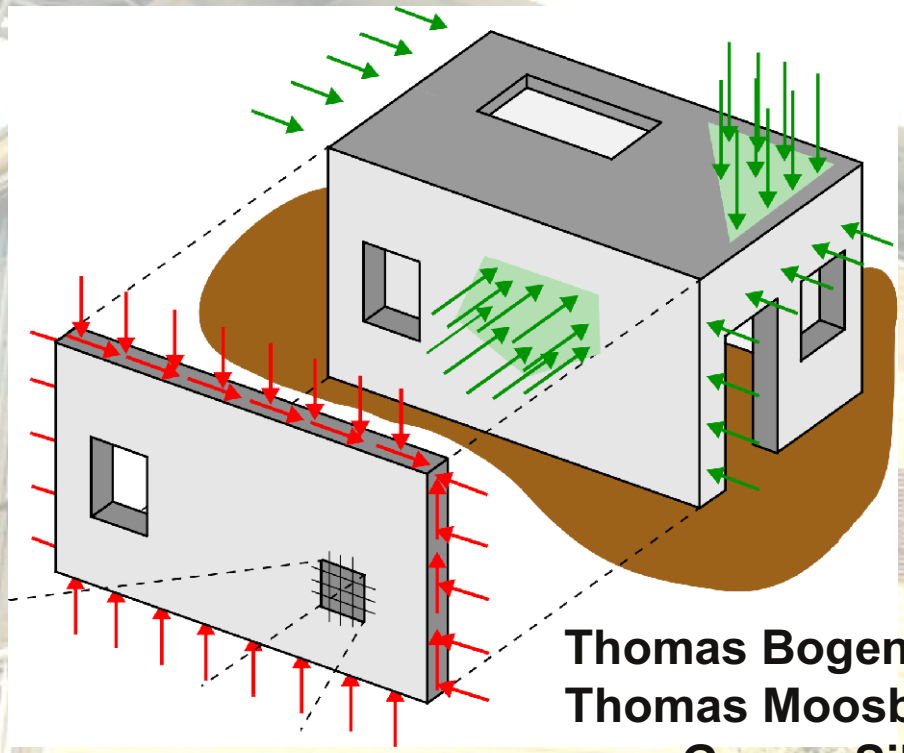
Verification of CLT-plates under loads in plane



June 20-24, 2010
Riva del Garda, Trentino, Italy

WCTE
WORLD CONFERENCE ON TIMBER ENGINEERING
2010

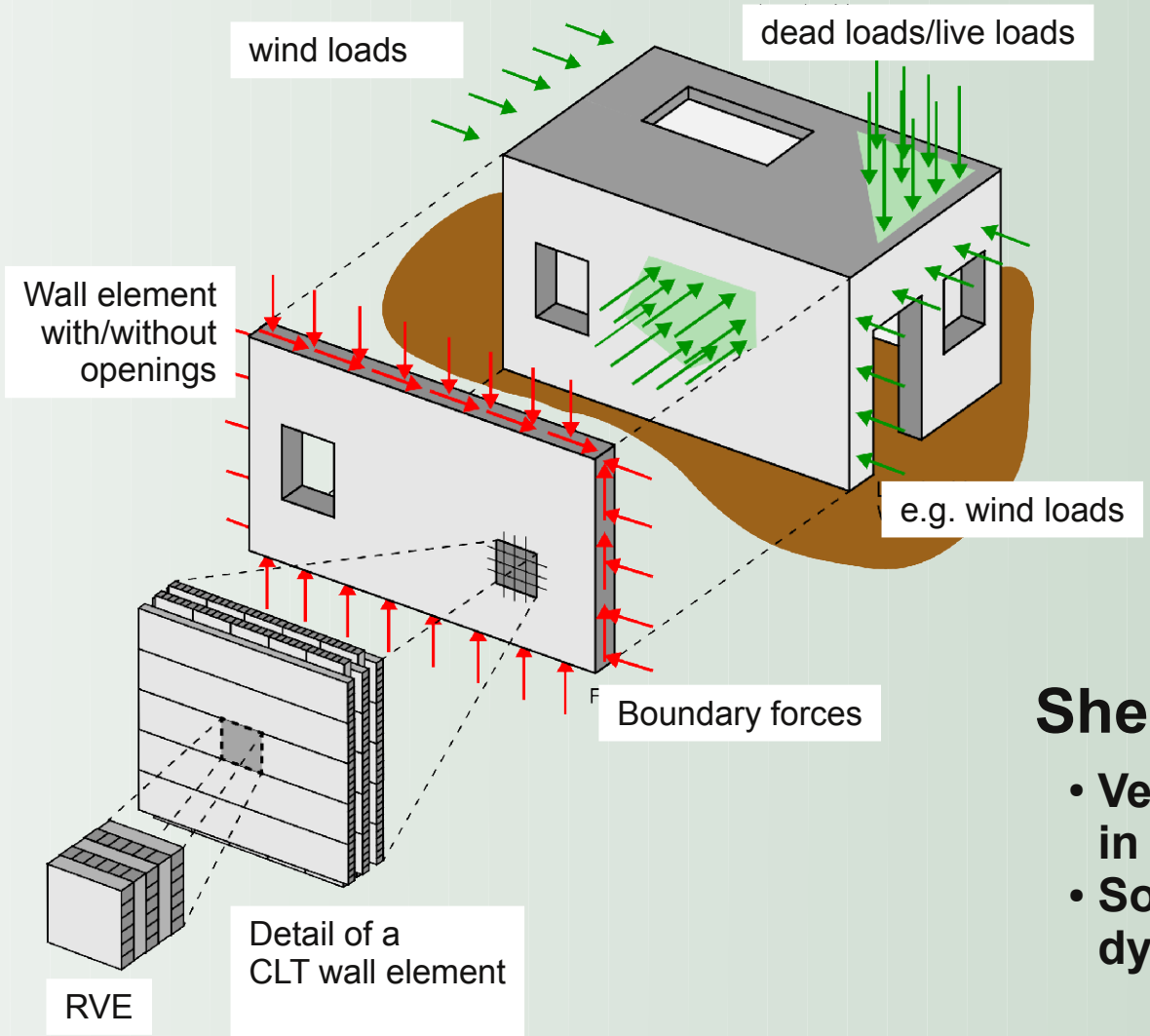
Thomas Bogensperger
Thomas Moosbrugger
Gregor Silly

Competence Centre holz.bau forschungs gmbh Graz | AT
Institute for Timber Engineering and Wood Technology, Graz University of Technology | AT

CONTENT

- Introduction to Cross Laminated Timber (CLT)
- Shear Stiffness of CLT Elements
- Shear Strength of CLT Elements
- Summary and Outlook

Definition of Task



New solid Timber Construction System

Shear

- **Verification of shear loads in wall elements**
- **Source e.g. wind loads, dynamic loads, ...**

Timber Solid Construction: Single family house Styria/Austria 2007

Timber Solid Construction: Wiskeymaker's house in St. Nikolai Styria/Austria

Foto-Quelle: Arch. G. Mitterberger, Graz

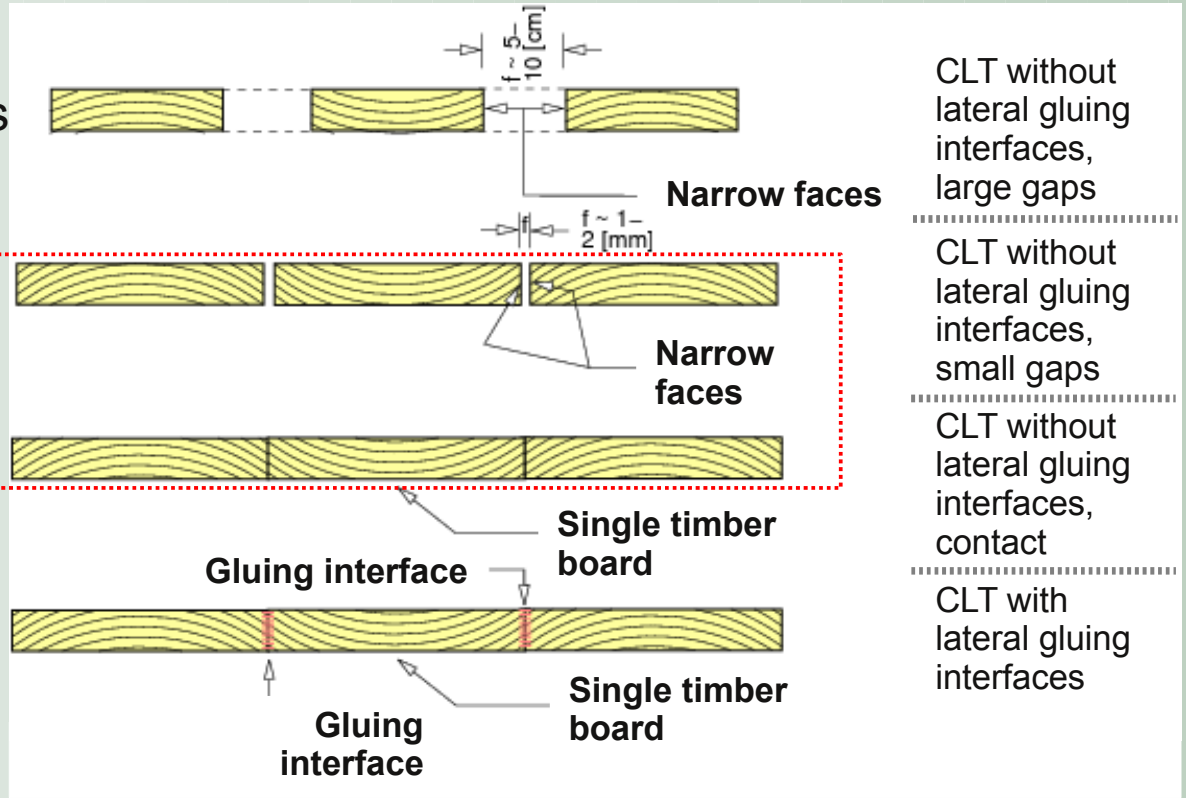
Definition: Cross Laminated Timber (CLT)

- Large-sized laminar structure
- Build up by odd number of layers
- Each layer consists of parallel timber boards
- orientation of timber boards in two adjacent layers is orthogonal
- Layers are glued together

- Narrow faces of boards
  - with small gaps
  - only contact
  - Glued

- Product development since ~ 1995

Illustration of various possibilties of narrow faces of individual boards



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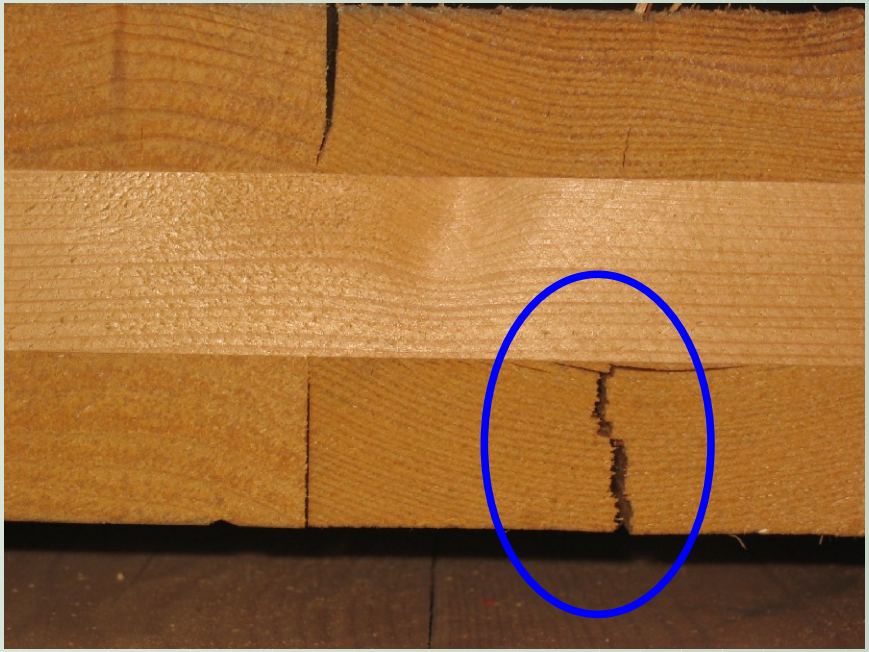


CLT – general specifications

(small variation possible – depending on manufacturer)

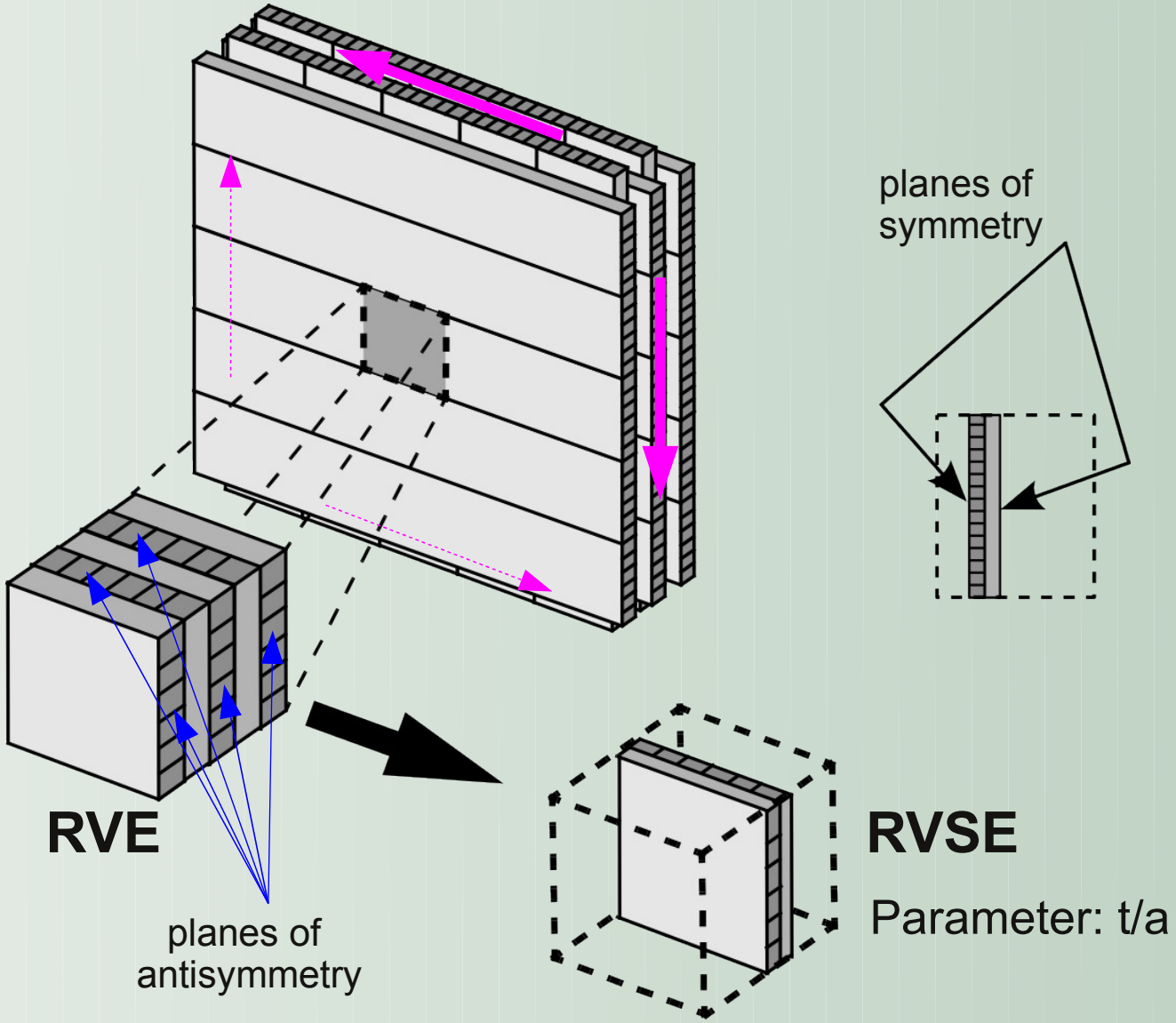
- industrial production
- Assurance in quality
- max size ~ 3,0 m x 18(24) m
- max thickness ~ 300 mm
- Max number of layers: 7

Detailed look at
7-layered CLT

Foto-Quelle: Mayr Melnhof, Gaishorn, Stmk

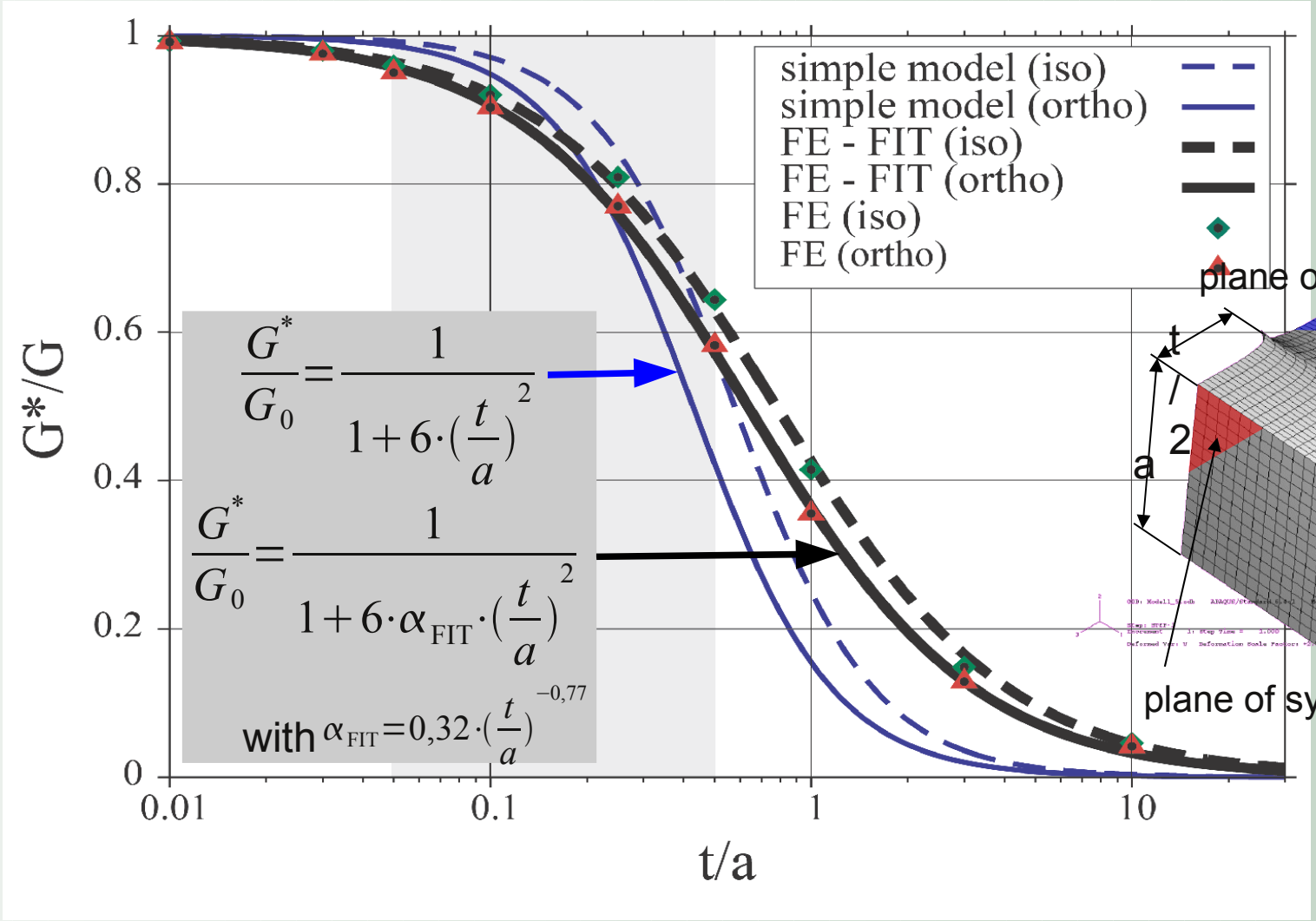
- Introduction to Cross Laminated Timber (CLT)
- **Shear Stiffness of CLT Elements**
- Shear Strength of CLT Elements
- Summary and Outlook

RVE/RVSE for CLT Elements



WCTE 2006: Moosbrugger/Guggenberger/Bogensperger:

„Cross-Laminated Timber Wall Segments under homogenous Shear – with and without Openings“

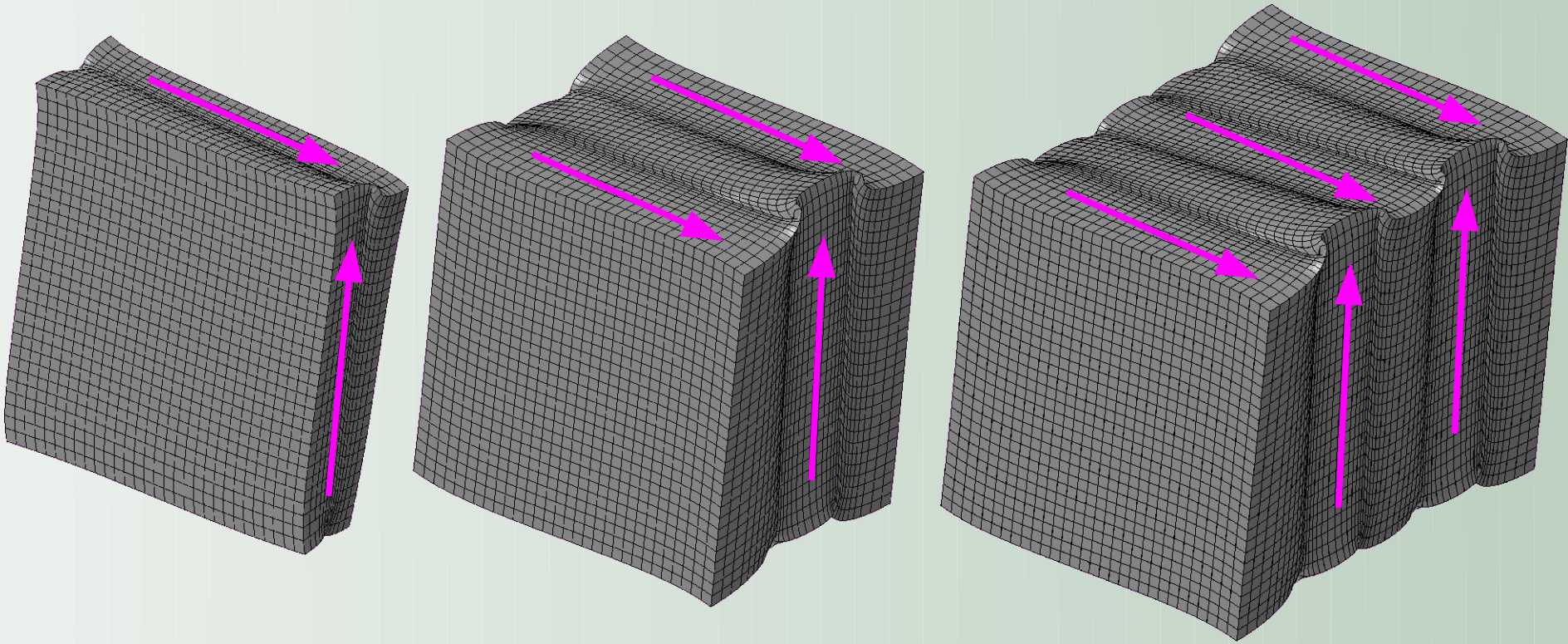


Shear Stiffness for CLT Elements with boundary effect

RVSE

CLT 3-layered

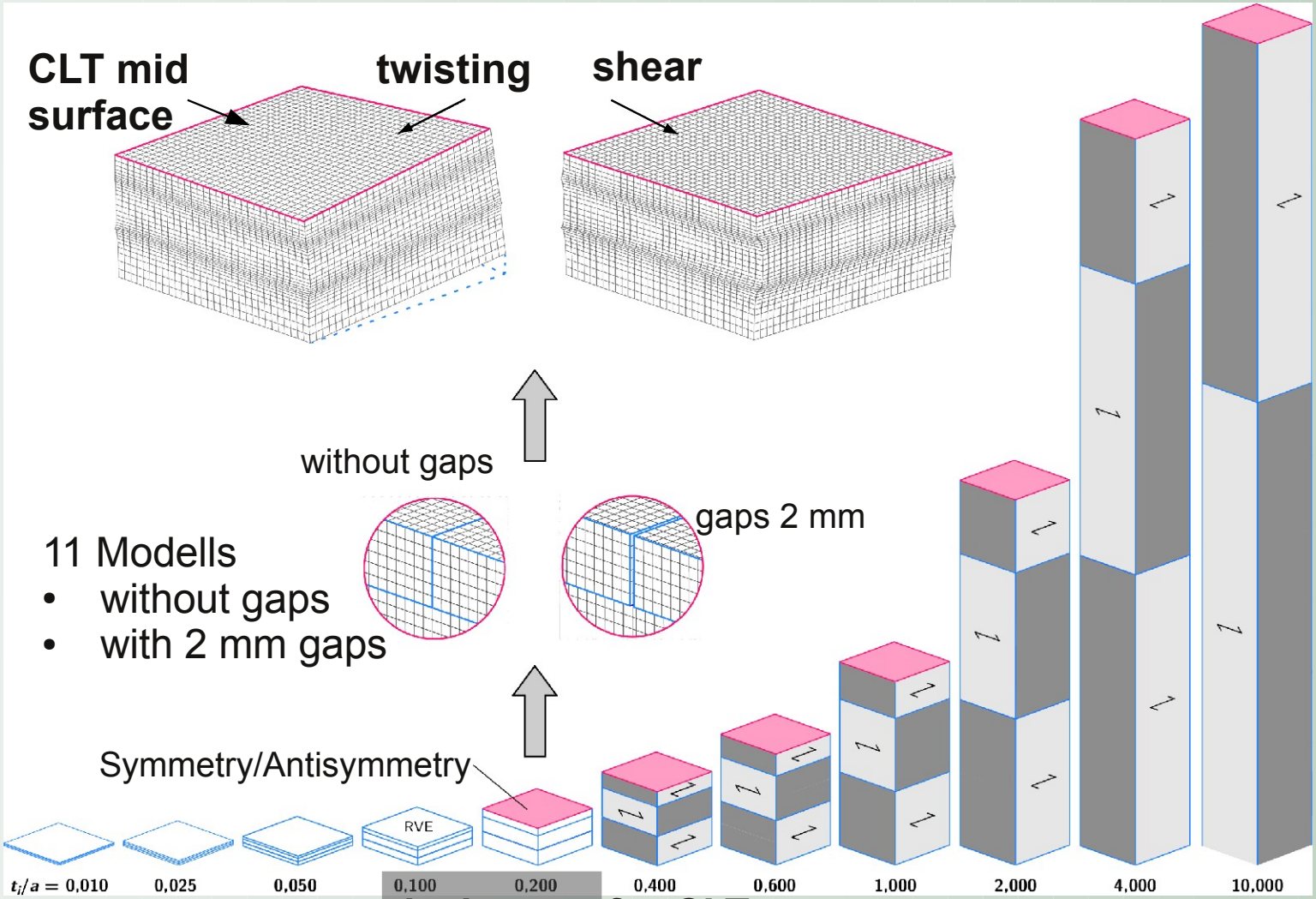
CLT 5-layered



2010: diploma thesis G. Silly

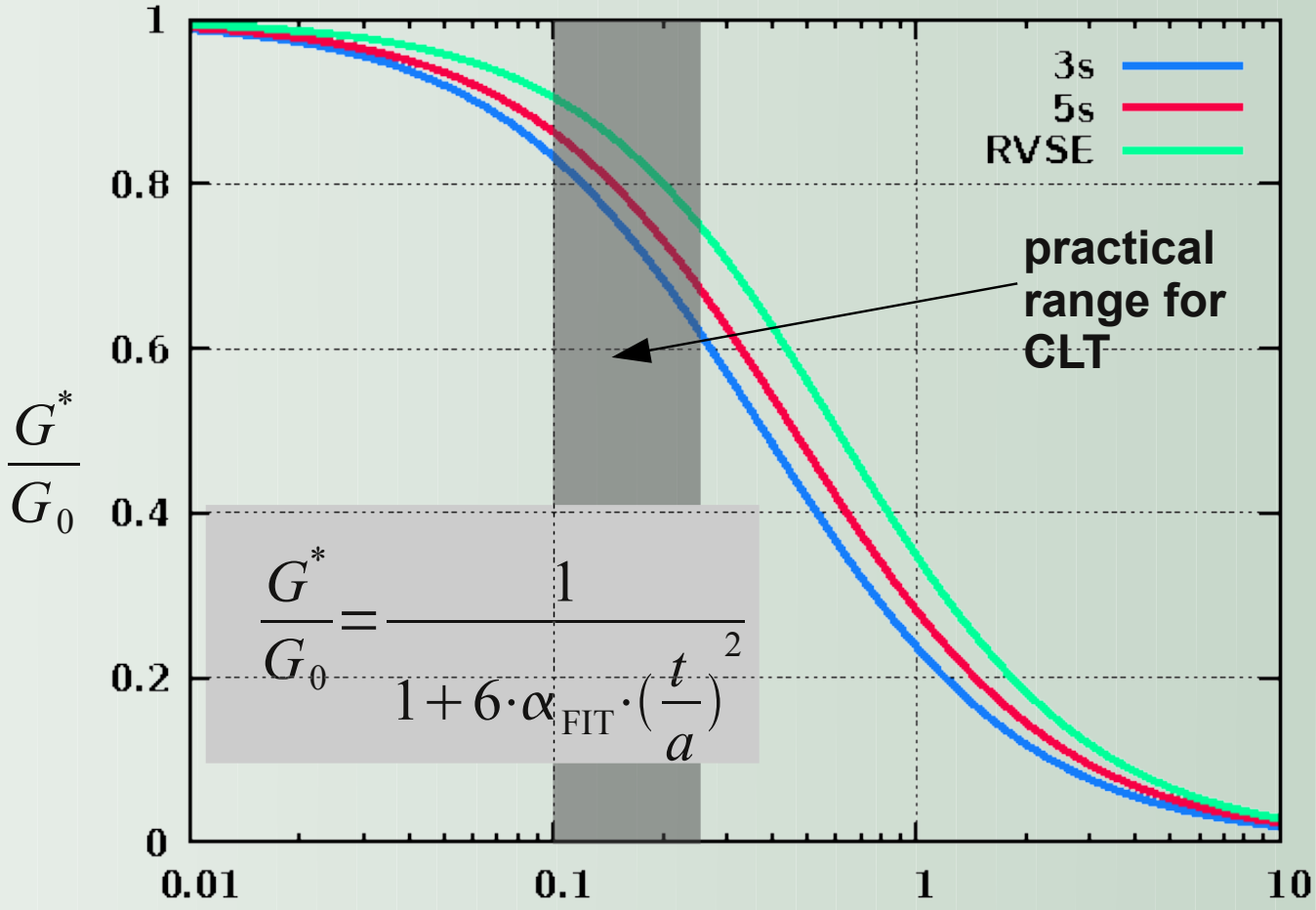
„Numerical studies to twisting stiffness and shear stiffness of CLT elements“

Shear Stiffness for CLT Elements with boundary effect



practical range for CLT

Shear Stiffness for CLT Elements with boundary effect



$$\alpha_{FIT} = p \cdot \left(\frac{t}{a}\right)^q$$

	RVSE	3s	5s
p	0,32	0,53	0,43
q	-0,77	-0,79	-0,79

- Introduction to Cross Laminated Timber (CLT)
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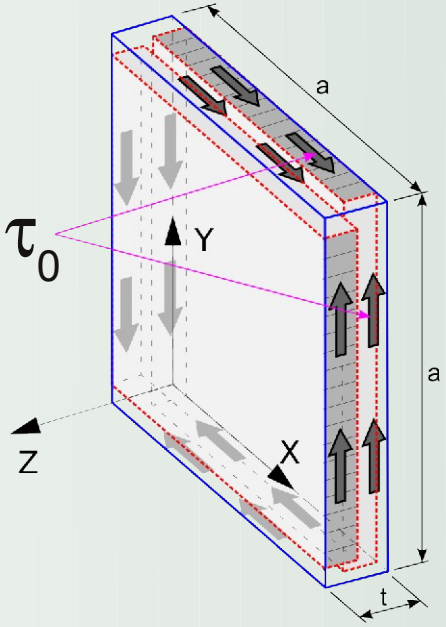
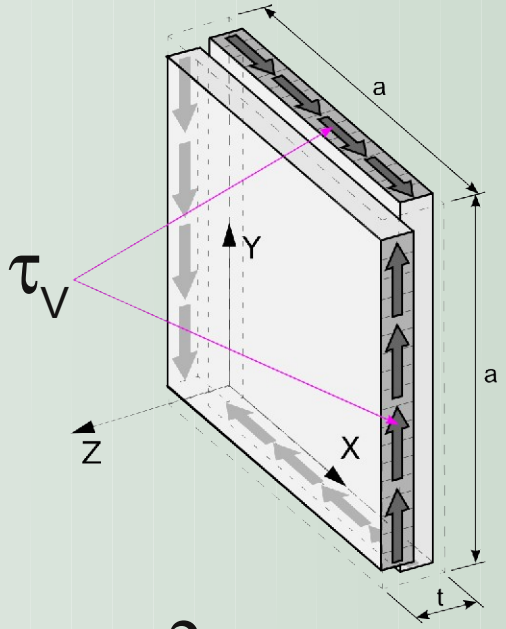
Shear Stresses in RVSE

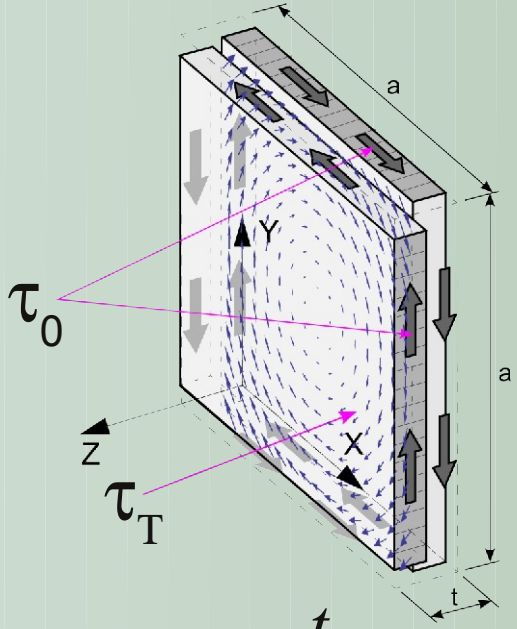


τ_0 nominal shear stress in plane



$$\tau_v = 2 \cdot \tau_0$$

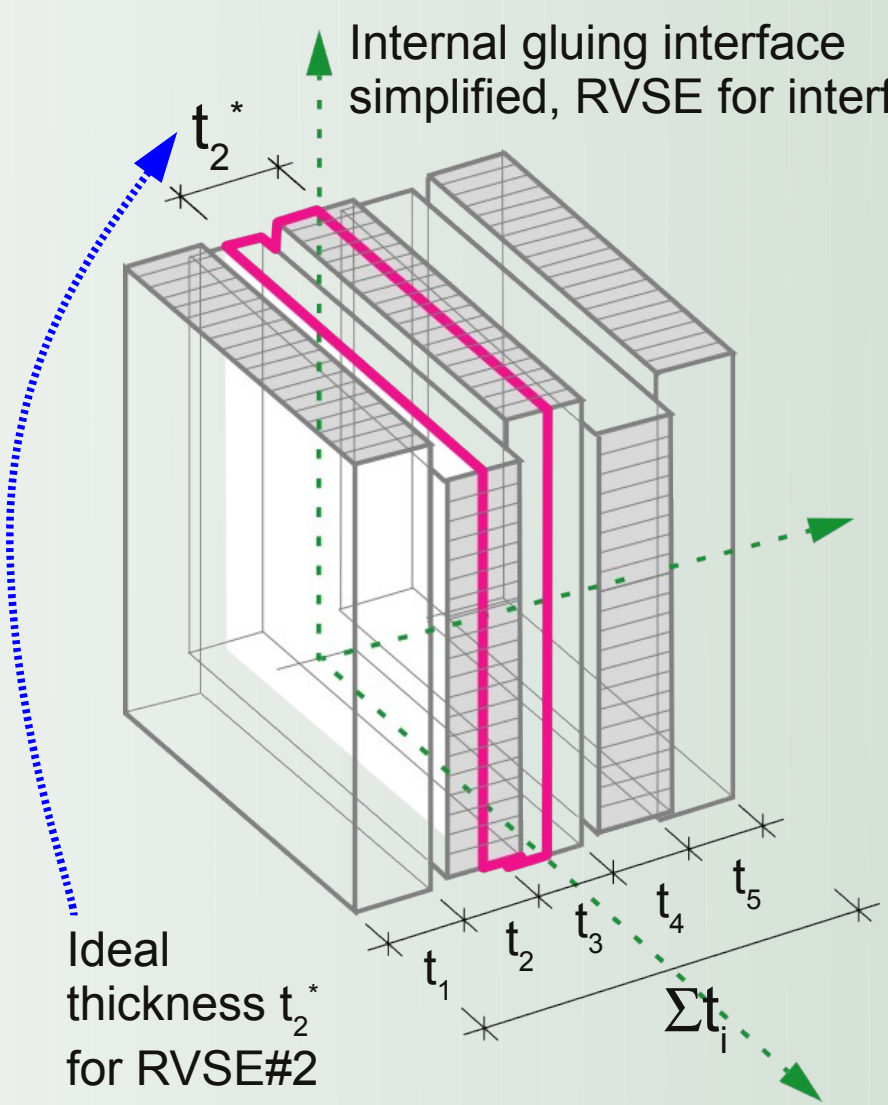
τ_V shear stress in cross section

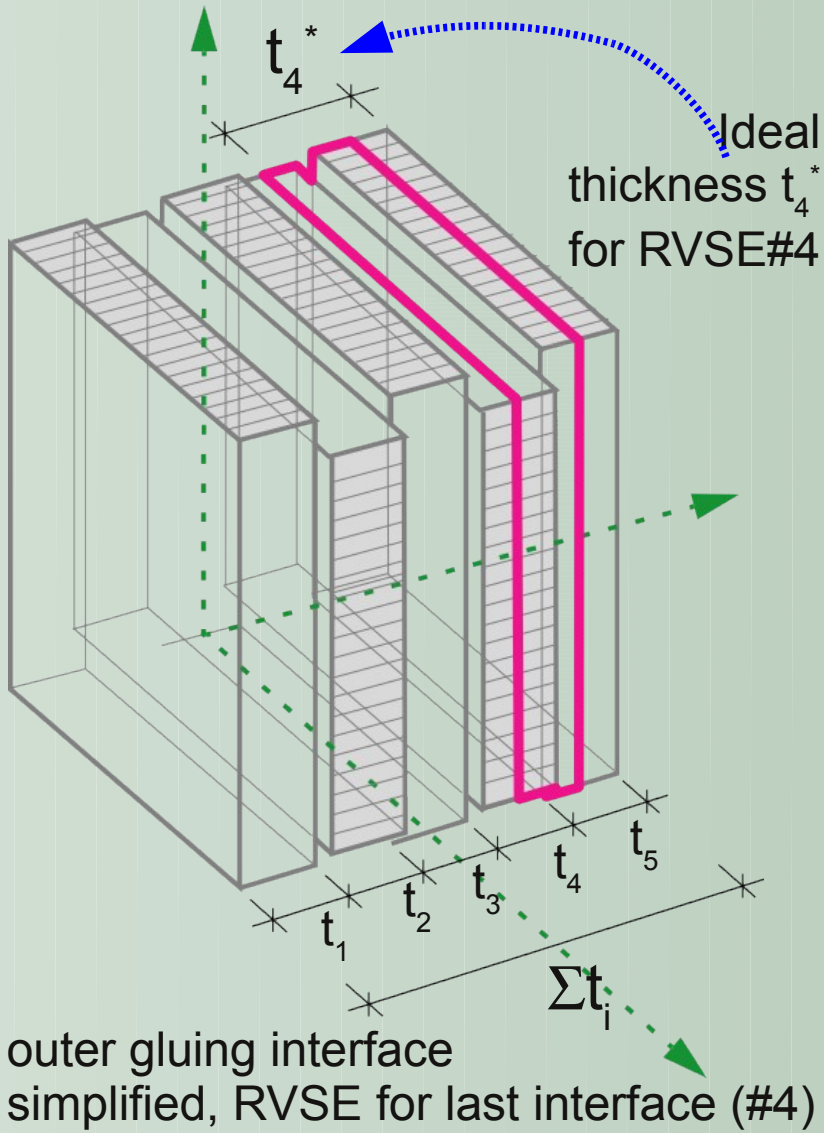


$$\tau_T = 3 \cdot \tau_0 \cdot \frac{t}{a}$$

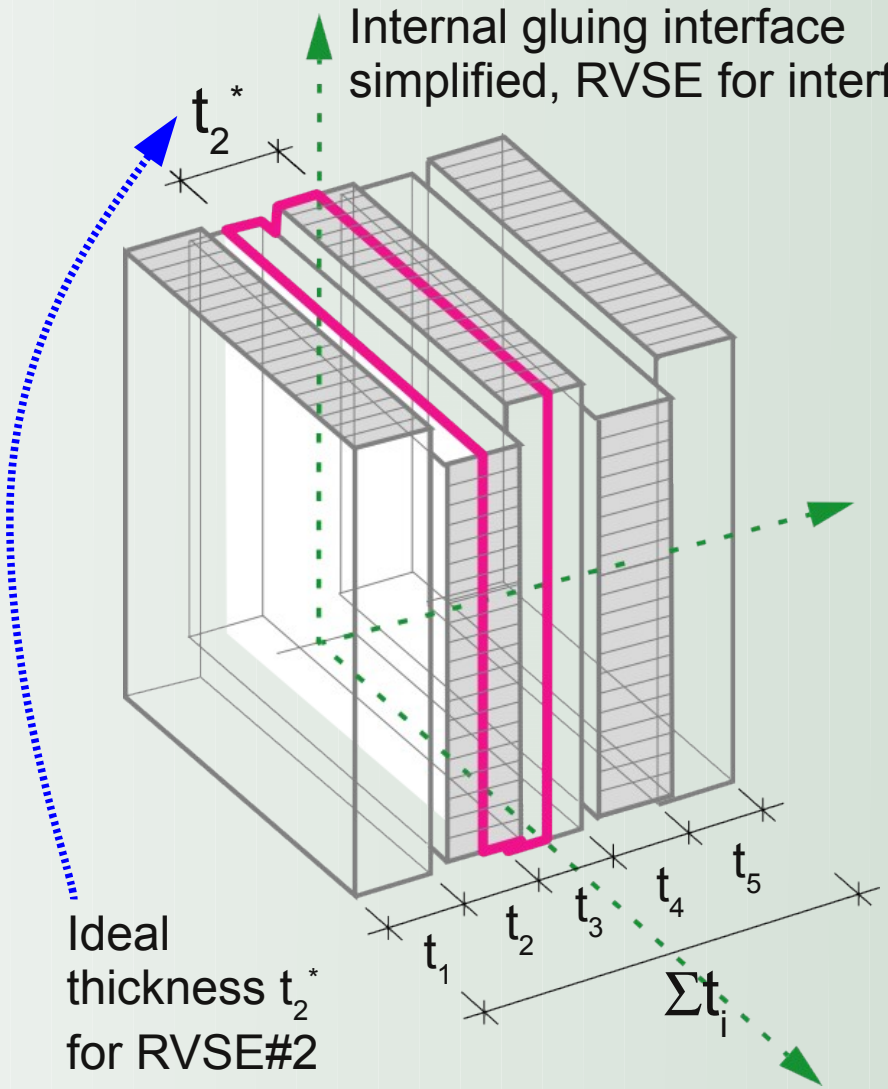
τ_T shear stress due to torsional moment in gluing interface

Shear Stresses in CLT Elements





Shear Stresses in CLT Elements



Ideal thickness t_i^* for regular RVSE's

- Simple approach
- Conservativ

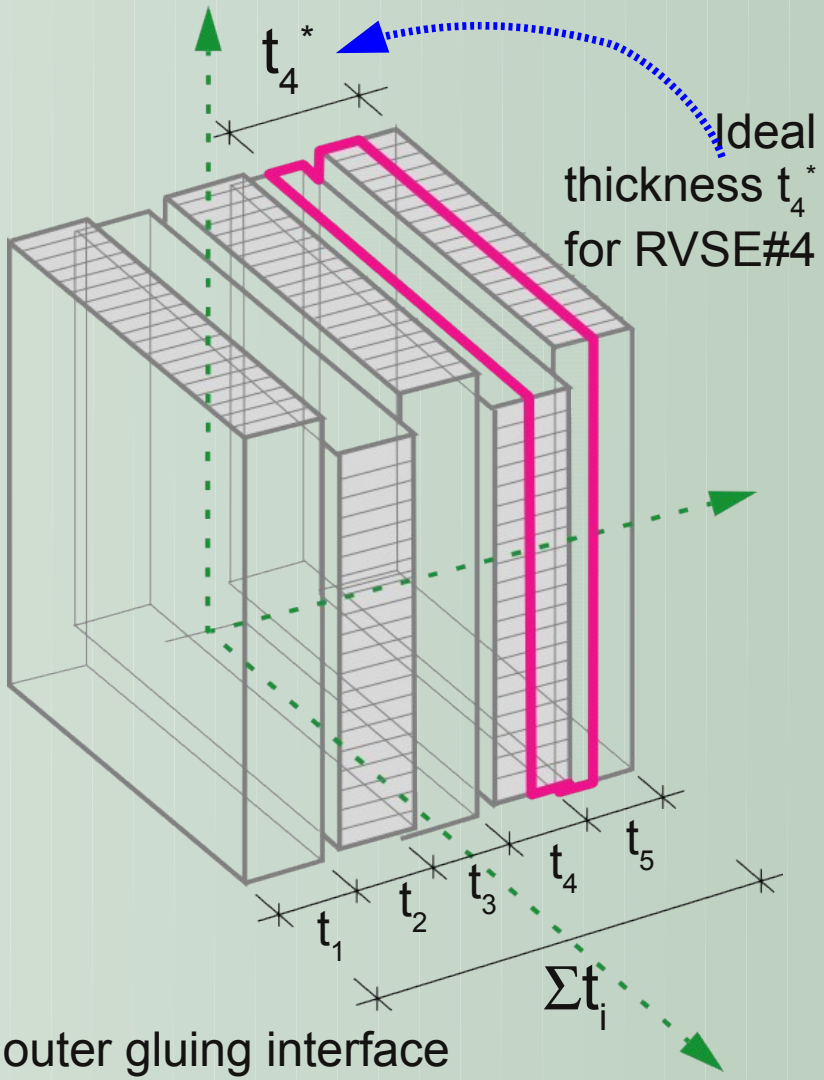
# of RVSE	t_i^*
2	$=min(t_2, t_3)$
3	$=min(t_3, t_4)$

Shear Stresses in CLT Elements

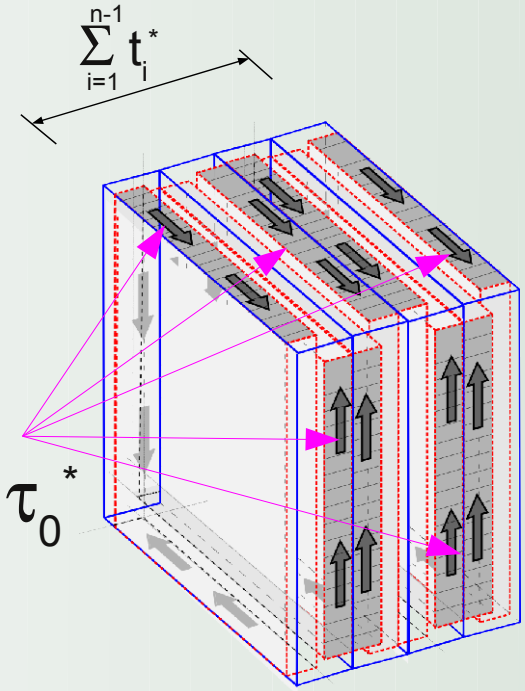
Ideal thickness t_i^* for both outer RVSE's

- Simple approach
- Outer boards with double thickness!

# of RVSE	t_i^*
1	$= min(2 \cdot t_1 , t_2)$
4	$= min(t_4 , 2 \cdot t_5)$

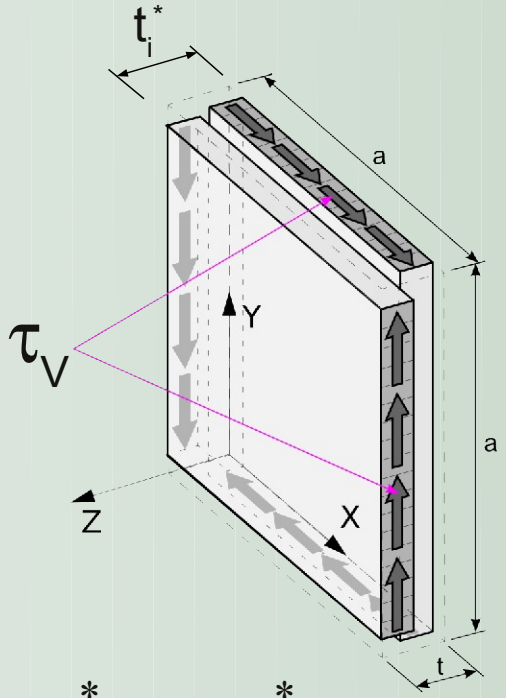


Shear Stresses in CLT Elements



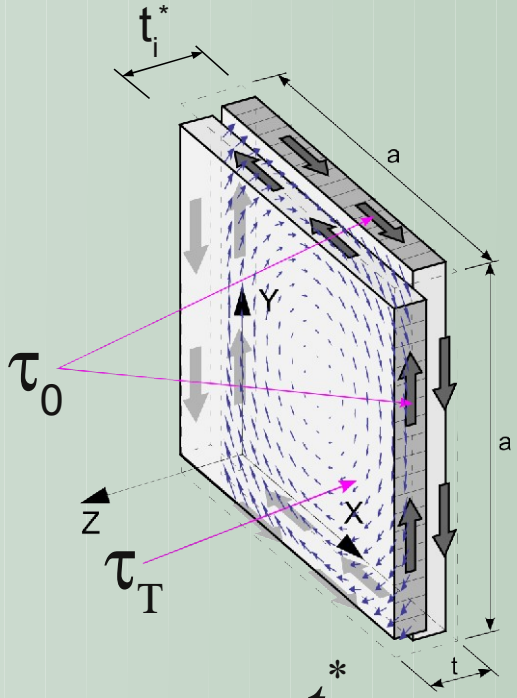
τ_0^* ideal shear stress in plane

$$\tau_0^* = \frac{n_{xy}}{\sum_{i=1}^{n-1} t_i^*}$$



$$\tau_v^* = 2 \cdot \tau_0^*$$

τ_V^* ideal shear stress in cross section of RVSE#i

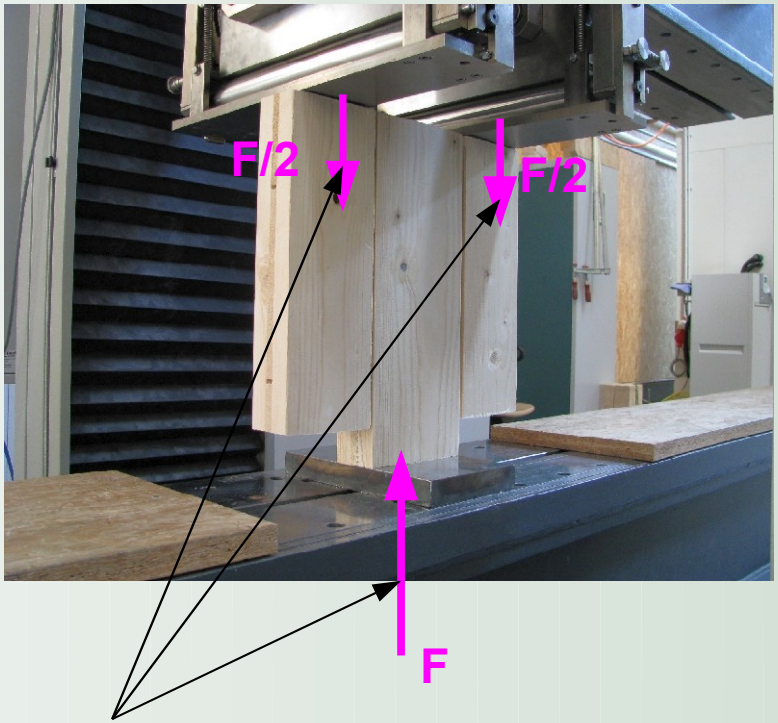


$$\tau_T^* = 3 \cdot \tau_0^* \cdot \frac{t_i^*}{a}$$

τ_T^* ideal shear stress due to torsional moment in gluing interface of RVSE#i

Shear Strength tests – mechanism 1

Test configuration

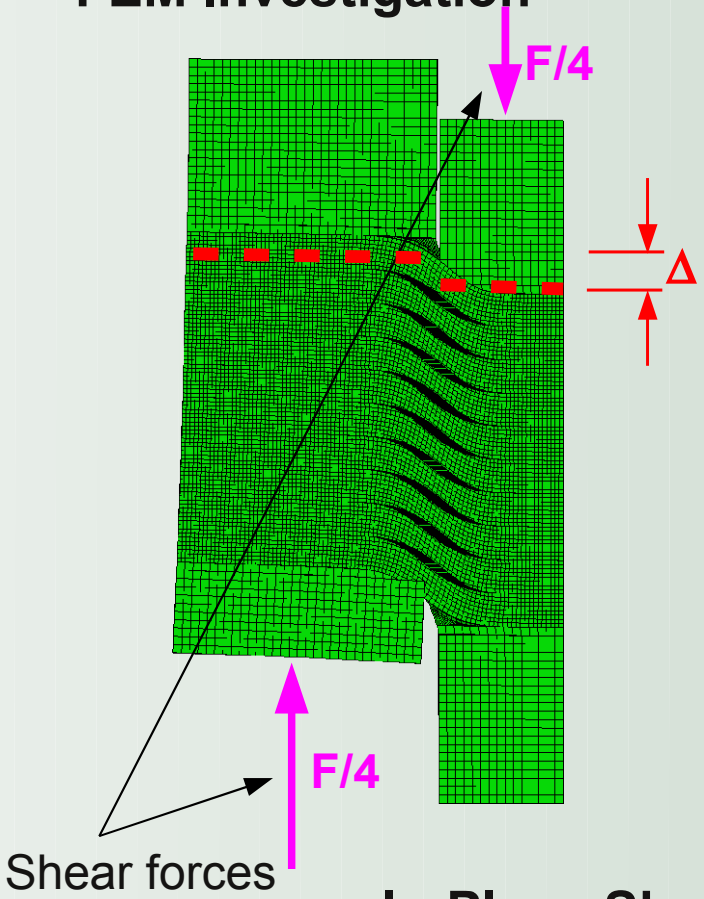


Local failure

CIB 2008:
In-Plane Shear Strength of Cross Laminated Timber
Jöbstl/Bogensperger/Schickhofer

Shear Strength tests – mechanism 1

FEM Investigation



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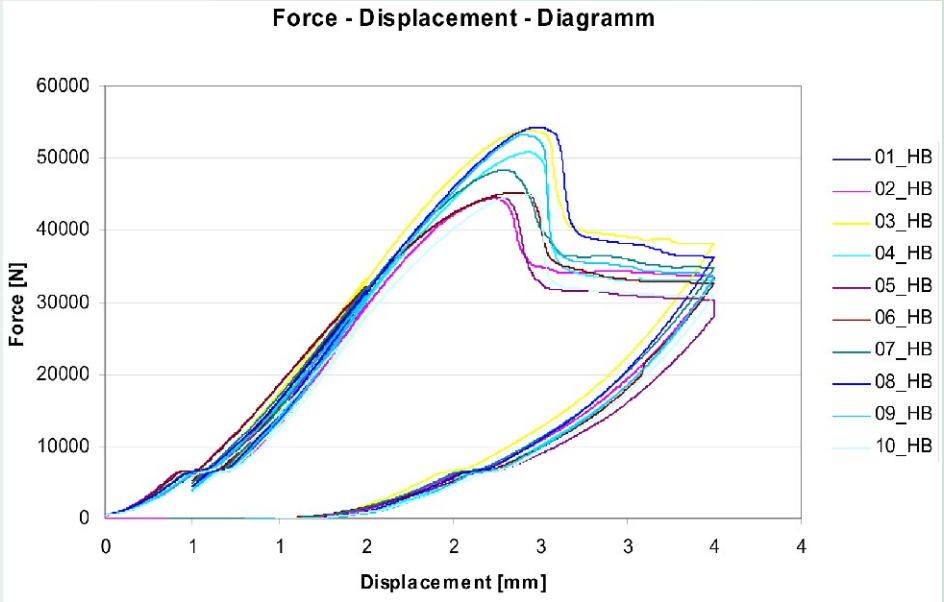


Load — displacement behaviour

Shear Strength value for mechanism 1

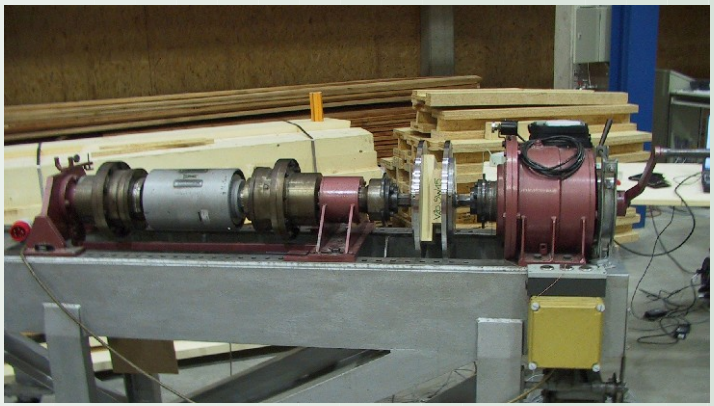
$$f_{v,k} = 10 \text{ [N/mm²]}$$

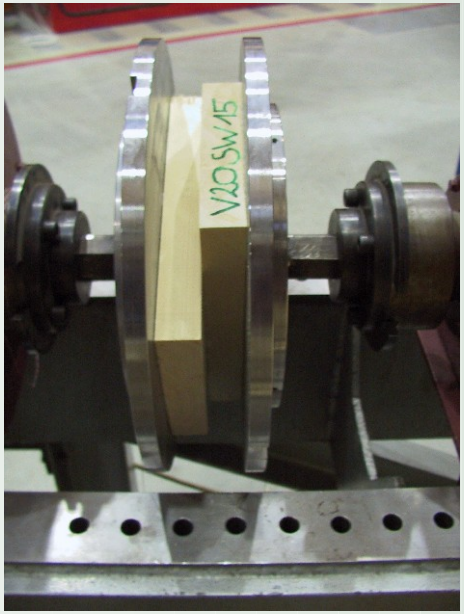
Remark: Value still in discussion!

Series	Value	
#	20	[-]
Height a	200	[mm]
Thickness t	10	[mm]
$f_{v,d}$ - mean value	12.8	[N/mm^2]
Standard deviation	1.45	[N/mm^2]
COV	11.3%	[-]
$f_{v,d}$ 5% - Quantile normal distribution	10.4	[N/mm^2]
$f_{v,d}$ 5% - Quantile log normal distribution	10.6	[N/mm^2]
$f_{v,d}$ 5% - Quantile EN 14358	10.3	[N/mm^2]

shear strength tests – mechanism 2

Test configuration





Detail of test specimen

shear stresses in the gluing interface

$$\tau_{max} = \frac{M_T}{I_P} \cdot \frac{1}{2} \cdot a$$

M_T Torsional moment

I_P polar sectional moment of gluing interface

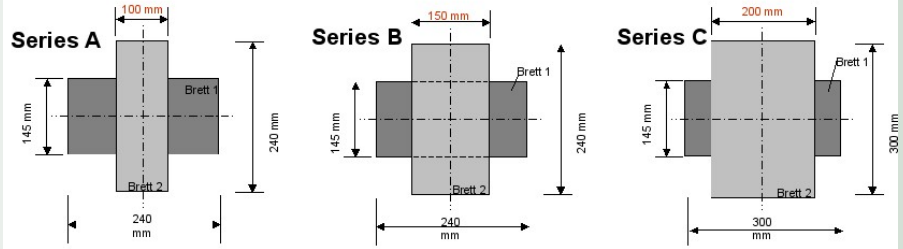
$$I_P = \frac{a^4}{6}$$

a dimension of RVE

2004: diploma thesis G. Jeitler „Versuchstechnische Ermittlung der Verdrehungs-kenngrössen von orthogonal verklebten Brettlamellen“

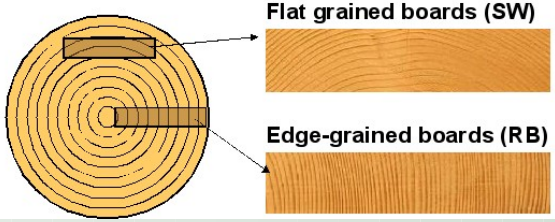
Coverage of tests

Variation of glued surface geometry



Annual ring gradient

Spruce (lat. picea abies)



Shear strength value for mechanism 2

$$\tau_{max} = \frac{M_T}{I_P} \cdot \frac{1}{2} \cdot a$$

$$f_{T,k} = 2.5 \text{ [N/mm²]}$$

Remark: Value generally accepted!

Shear stresses in the gluing interface

Series	Annual ring orient.	5% Quantile	
A	Edge-grained	3.67	[N/mm^2]
A	Flat grained	2.79	[N/mm^2]
B	Edge-grained	3.20	[N/mm^2]
B	Flat grained	2.69	[N/mm^2]
C	Edge-grained	2.98	[N/mm^2]
C	Flat grained	3.10	[N/mm^2]

Examples and further references

CLThandbook

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Schickhofer/Bogensperger/Moosbrugger
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English translation is intended

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- Shear Strength of CLT Elements
- **Summary and Outlook**

- Shear stiffness for CLT is verified
- Proposal for Shear strength verification has been given
- Minimum condition is on the conservative side – improvements in stress calculation are possible
- Shear strength value for mechanism 1 is still in discussion – further investigations are ongoing ...
- Shear strength value for mechanism 2 is widely accepted
- Shear strength verifications for walls under shear with large openings and their typical elastic stress peaks in corners is still an open question ....

Thank you for your attention!

Contact:

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