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Engineered Wood Products (EWP's) – Strength and Stiffness Estimation and Modelling

Bearing Model for GLT in Bending – new Aspects concerning Modelling

In the frame of COST E55
'Modelling of the performance of timber structures'

Center of Competence
for Timber Engineering and Wood Technology

at Center for Structural Engineering
Graz University of Technology

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Graz, 14th May 2007

Bearing model for GLT in bending – Content:

- General aspects concerning GLT-model in bending
- Current status acc. EN 1194:1999
- Mech. potential of boards in tension
- Mech. potential of GLT in bending
- Model for GLT in bending
- Proposal for further regulations in EN 1194:new

Main characteristics for the design of timber:

Strength	Modulus of elasticity	Density

Main mech. and phys. wood characteristics (determining strength class)
dispersing locally and globally

Interest locally **Load carring capacity** (min., 5 %-qu.)	Interest globally **Serviceability** (mean)	Interest locally **Connection systems** (min., 5 %-qu.)
Measurement of local imperfections **‚extreme value theory‘**	Measurement of global influences of local imperfections **‚central limit theorem‘**	Measurement of global influences of local imperfections **‚extreme value theory‘** **‚central limit theorem‘**

Bearing model for GLT in bending – General:

→ **Model to describe the relationship:**

Predominant failure mode

$$f_{m,g} \text{ vers. } f_{t,0,l}$$

Predominant loading

Lamella! = boards + finger joints

→ **For design and reliability** (based on current semi-probabilistic safety concept):

$$f_{m,g,k} \text{ vers. } f_{t,0,l,k}$$

Characteristic value:

→ Lower boundary value of the confidence interval representing the fuzziness of the 5 %-quantile as point estimation

$$f_k \rightarrow f\{ DM, f_{mean}, COV\text{-}f, n, \alpha \}$$

Bearing model for GLT in bending – Influences I:

Influences on the model (acc. Colling 1990):

→ Single boards / finger joints vers. boards / lamellas bonded in GLT

→ Reinforcement of low stiffness / strength areas in the system GLT

→ Distribution and random positioning of low strength / stiffness lamellas within GLT

Influences on the model in regard to test arrangement and calculation:

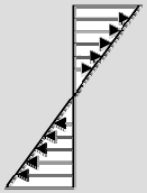
→ Test execution and collection of test results and reproducibility

→ Examination of test results – statistical analysis

→ Subjectiveness of interpretation of test results

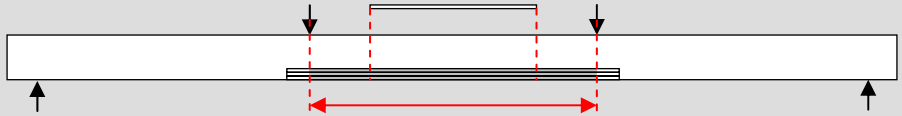
Bearing model for GLT in bending – Influences II:

Comparison $f_{m,g}$ vers. $f_{t,0,l}$:



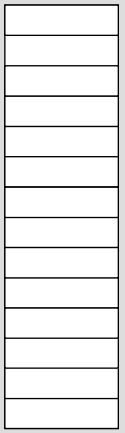
vers.

- **Differences due to stressed cross section**
- **Differences due to stressed tested length**
  - Boards → l_0 = 2000 mm
  - GLT → $l_0 = (18 \pm 3) \cdot h_0$



but constant moment over $l_{test} = 6 \cdot h_0 = 3600$ mm

- **Differences due to reference dimensions**
  - Boards in tension → w_0 = 150 mm, l_0 = 2000 mm, (h ~ 40 mm)
  - GLT in bending → w_0 = 150 mm, h_0 = 600 mm, $l_0 = (18 \pm 3) \cdot h_0$

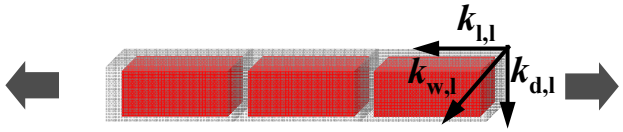


- **Differences due to different structures**
  - Boards in tension → serial arranged RVE's → serial system (weakest link theory, extreme value theory)
  - GLT in bending → parallel arranged, rigid connected lamellas, but serial loaded in edgewise bending

Bearing model for GLT in bending – System / size effects

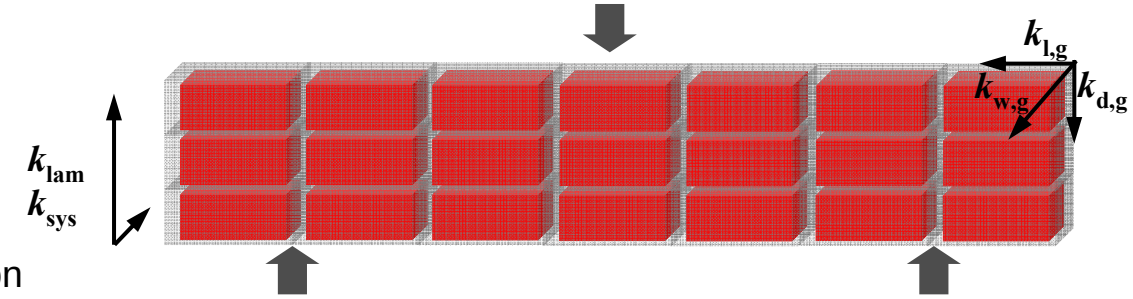
Lamellas = predominant serial con. boards / board segments (RVE's) and finger joints

→ Tension: serial loaded
→ High dispersion



GLT = parallel, rigid con. lamellas

→ Bending: serial loaded
→ Low dispersion due to homogenisation



General: Laminating factor / size factor / system factor

→ **Interaction of statistical and mechanical effects!**

$$f_{m,g,k} \rightarrow f\{ f_{t,0,l,k}, f_{t,j,k} \}$$

$$f\{ DM, f_{mean}, COV\text{-}f, n, \alpha \}$$

Bearing model for GLT in bending – Current situation EN 1194:1999

Bending strength of GLT ($f_{m,g,k}$) in dependence of:

→ **Tension strength of boards ($f_{t,0,l,k}$)** $f_{m,g,k} = 7 + 1.15 \cdot f_{t,0,l,k}$

→ **Tension strength of finger joints ($f_{t,j,k}$)** $f_{t,j,k} \geq 5 + f_{t,0,l,k}$

→ **Determination of relationships on the level of the 5 %-quantile is statistically rather sensitive**

→ **Dependence of 5 %-quantile from:**

- →**Representative statistical distribution model (DM)**
- →**Parameters of statistical distribution (parameter of location and dispersion)**

→ **Dispersions of strength values ($COV\text{-}f_{t,0,l}$, $COV\text{-}f_{m,g}$, $COV\text{-}f_{t,j}$) have not been considered so far!!!**

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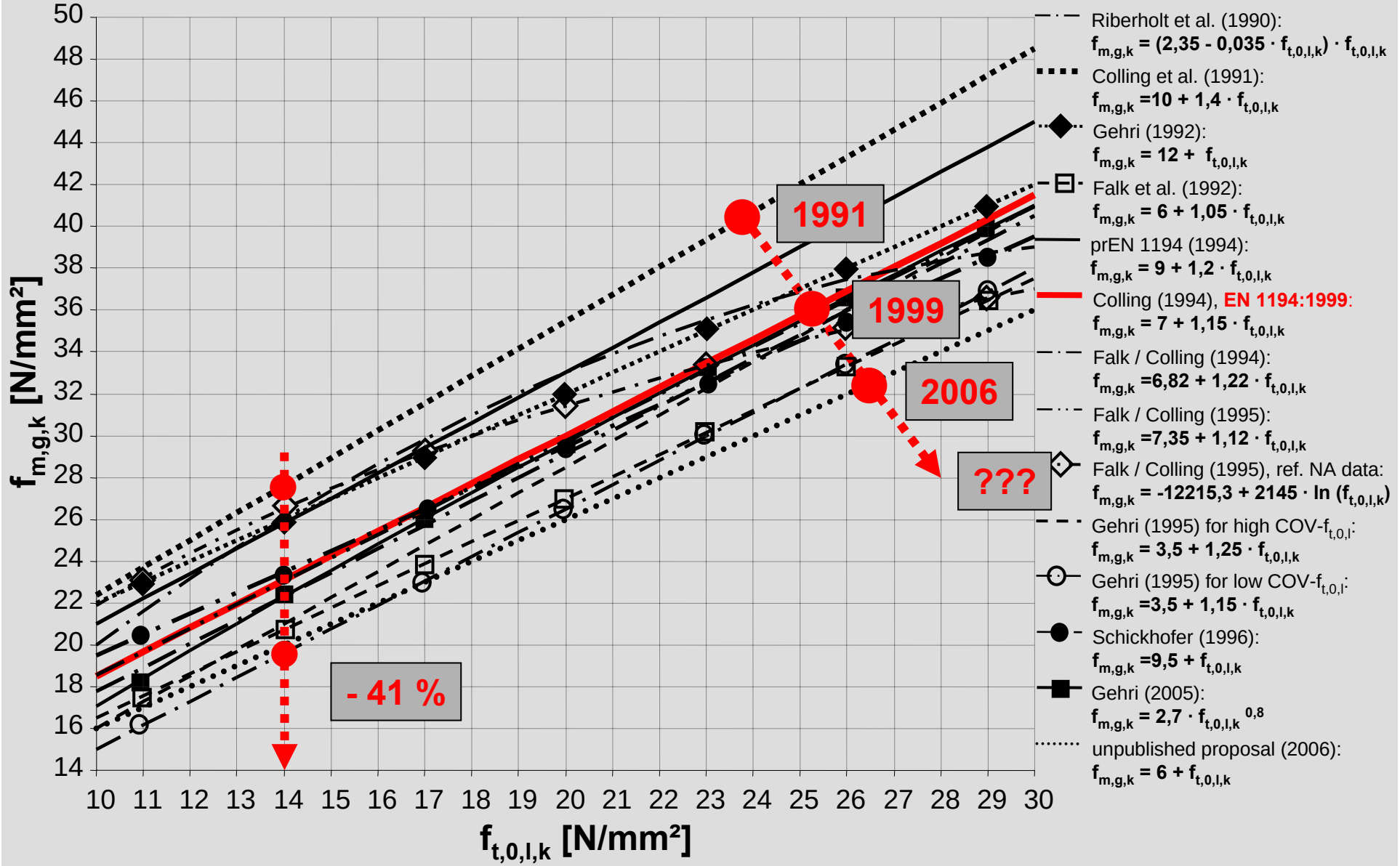
GLT-model – **Literature study**



Bearing model for GLT in bending – Examined data sets

Examined data sets to describe the mech. potential of boards in tension:

- → Data sets of TU Graz and hbf: 7 (sub) series with total 1400 #, spruce, Central Europe
- → Average weighted dimension: l / b / h = 3660 / 150 / 39 mm → free testing length l_0 ~ 3000 mm
- → Machine graded (MS7) MS10 – MS17

Examined data sets to describe the mech. potential of GLT in bending:

- → Data sets of TU Graz and hbf: (1994 – 2006), 10 (sub) series with total 177 # GLT tests without apparent induced failure in finger joint, spruce, Central Europe
- → With knowledge of mech. potential of boards in tension ($f_{t,0,l}$, $E_{t,0,l}$ and ρ_l)

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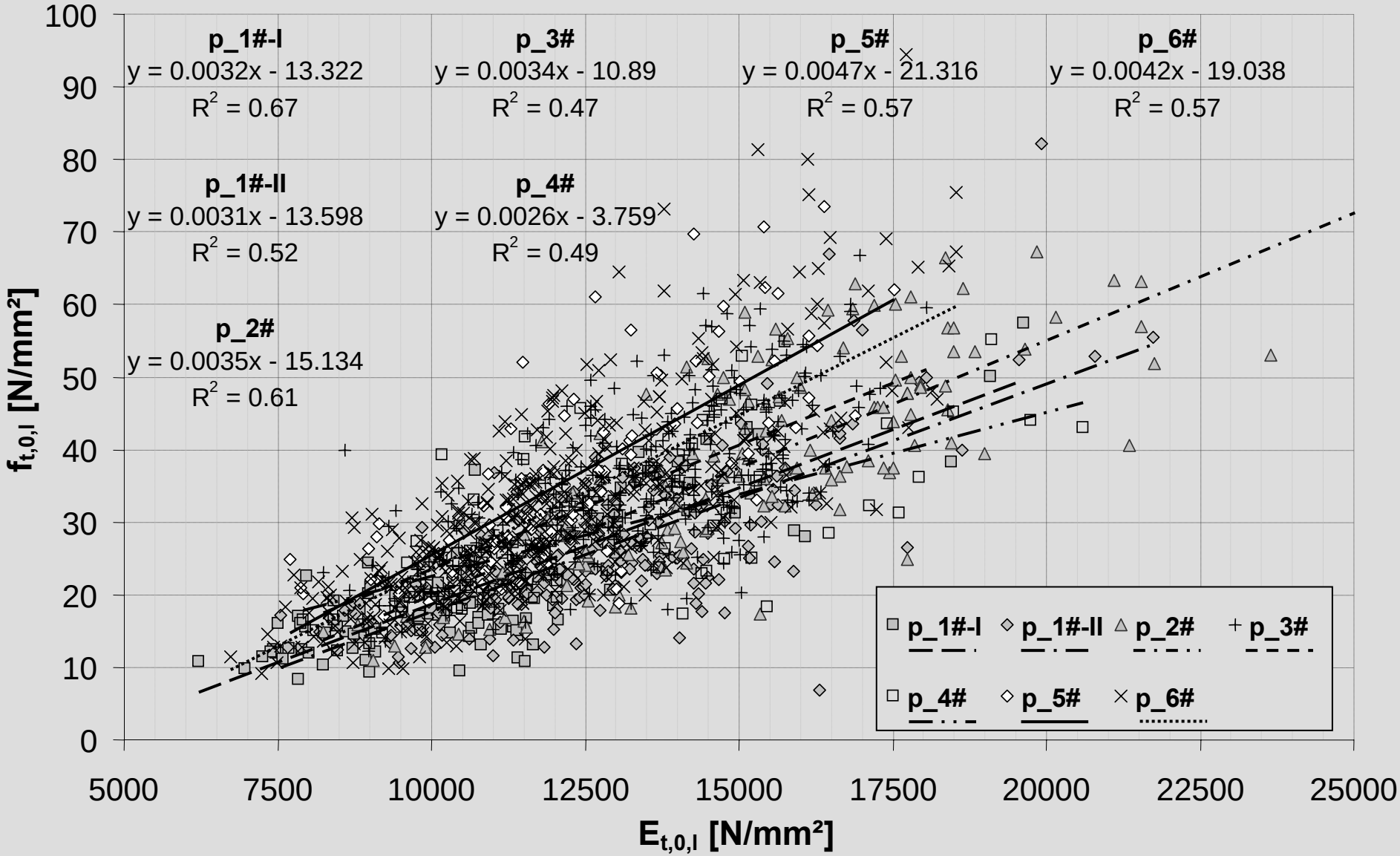
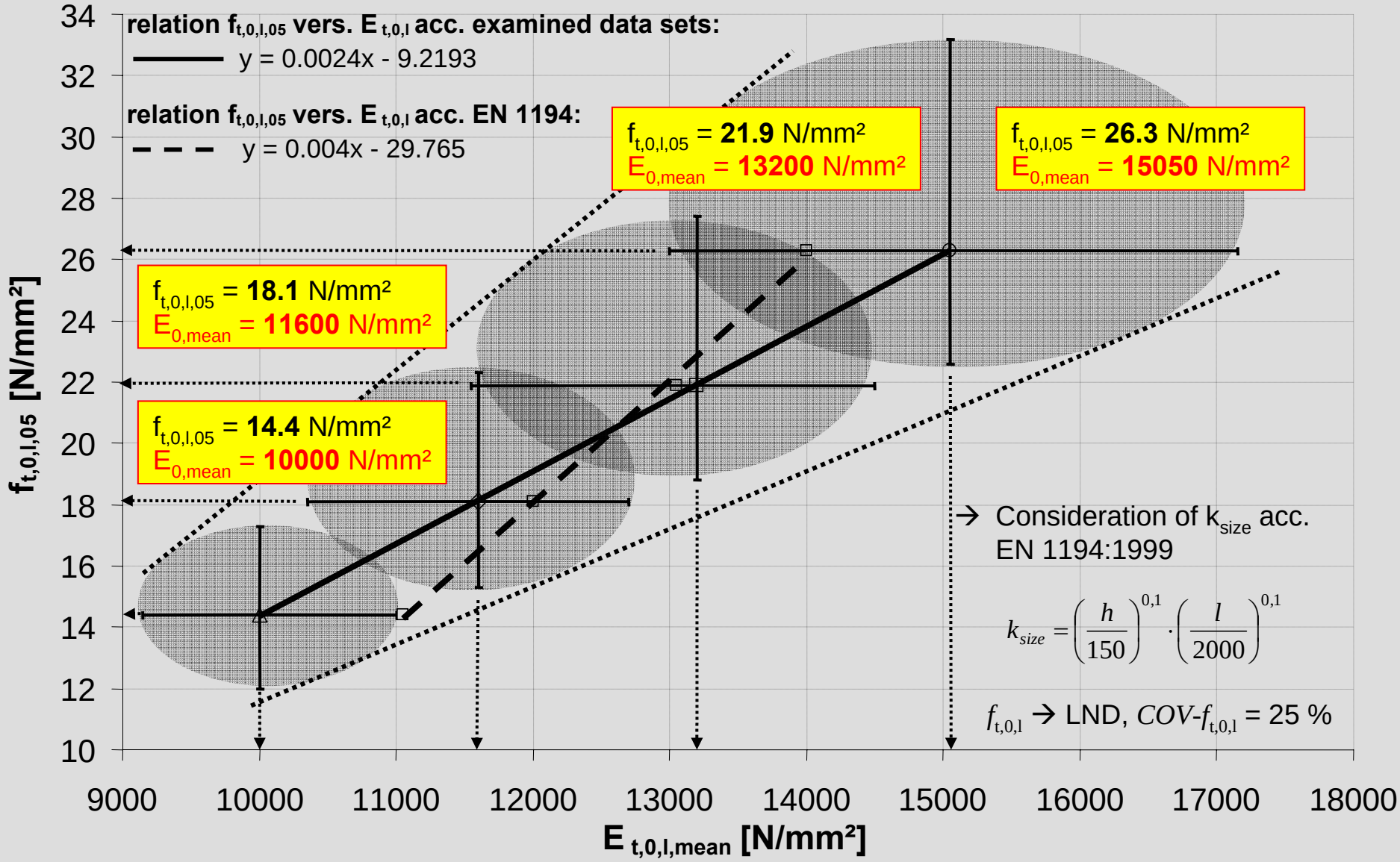
GLT-model – **Mech. potential of boards**



GLT-model – **Mech. potential of boards**



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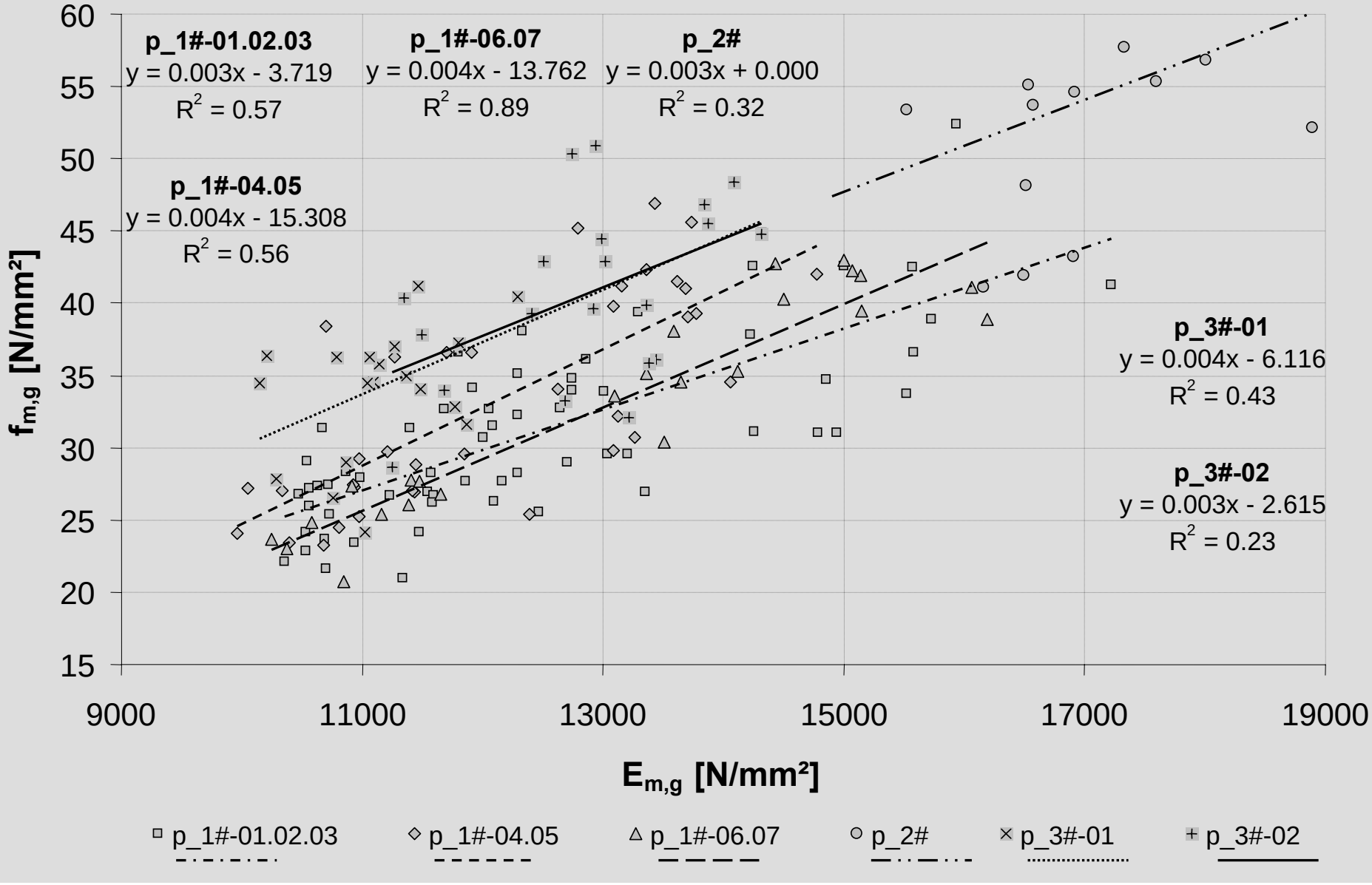
GLT-model – **Mech. potential of GLT**



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GLT-model – **Scheme**

$COV\text{-}f_{t,0,l} \rightarrow$ { **35 ± 5 %** ; **25 ± 5 %** }

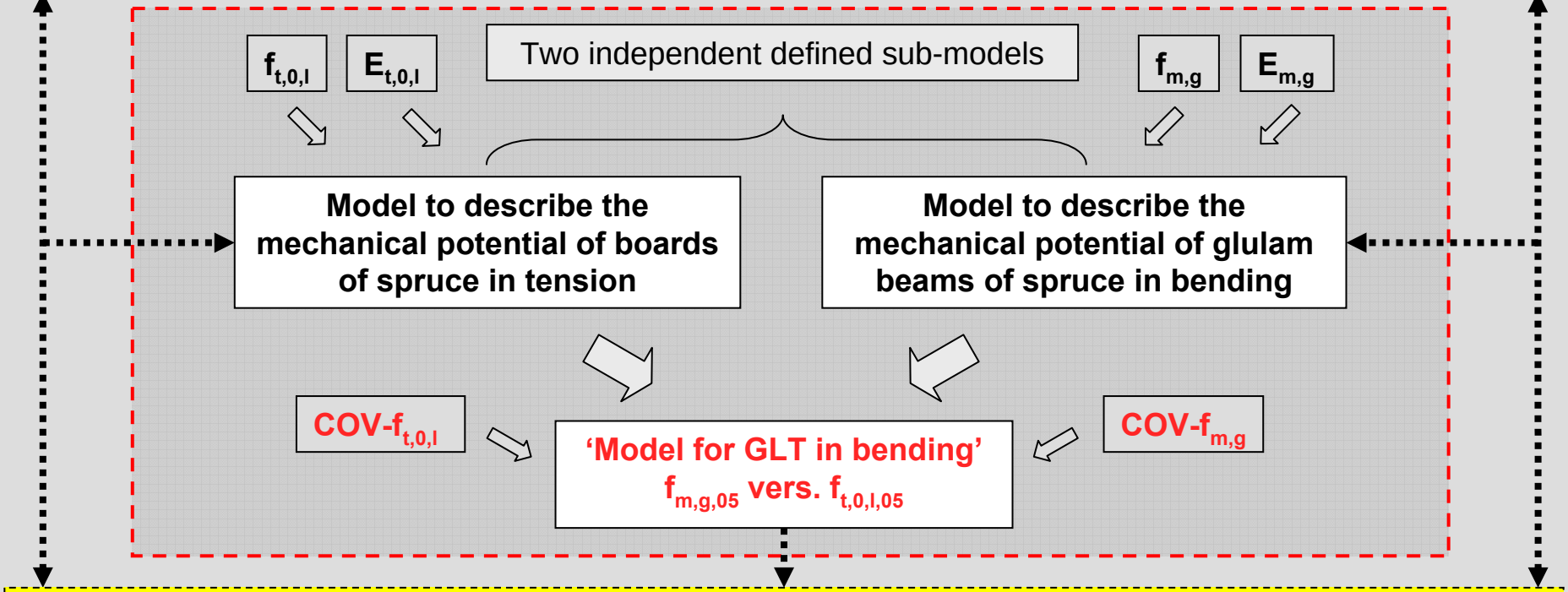
DM $\rightarrow$ { $f_{t,0,l} \rightarrow$ **LND** ; $E_{t,0,l} \rightarrow$ **ND** }

$f_{t,0,l,05} = 0.0024 \cdot E_{t,0,l,mean} - 9.22$

$f_{m,g,05} = 0.0022 \cdot E_{m,g,mean} - 2.22$

$COV\text{-}f_{m,g} \rightarrow$ **15 ± (5) %**

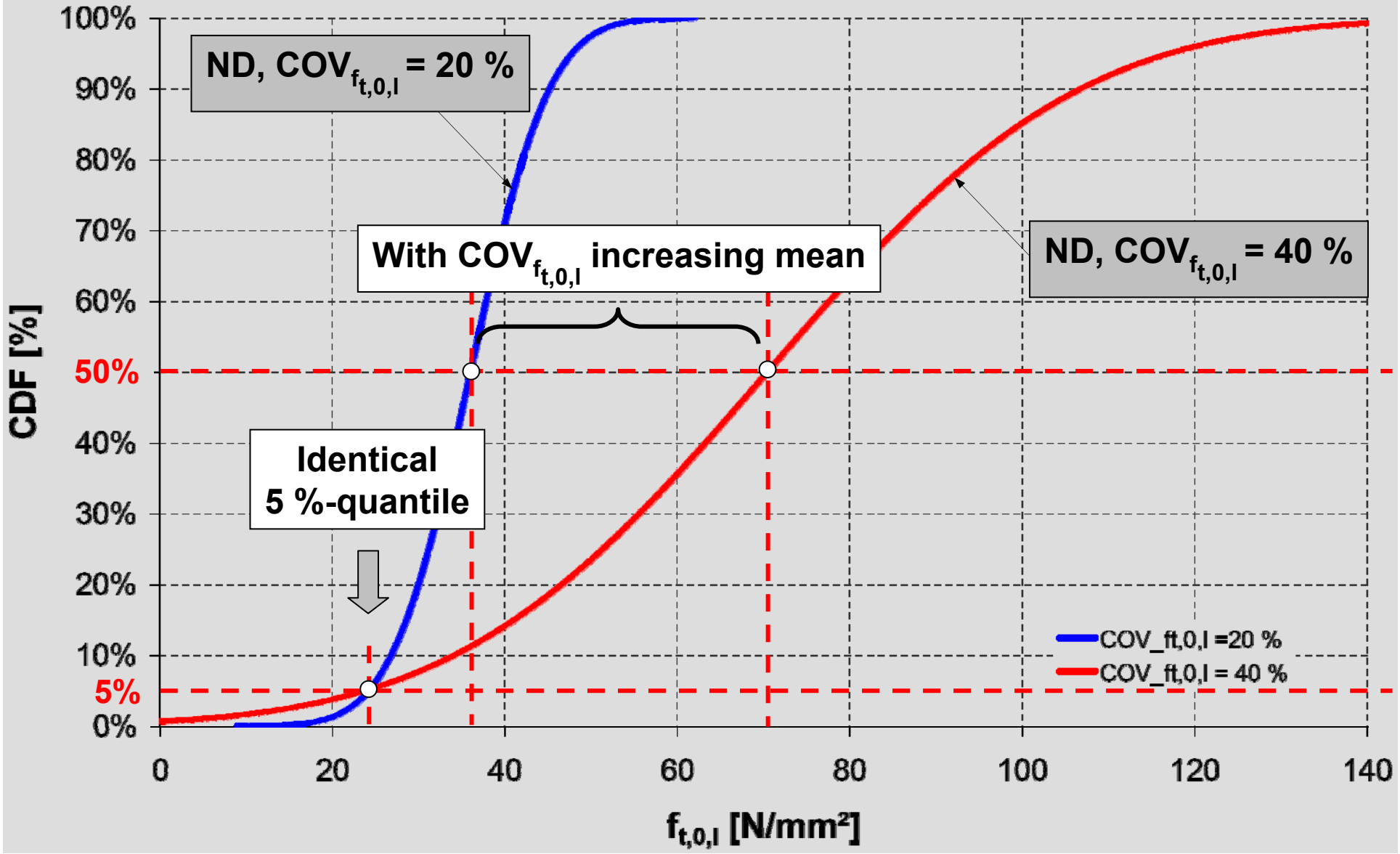
DM $\rightarrow$ { $f_{m,g} \rightarrow$ **ND** ; $E_{m,g} \rightarrow$ **ND** }



On the basis of mean-regression models

$f_{m,g,mean} = 2.25 \cdot f_{t,0,l,mean}^{0.82} \rightarrow f_{m,g,05} = m \cdot f_{t,0,l,05}^{0.82}$ **with** $m \rightarrow f\{ COV\text{-}f_{t,0,l}, COV\text{-}f_{m,g} \}$

GLT-model – **Influence of COV**



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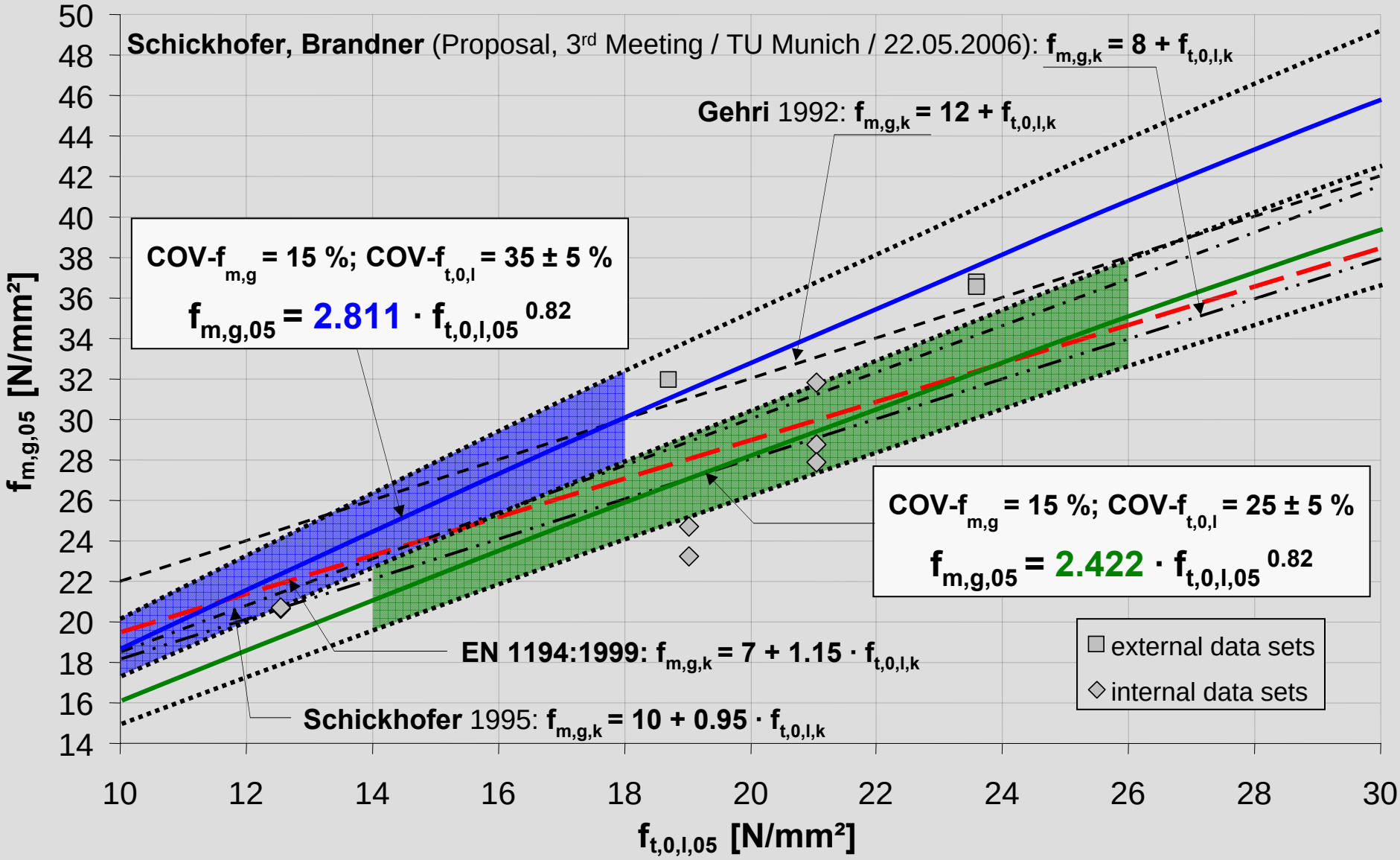
GLT-model – **Expectable ranges**



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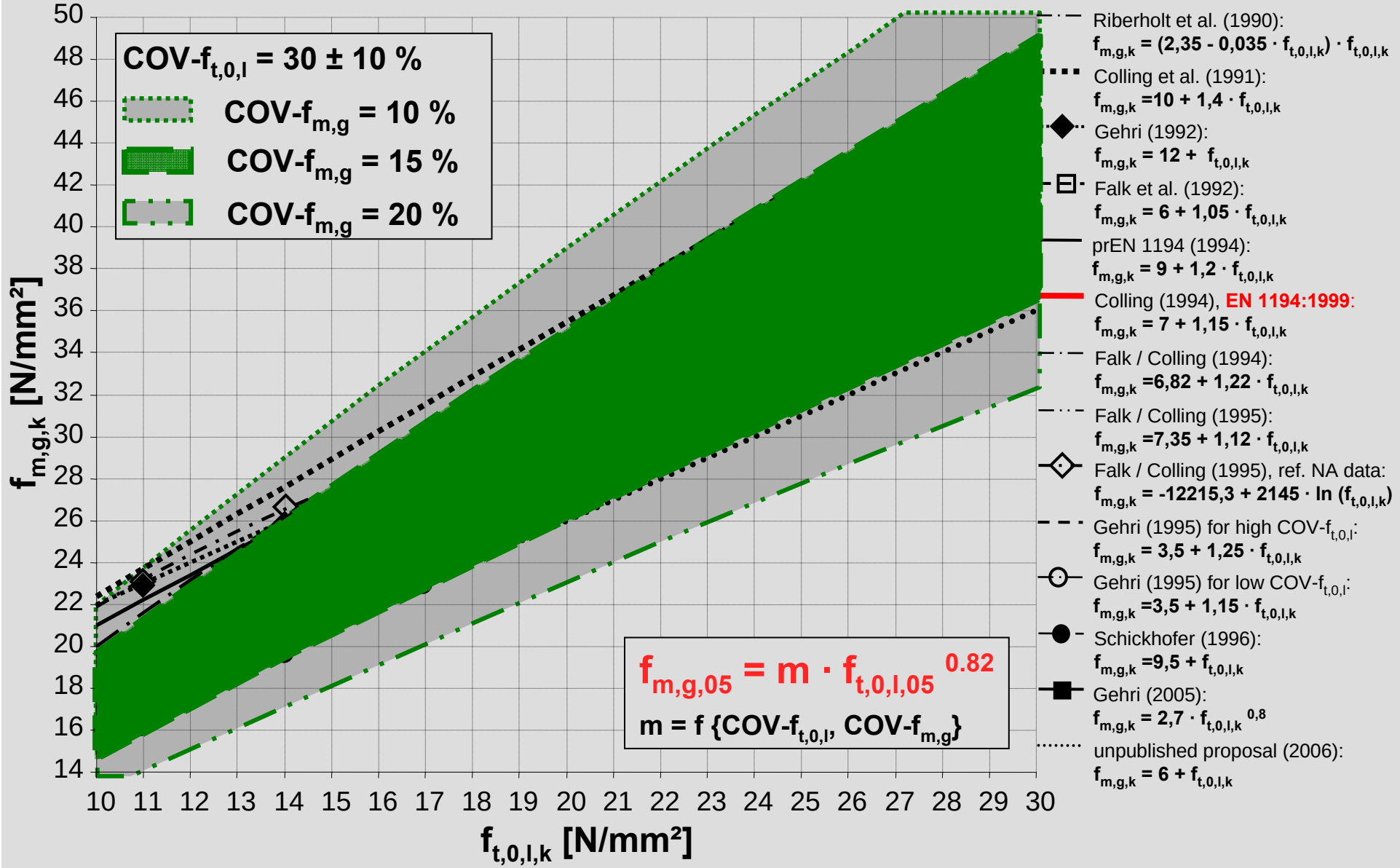
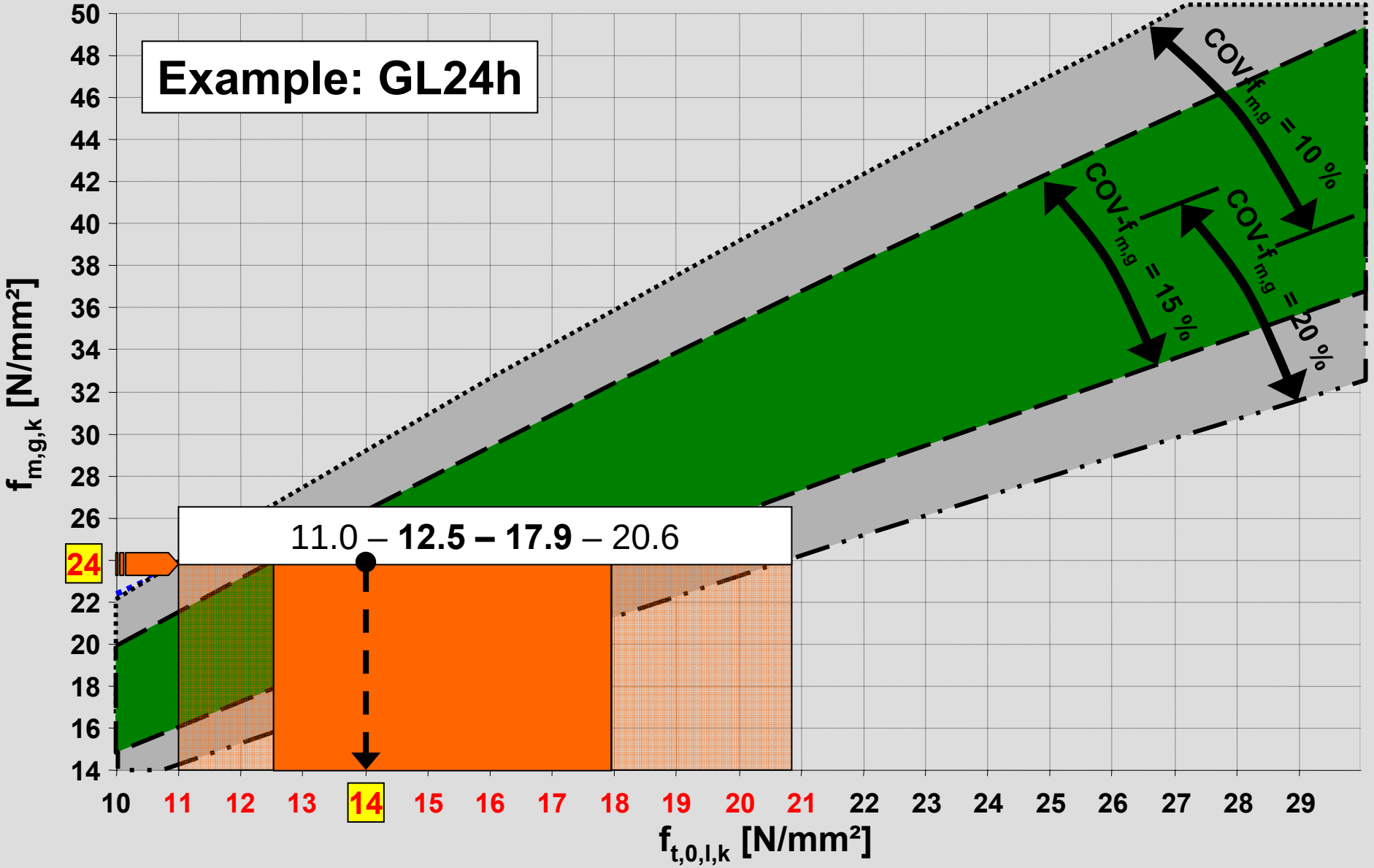
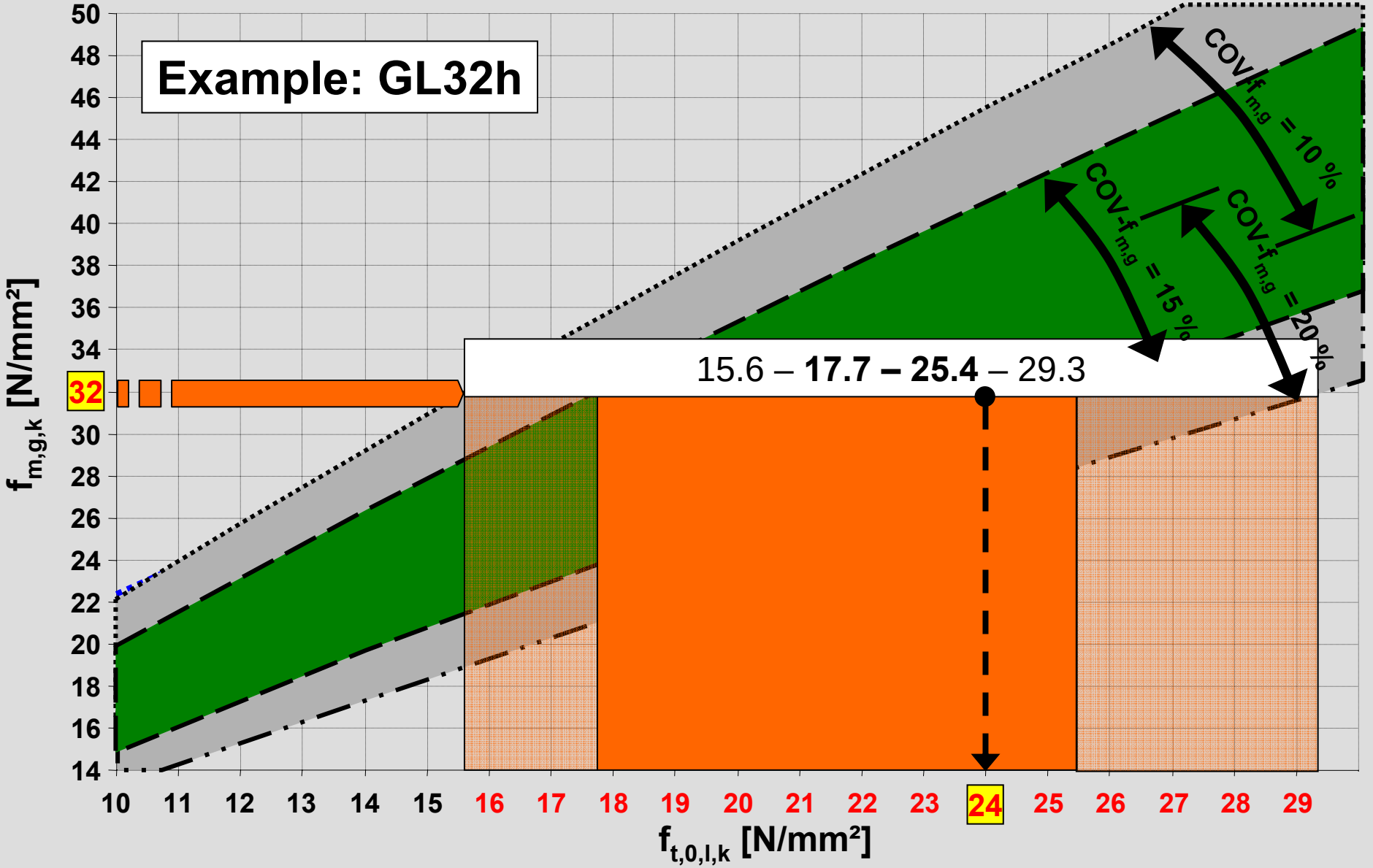
GLT-model – **GBM compared to literature**



GLT-model – **Effect: e.g. GL24h**



GLT-model – **Effect: e.g. GL32h**



Bearing model for GLT in bending – Proposal for EN 1194:new

→ **Tension strength of boards ($f_{t,0,l}$)**

$$f_{m,g,05} = m \cdot f_{t,0,l,05}^{\,0.82}$$

with $m \rightarrow f\{ COV\text{-}f_{t,0,l}, COV\text{-}f_{m,g} \}$

→ **Tension strength of finger joints ($f_{t,j}$)** $f_{t,j,k} \rightarrow f\{ f_{t,0,l}, COV\text{-}f_{t,0,l}, COV\text{-}f_{t,j} \}$

Bending [1)]	$f_{mg,k}$	$= m \cdot f_{t,0,l,k}^{\,0.82}$	m = **2.811** for $COV\text{-}f_{t,0,l}$ = 35 ± 5 %, $COV\text{-}f_{m,g}$ = 15 %
			m = **2.422** for $COV\text{-}f_{t,0,l}$ = 25 ± 5 %, $COV\text{-}f_{m,g}$ = 15 %

[1)] **Reference dimensions: GLT** - h_0 = 600 mm, w_0 = 150 mm, u_0 = 12 %, **boards** – l_0 = 2000 mm, w_0 = 150 mm, u_0 = 12 %

Txx.x Exx.x (e.g. **T28.0 E15.5**) with $E_{0,g,mean} = E_{0,l,mean}$

referring $E_{t,0,l,mean}$

referring $f_{t,0,l,k}$

→ **Based on mean regression models!**

- → **Studies concerning representative statistical distribution models**
- → **Studies concerning parameters / dispersions**
- → **Studies concerning relationships (describing formulations) under consideration of constraints**

Bearing model for GLT in bending – Proposal for EN 1194:new

Proposal for required tension characteristics of boards acc. GLT-strength classes regulated in current EN 1194: assumed $COV\text{-}f_{t,0,l}$ = 35 ± 5 %, $COV\text{-}f_{m,g}$ = 15 %

GLT-strength class [--]	$f_{m,g,k}$ [N/mm²]	$E_{m,g,mean}$ [N/mm²]	Board-strength class [--]	$f_{t,0,l,k}$ [N/mm²]	$E_{t,0,l,mean}$ [N/mm²]
GL24h	24.0	11000	T14.5 E11.0 +	14.5	11000
GL28h	28.0	12500	T18.0 E12.5 +	18.0	12500

Proposal for required tension characteristics of boards acc. GLT-strength classes regulated in current EN 1194: assumed $COV\text{-}f_{t,0,l}$ = 25 ± 5 %, $COV\text{-}f_{m,g}$ = 15 %

GLT-strength class [--]	$f_{m,g,k}$ [N/mm²]	$E_{m,g,mean}$ [N/mm²]	Board-strength class [--]	$f_{t,0,l,k}$ [N/mm²]	$E_{t,0,l,mean}$ [N/mm²]
GL24h	24.0	11000	T16.5 E11.0	16.5	11000
GL28h	28.0	12500	T20.0 E12.5	20.0	12500
GL32h	32.0	14000	T24.0 E14.0	24.0	14000
GL36h	36.0	15500	T28.0 E15.5	28.0	15500

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