STRUCTURES AND ARCHITECTURE

1st International Conference

Verification Processes for Cross Laminated Timber (CLT) in the Frame of EN 1995

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Speaker:

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- Introduction: Cross Laminated Timber
  CLT – a Wood Based Product
- Bending under loads perp. to Plane
- Shear loads in Plane
- Conclusion and open points

Timber Solid Construction: Single family house „Dringel-Techt“

lignum
study research engineering

Timber Solid Construction: Single family house „Dringel-Techt“

Timber Solid Construction: Single family house „Dringel-Techt“

Timber Solid Construction: Single family house „Jeitler“

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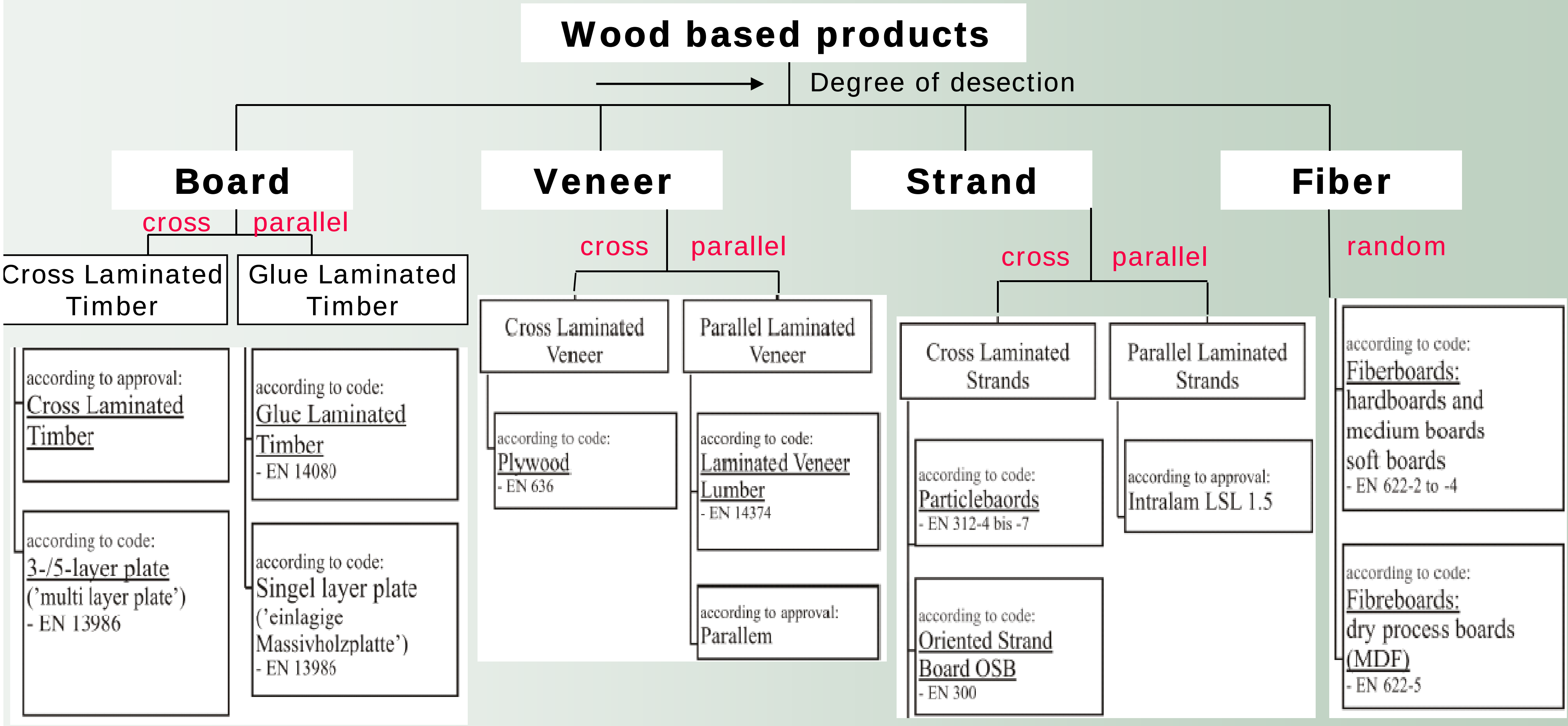
Timber Solid Construction: Wiskeymaker's house in St. Nikolai Styria / Austria

Foto-Quelle: Arch. G. Mitterberger, Graz

One possibility of definition of wood based products:

degree of desection and orientation of base-material



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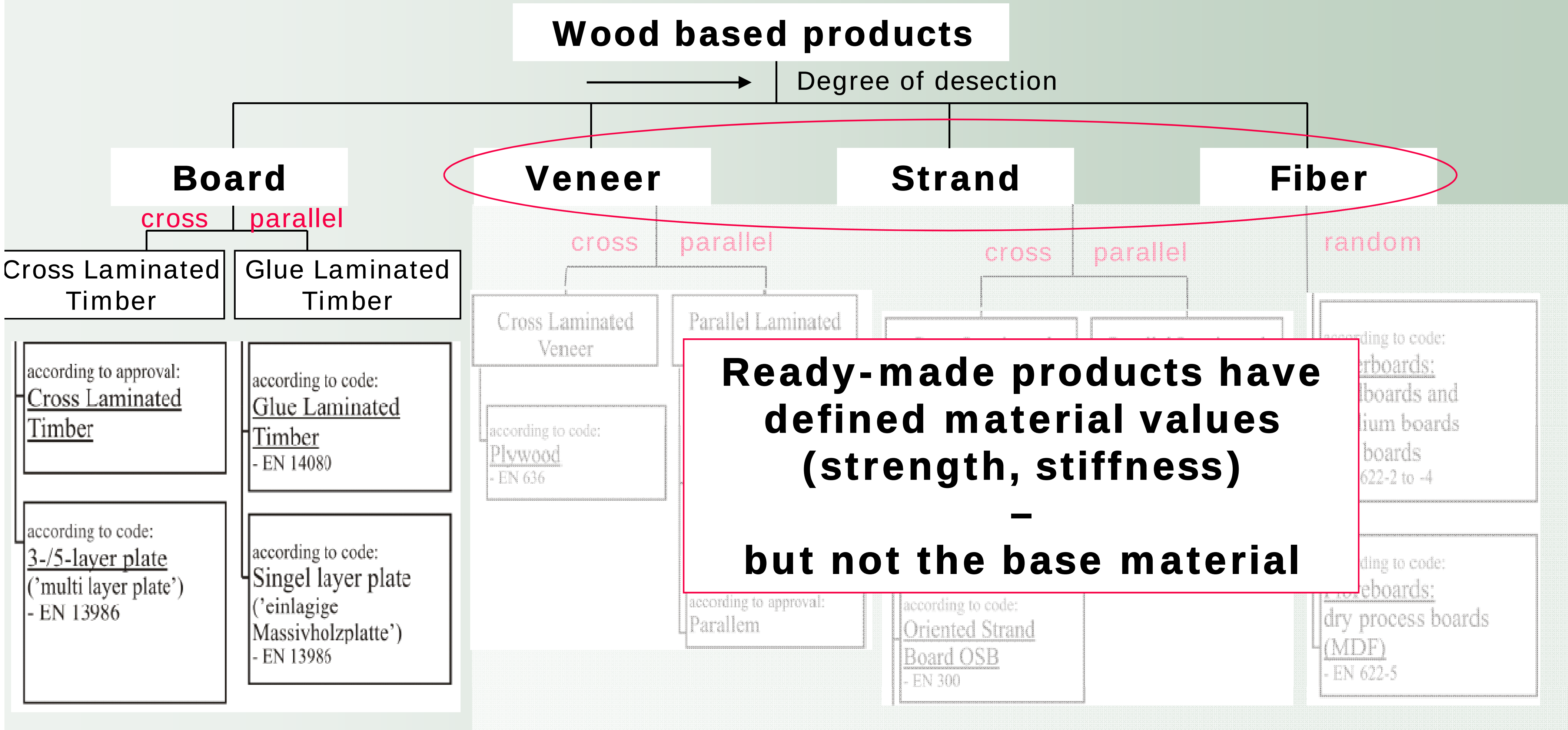
- Cross Laminated Timber CLT – a wood based product

One possibility of definition of wood based products:

degree of desection and orientation of base-material



One possibility of definition of wood based products:

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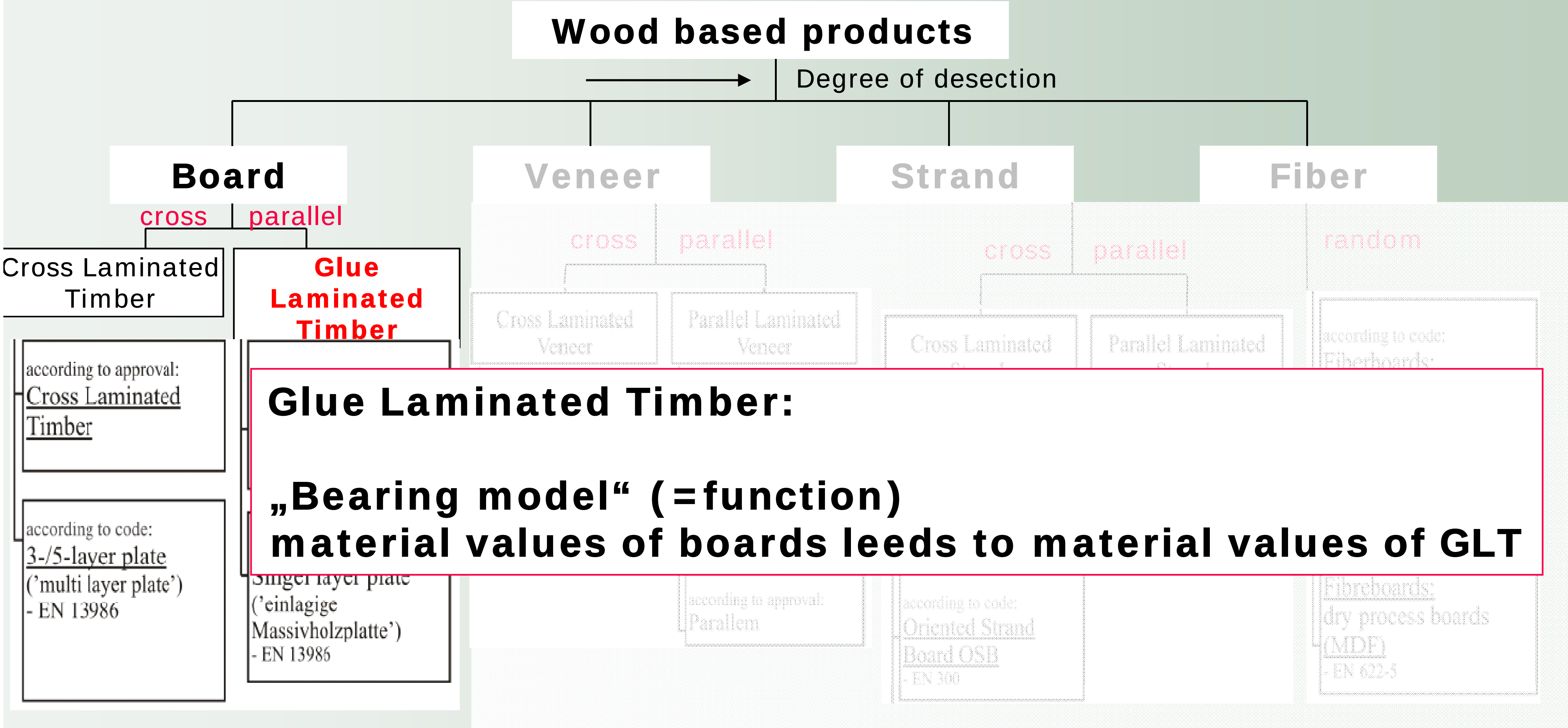

Glue Laminated Timber:

„Bearing model“ (=function)
material values of boards leeds to material values of GLT

One possibility of definition of wood based products:

degree of desection and orientation of base-material

Wood based products

Degree of desection

Board | **Veneer** | **Strand** | **Fiber**

cross | parallel

Cross Laminated Timber

according to approval:
Cross Laminated Timber

according to code:
3-/5-layer plate
('multi layer plate')
- EN 13986

Cross Laminated Timber:
„modified, new Bearing model"
material values of Boards leeds to material values of CLT

- special behavior of CLT is taken into account by this new bearing model
- No intensive test procedures of huge elements in **production control** are needed later

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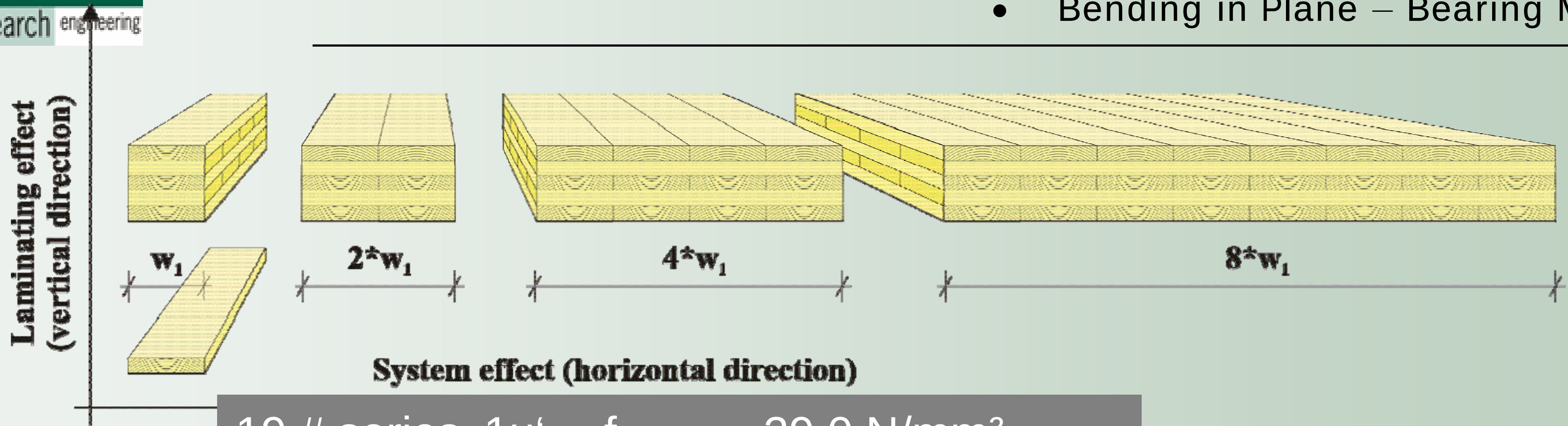
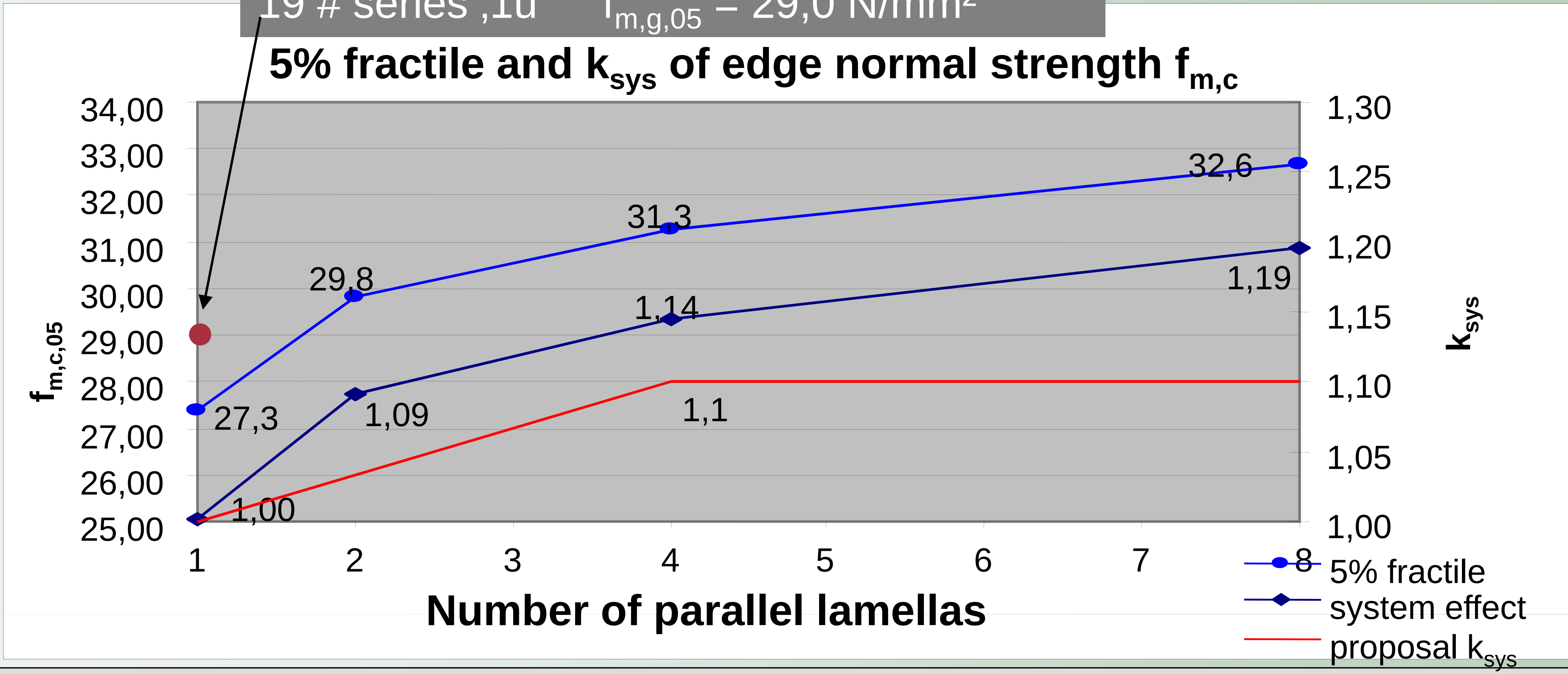
- Bending in Plane – Bearing Model



19 # series ‚1u' $f_{m,g,05}$ = 29,0 N/mm²



New proposal for GLT - Bearing Model:

$$f_{m,g,k} = a_{glt} \cdot f_{t,0,l,k}^{0,82} \qquad \text{with} \qquad a_{glt} = \begin{Bmatrix} 2,422 & COV_t = 0,25 \\ 2,811 & COV_t = 0,35 \end{Bmatrix}$$

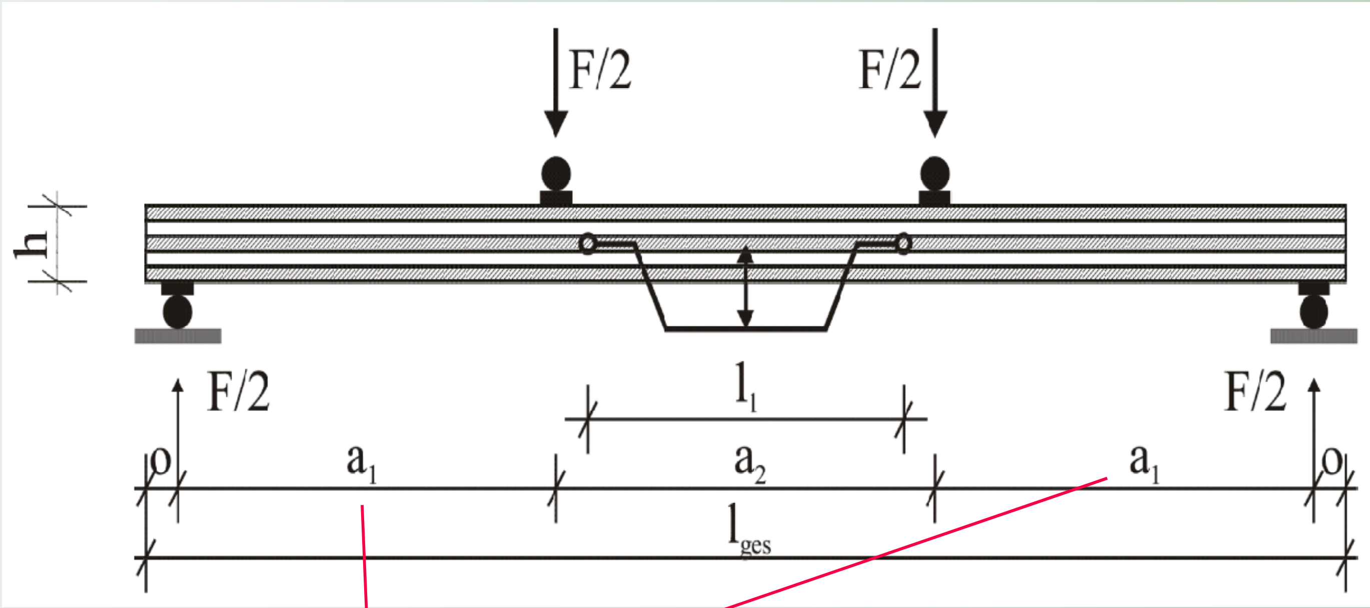
$f_{m,g,k}$ ...... bending strength of GLT
$f_{t,0,l,k}$ ...... tensile strength of lamella
a_{glt} ...... factor considering lamination effect for GLT

proposal for CLT - Bearing Model on the same basis:

$$f_{m,c,k} = a_{clt} \cdot f_{t,0,l,k}^{0,80} \qquad \text{with} \qquad a_{clt} = \begin{Bmatrix} 3,0 & COV_t = 0,25 \\ 3,5 & COV_t = 0,35 \end{Bmatrix}$$

$f_{m,c,k}$ ...... bending strength of CLT
$f_{t,0,l,k}$ ...... tensile strength of lamella
a_{clt} ...... factor considering system and lamination effect for CLT

4-point-bending test according to EN 408:



According to EN 408: $a_1 = f_{a1} \cdot h$ with $f_{a1} = 6 \pm 1{,}5$

4-point-bending test according to EN 408: **bending failure requested**

For bending failure we need at least a bending stress of 95%-quantile while (rolling) shear stress is 5%-quantile at a maximum

glulam

e.g.: GL 24 – visually graded ➔ COV = 35%

⇨ $f_{m,c,k} = a \cdot f_{t0,l,k}^{0,80} = 2,811 \cdot 14^{0,82} = 24,5\ N/mm^2$

CLT

⇨ $f_{m,c,k} = a_{CLT} \cdot f_{t0,l,k}^{0,80} = 3,5 \cdot 14^{0,8} = 28,9\ N/mm^2$

95% quantile (assuming normal distribution):

$$f_{m,c,95} = \frac{f_{m,c,05}}{1-1,645 \cdot COV_m} \cdot (1+1,645 \cdot COV_m) = 40,3\ N/mm^2$$

4-point-bending test according to EN 408: **bending failure requested**

(Rolling) shear strength of cross layers:

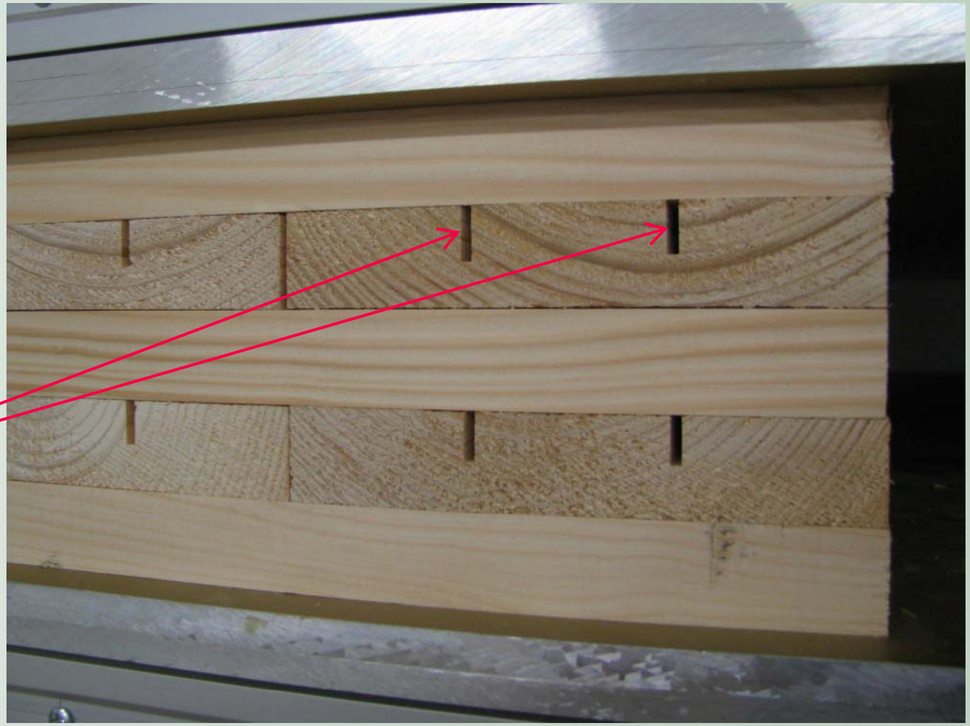
Without groovings:

$f_{v,9090,c,k} = 1{,}50\ N/mm^2$

With groovings:

$f_{v,9090,c,k} = 0{,}70\ N/mm^2$

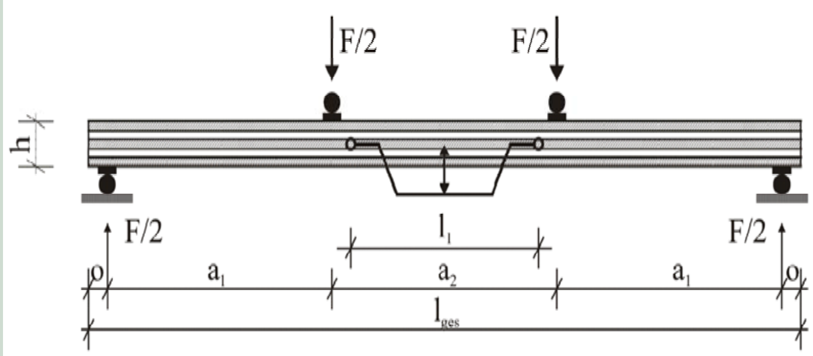
acc. to approval for Merk



Example for groovings

4-point-bending test according to EN 408: **bending failure requested**

$$\tau_{v,9090,c} = \frac{\frac{F}{2} \cdot S_{eff}}{I_{eff} \cdot b} \Rightarrow F = \frac{2 \cdot f_{v,9090,c,05} \cdot I_{eff} \cdot b}{S_{eff}}$$



$$\sigma_{m,c} = \frac{M}{W_{eff}} = \frac{\frac{F}{2} \cdot a_1}{W_{eff}} = \frac{\frac{F}{2} \cdot (f_{a1} \cdot h)}{W_{eff}} \Rightarrow f_{a1} = \frac{2 \cdot f_{m,c,95} \cdot W_{eff}}{F \cdot h}$$

	unit	without grooving	with grooving
$f_{m,c,05}$	[N/mm²]	28.9	28.9
$COV_{fm,c}$	[%]	10%	10%
$f_{m,c,95}$	[N/mm²]	40.3	40.3
$f_{v,9090,c,k}$	[N/mm²]	1.5	0.7
Faktor f_{a1}	[-]	6.0	12.8

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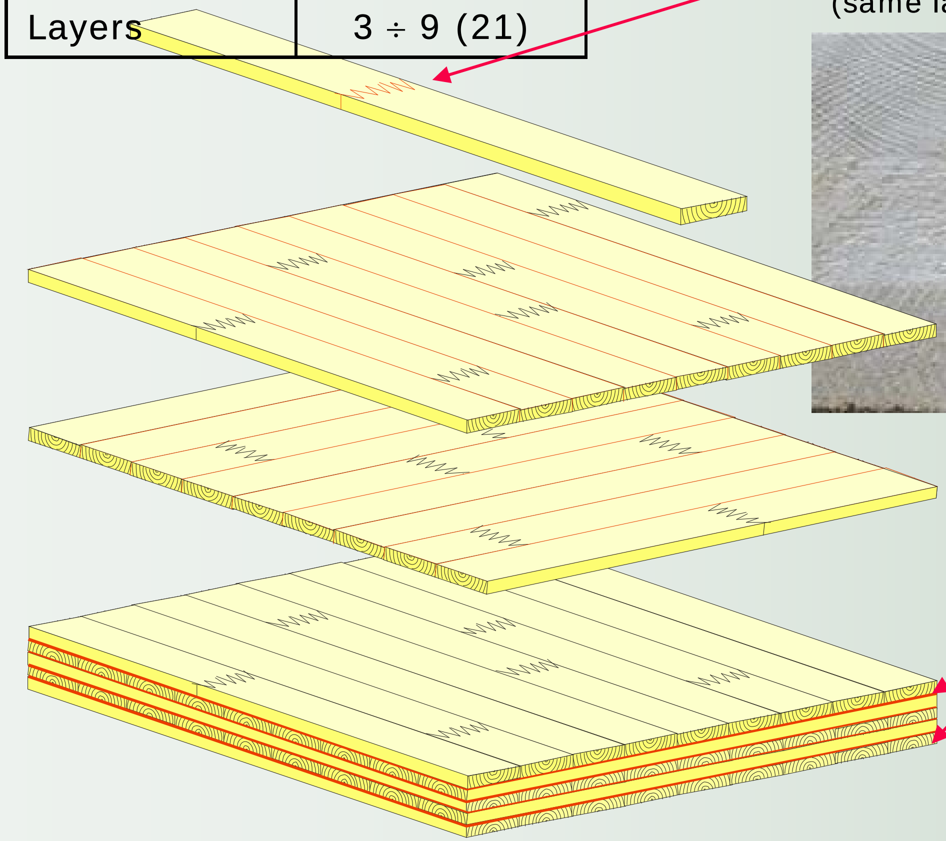
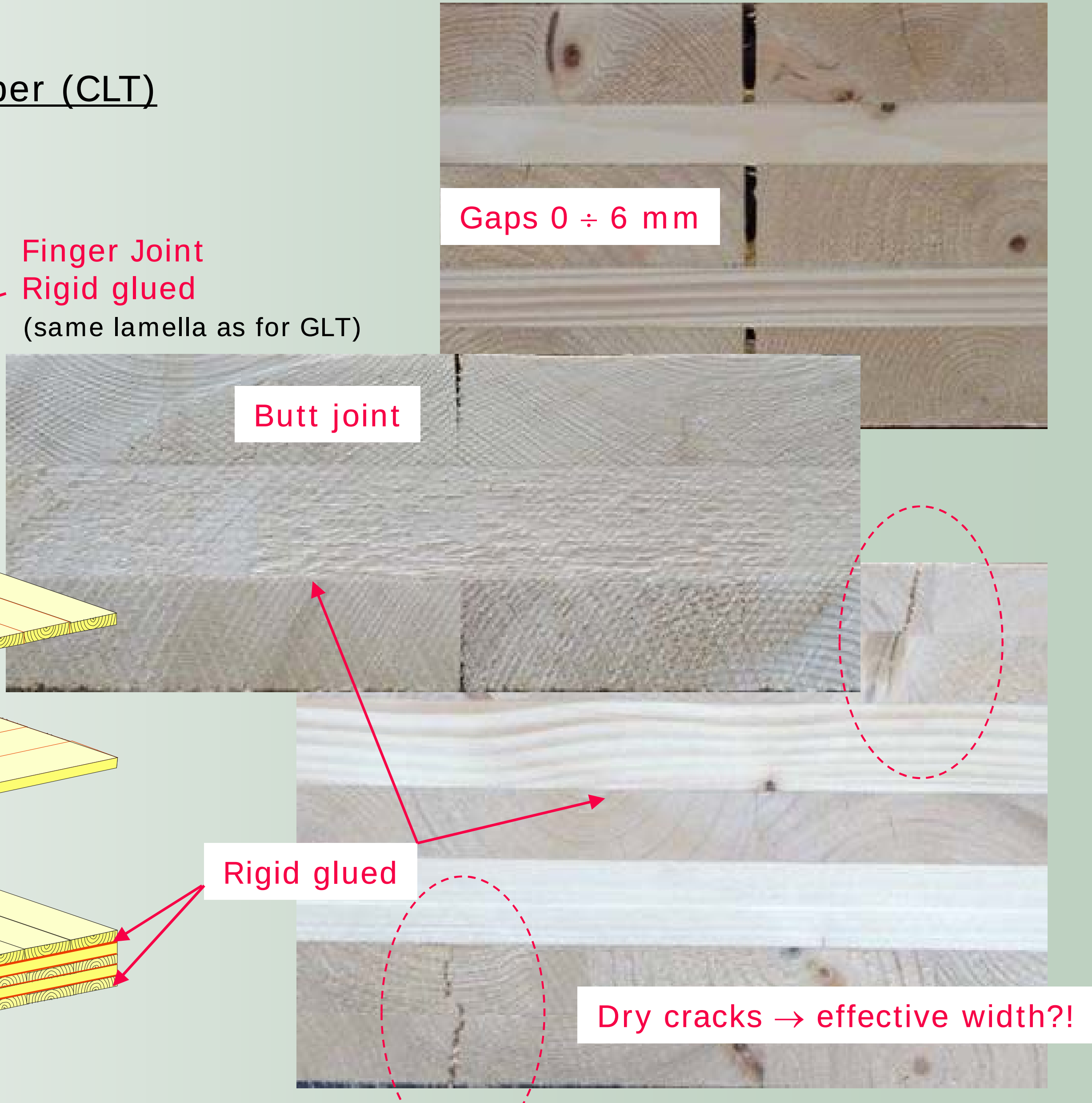
The mass product Cross Laminated Timber (CLT)

Length	16 m
Width	3 m
Thickness	60 ÷ 400 mm
Layers	3 ÷ 9 (21)

Finger Joint
Rigid glued
(same lamella as for GLT)

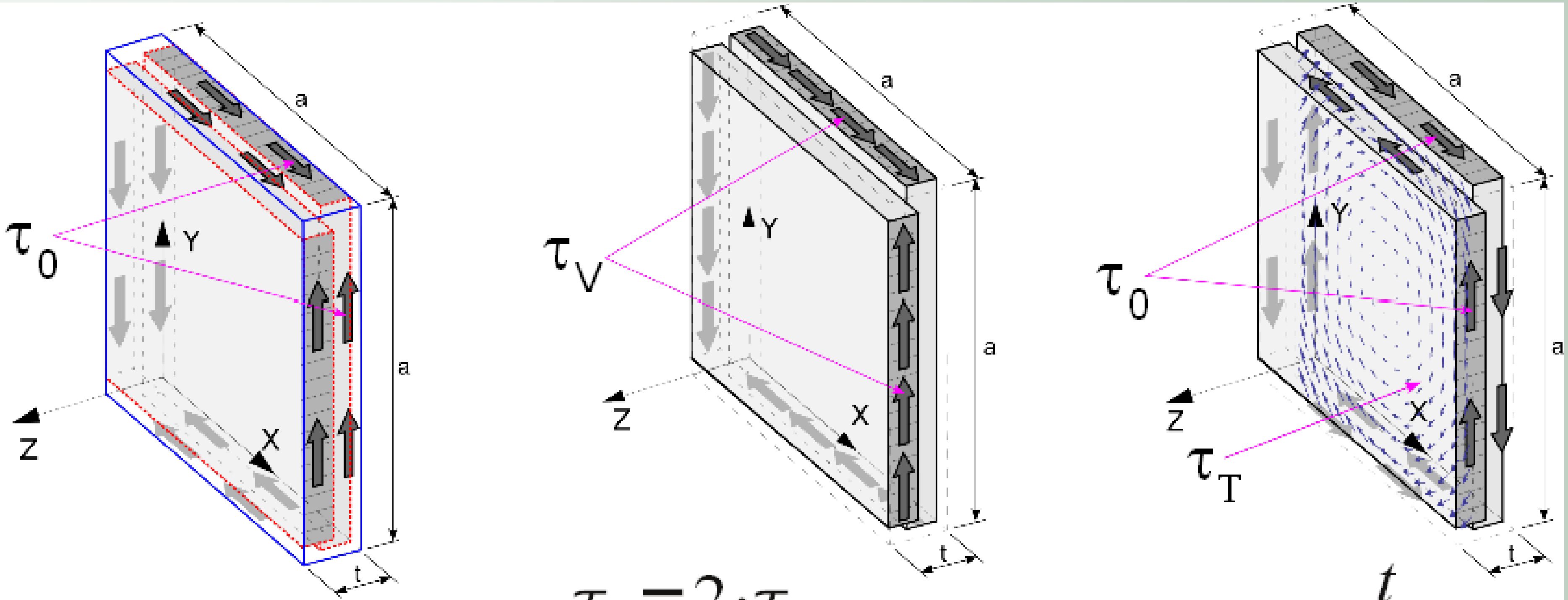




- Shear force in plane – Bearing Model

Mechanism I:

Mechanism II:



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

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

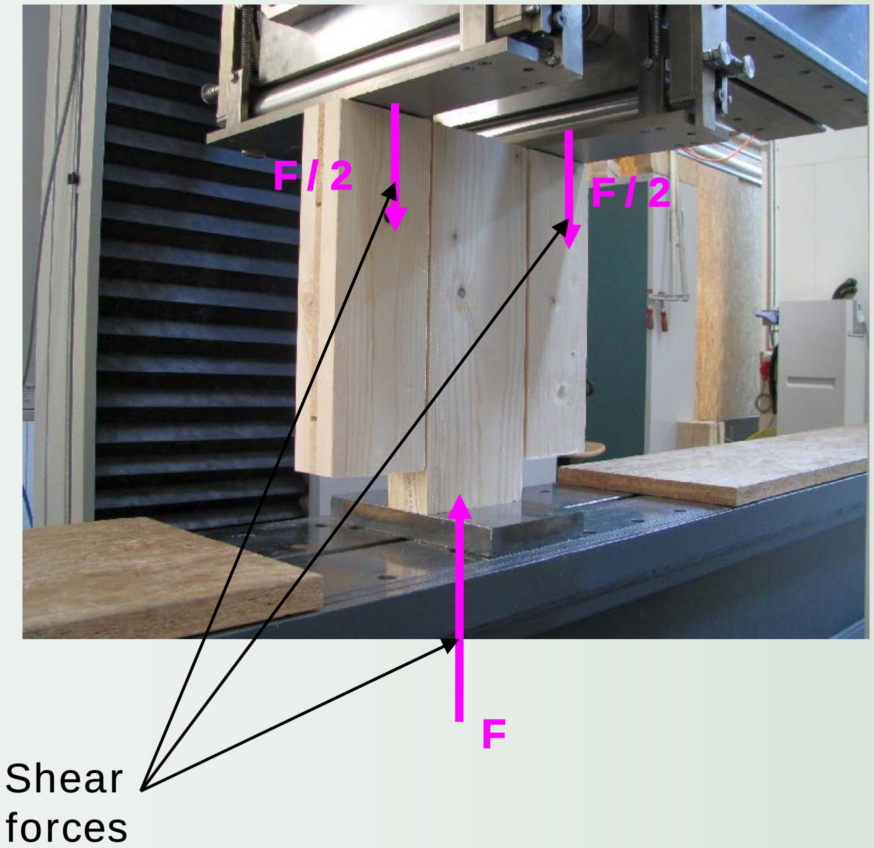
τ_0 nominal shear stress in plane

τ_V shear stress in cross section

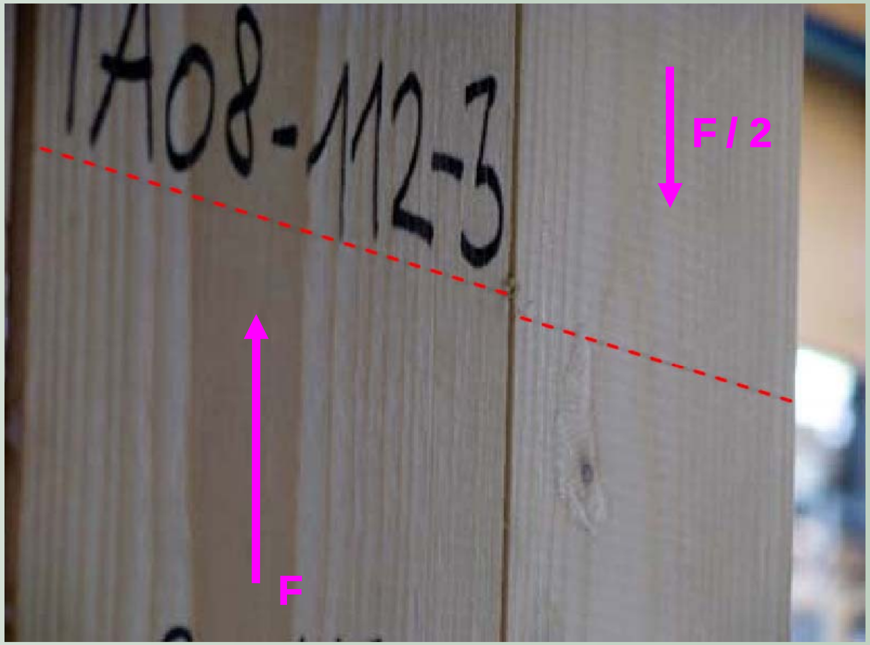
τ_T shear stress due to torsional moment in gluing interface

TUG test configuration – Mechanism I

Test configuration with symmetric shear block (2 tested cross sections)



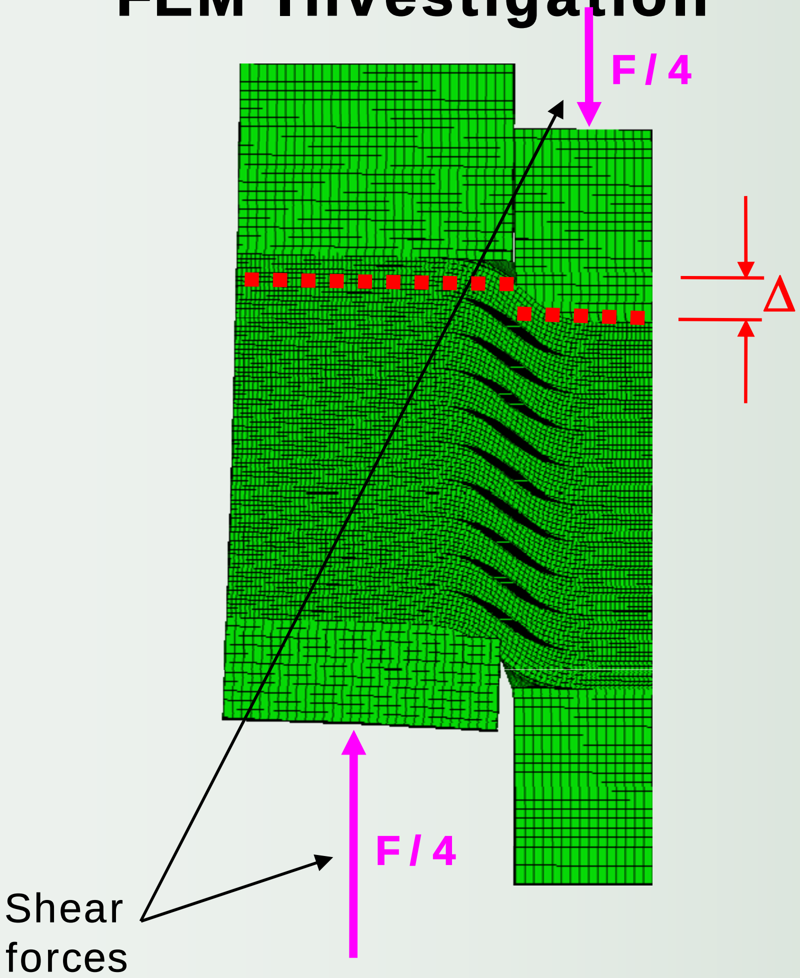
Test configuration



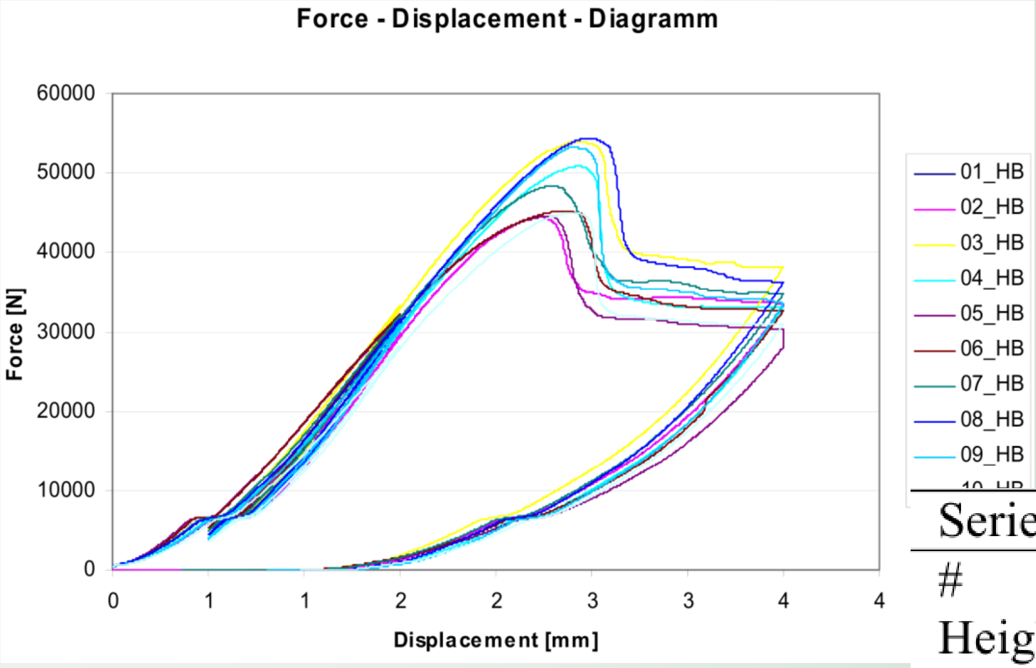
Local failure

TUG test configuration – Mechanism I

FEM Investigation



Local failure



Load — displacement behaviour

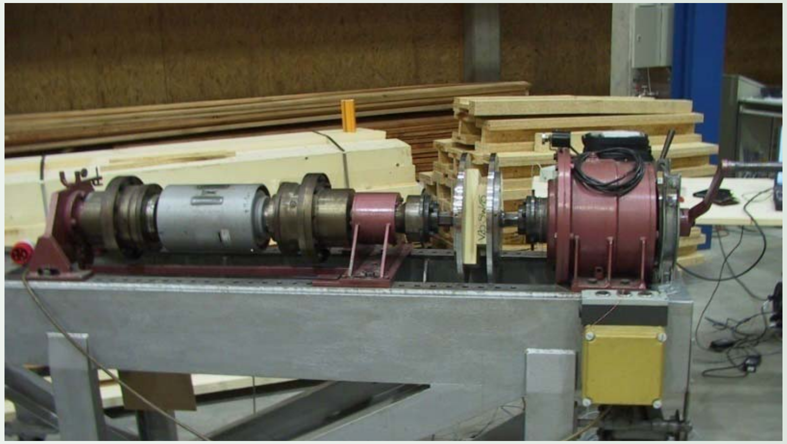
Shear Strength value for mechanism I

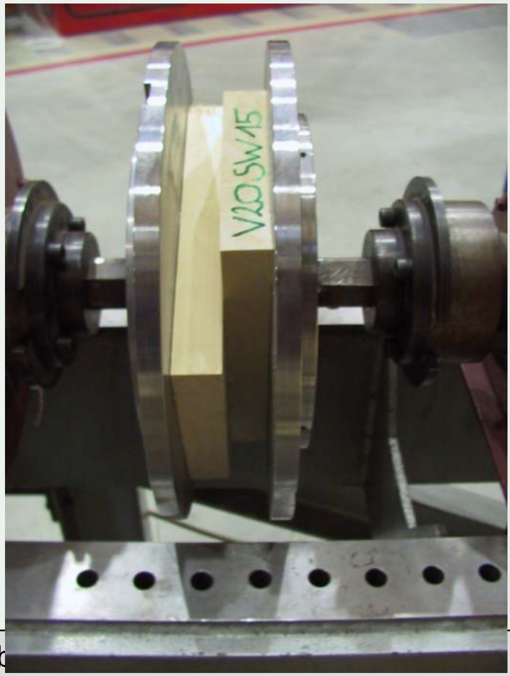
$$f_{v,k} = 10 \ [N/mm^2]$$

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]

TUG test configuration – Mechanism II





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

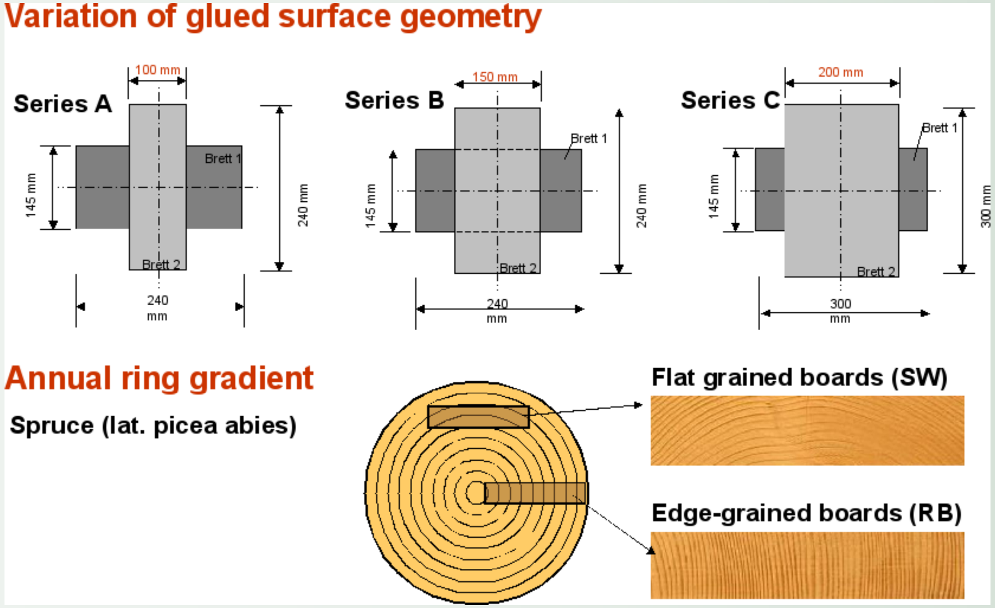
I_P polar sectional moment of gluing interface

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

a dimension of RVE

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

Coverage of tests



Shear strength value for mechanism II

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

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]

$$f_{T,k} = 2.5\ [\mathrm{N/mm^2}]$$

Remark: Value generally accepted!

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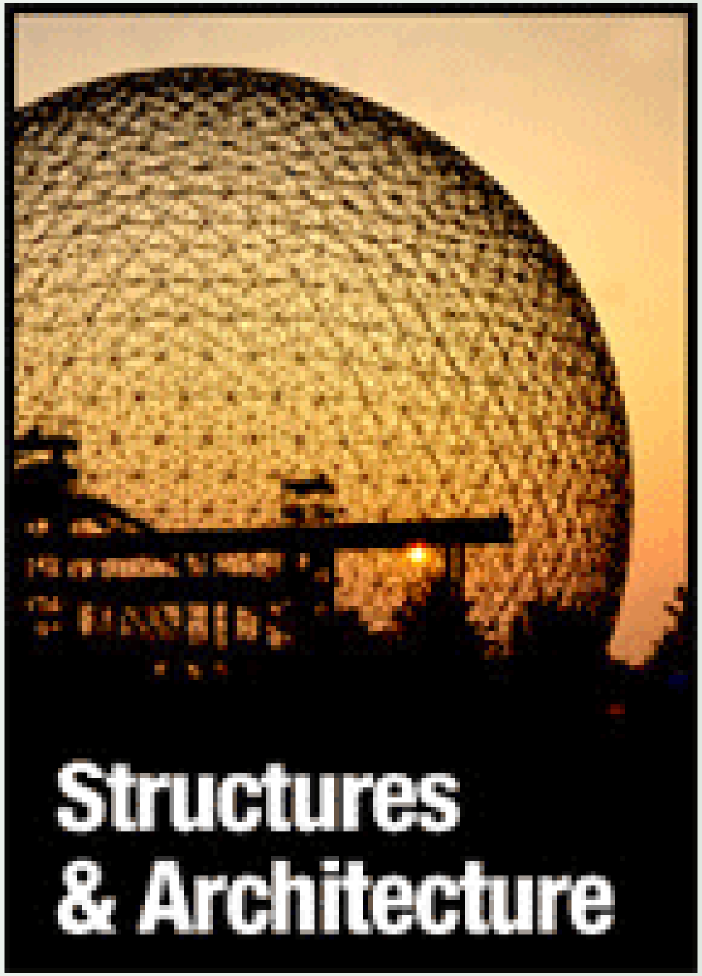
Conclusion

- Bearing models – like for bending loads perp. to plane or shear loads in plane - are needed for huge elements like CLT
- Test procedures must be new defined (shear loads in plane) or at least adapted (bending loads) from well known configurations (EN 408 configuration)

open points

- Bearings models for tension and compression forces should be still established.
- Interaction formulars between tension/compression with bending should be investigated in future.
- Bending strength near local support (e.g. column support) with its typical moment peaks has to be investigated.
- Compression strength perpendicular to grain – and factor $k_{c,90}$
- For some special cases tensile strength behavior perpendicular to grain is needed – e.g. curved elements.

Thank You for Your Attention



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