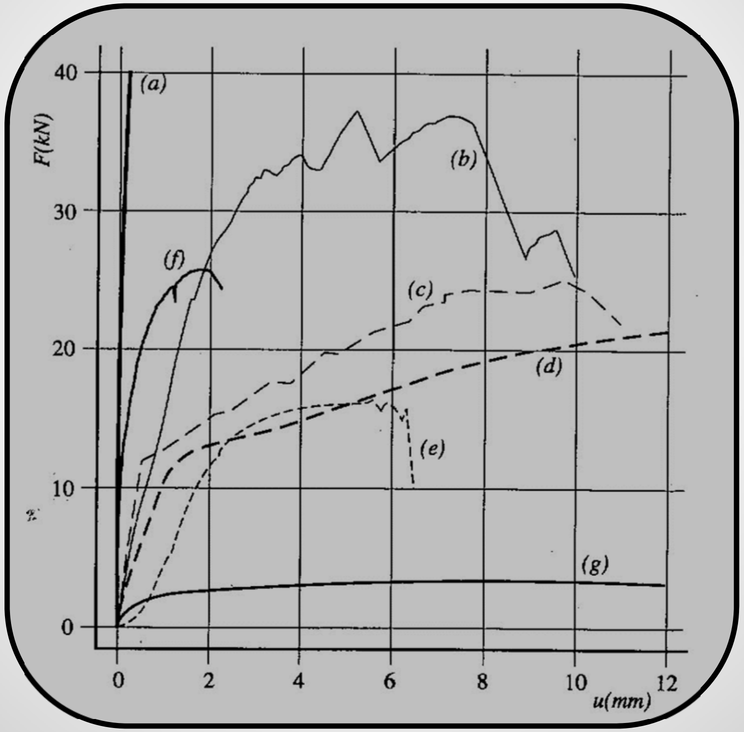
Consideration of plasticity within the design of timber structures due to connection ductility



Final conference
COST E55 – Modelling the Performance of Timber structures

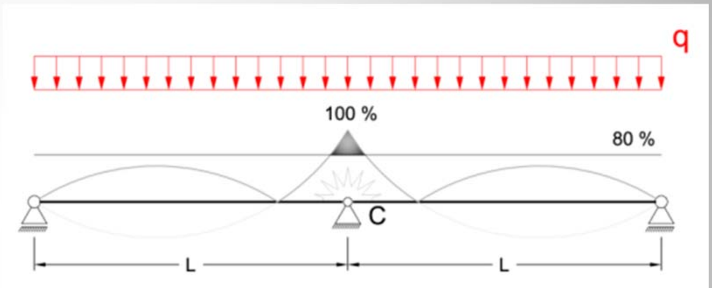
May 26th – 27th, 2011

Content

- Motivation
- Influence of the material scattering
- Joint requirements
- Outlook

Motivation

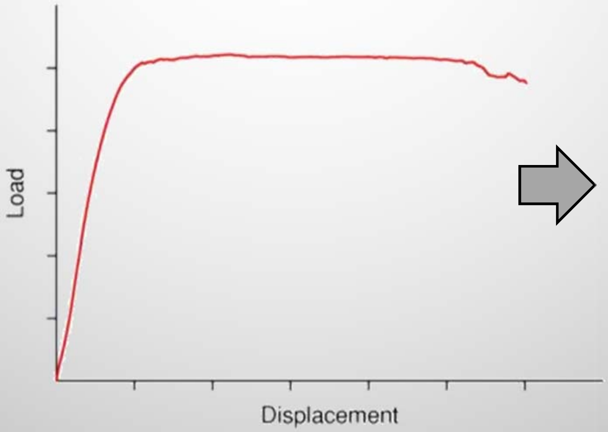
Stress redistribution within
statically undetermined structures

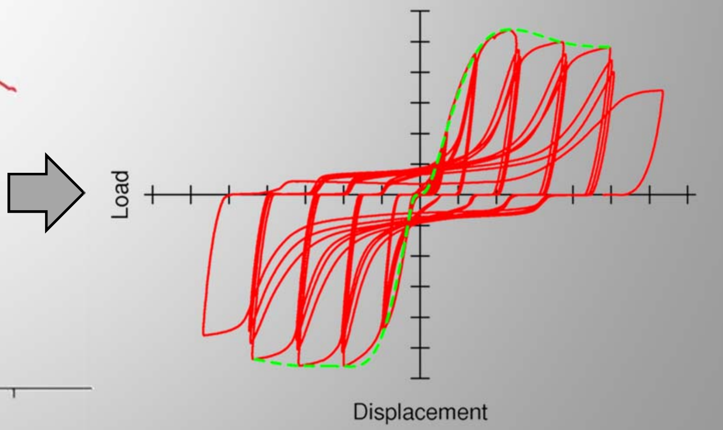


Increase of ultimate load

Robustness

Earthquake
Energy dissipation

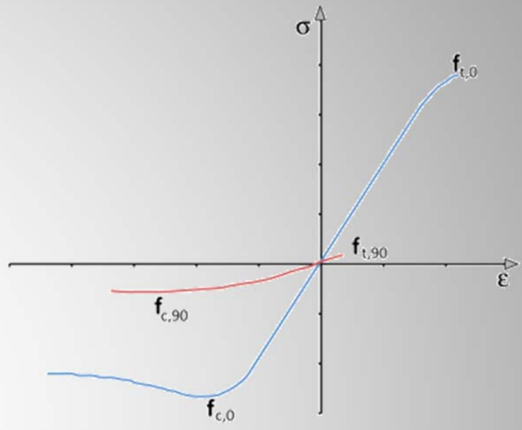




Plasticity in timber structures

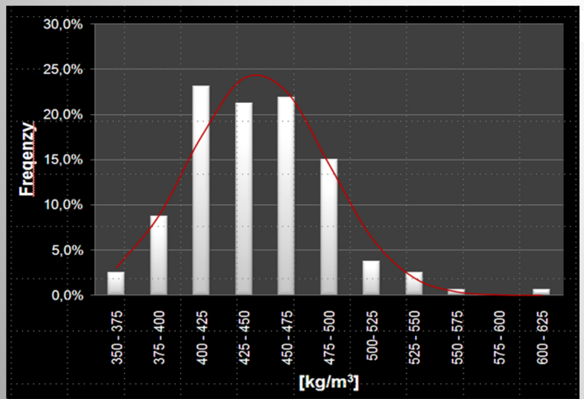
- Timber is in general a brittle material

$$\left(\frac{\sigma_{c,0,d}}{f_{c,o,d}}\right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_{red} \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$



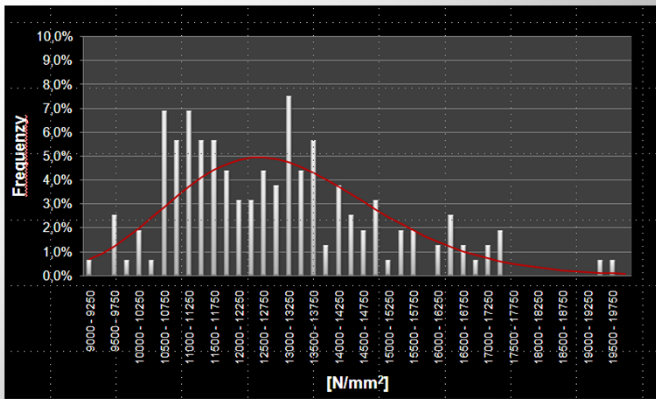
- Material properties of timber are characterized by extreme scattering of the properties and by anisotropy

Density



Mean value: 445.7 kg/m³
COV : 0.091

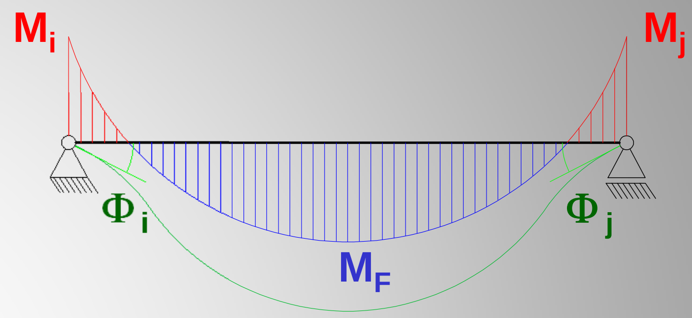
Modulus of Elastisity



Mean value: 12849.57kg/m³
COV : 0.159

Influence of the modulus of elasticity on the required rotation

- Evaluation of the differential equation



$$w''_{(x)} = \frac{M_{(x)}}{(EI_{eff})_{(x)}}$$

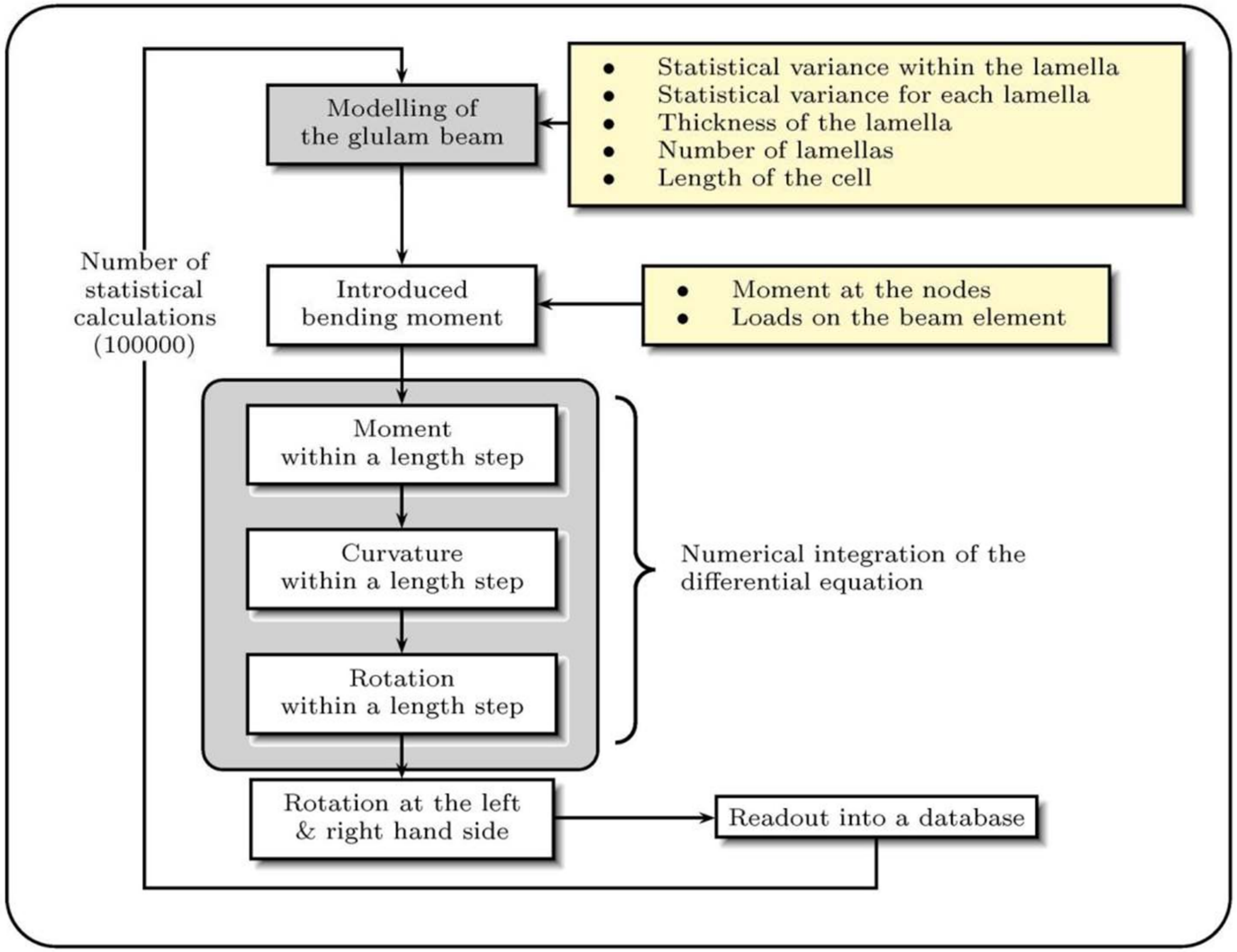
- Beam model with a scattering modulus of elasicity

$$w_{(x)} = \phi_{(x)} = \int \frac{M_{(x)}}{(EI_{eff})_{(x)}} dx + C_1$$

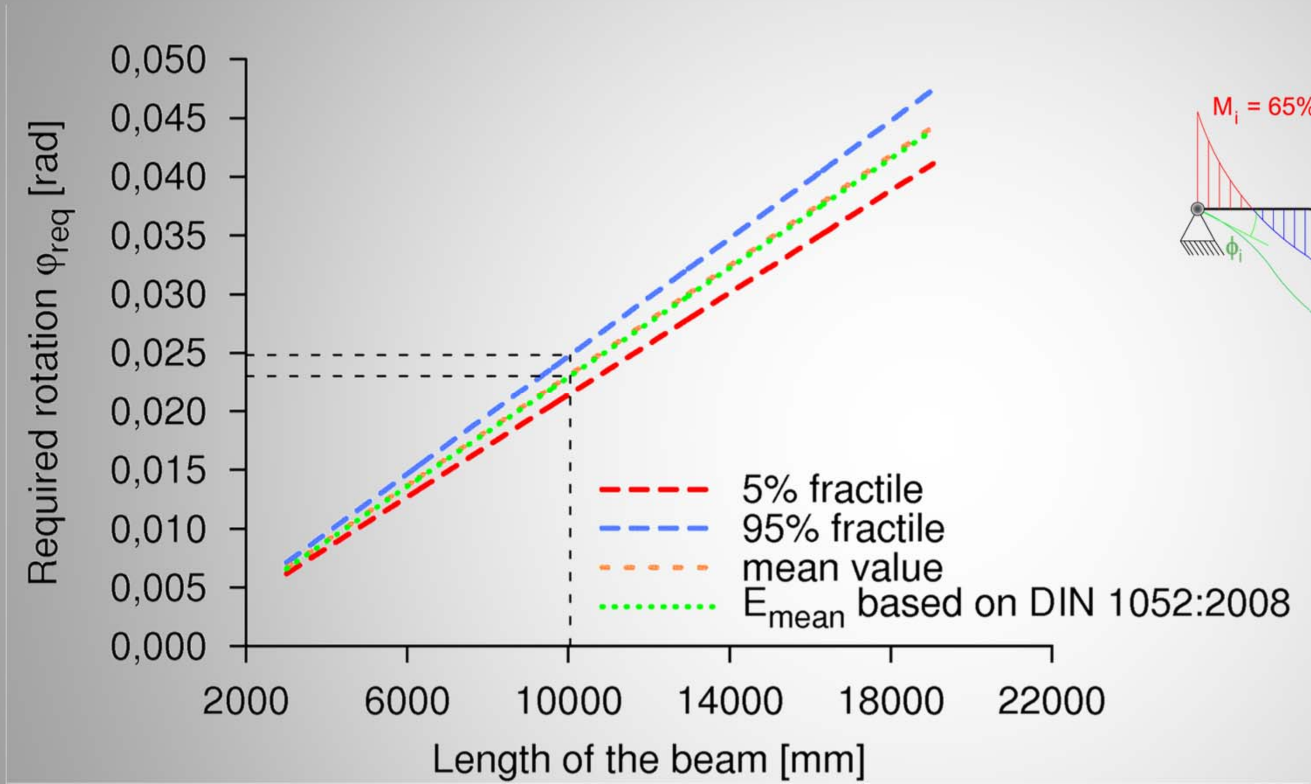
$$w_{(x)} = \int\int \frac{M_{(x)}}{(EI_{eff})_{(x)}} dx\, dx + C_1 x + C_2$$

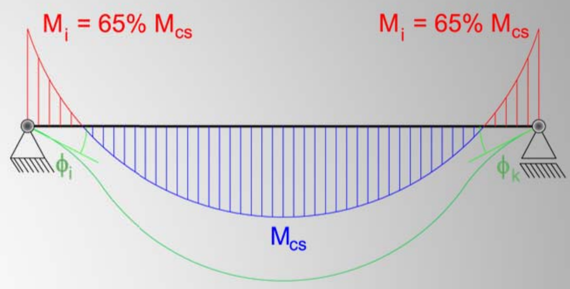
- Investigation based on the *Karlsruher model*
  - Division of the beam into 150mm long cells
  - Assuming scattering of the modulus of elasticity within each lamella and between each lamella
  - Determination of the minimum required rotation

Influence of the modulus of elasticity on the required rotation



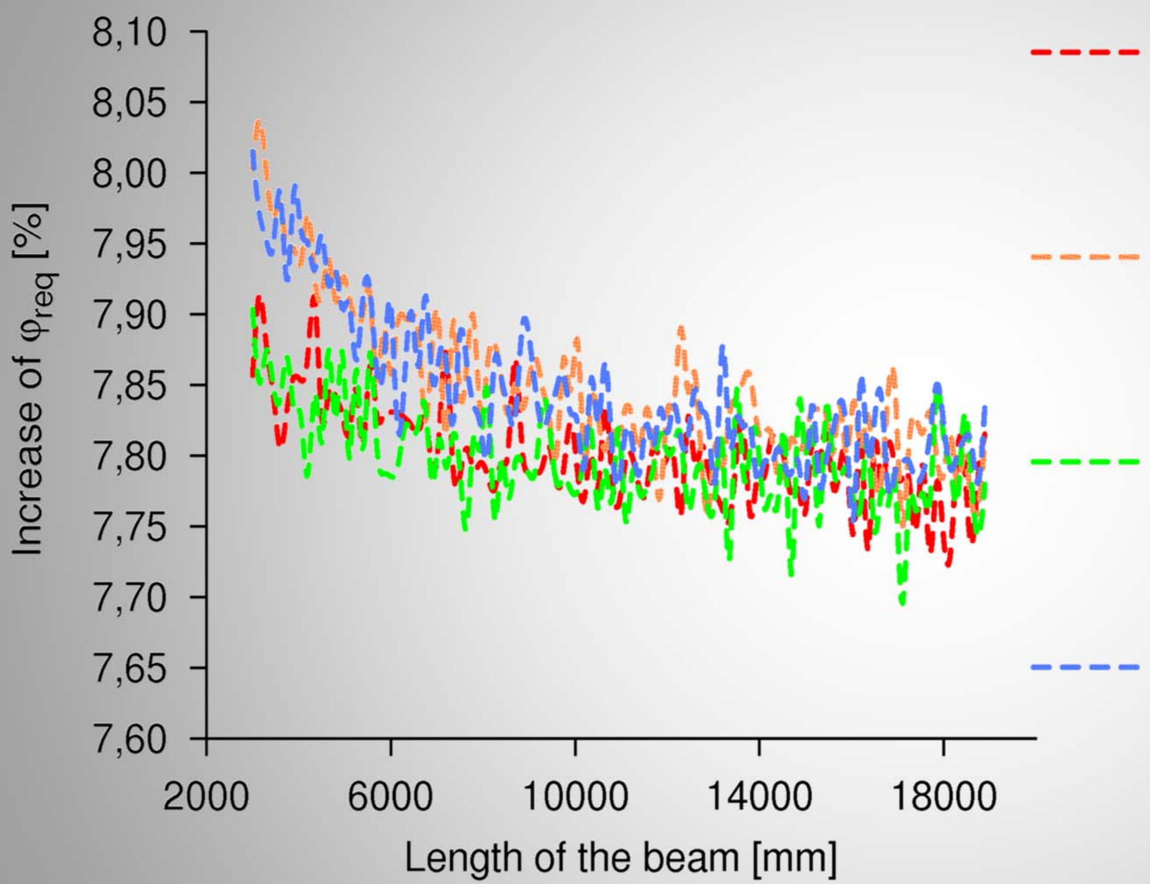
Influence of the modulus of elasticity on the required rotation

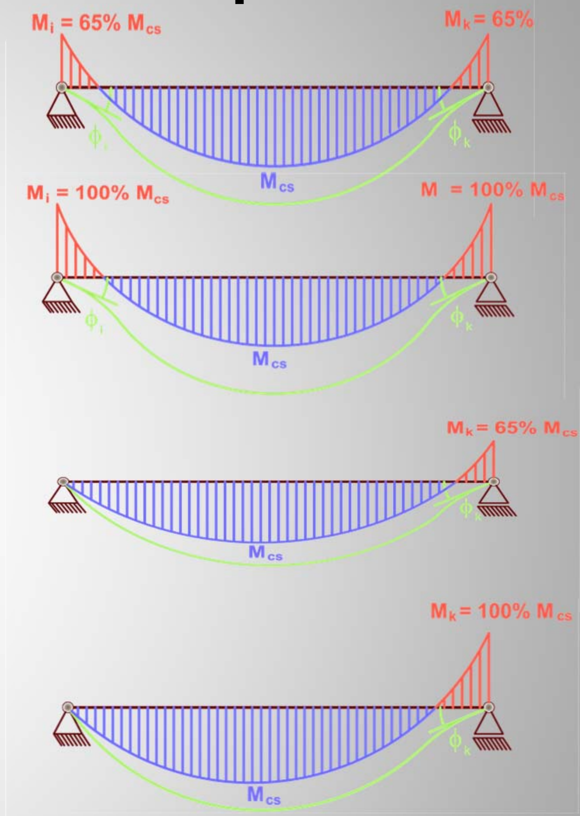




- Verification of the computer program
  ➡ Mean value of the calculation is identical with the calculation based on $E_{0,mean}$
- For a beam (GL24h) with a length of 10m the required rotation increases by approximate 8% due to the scattering of the modulus of elasticity

Influence of the modulus of elasticity on the required rotation



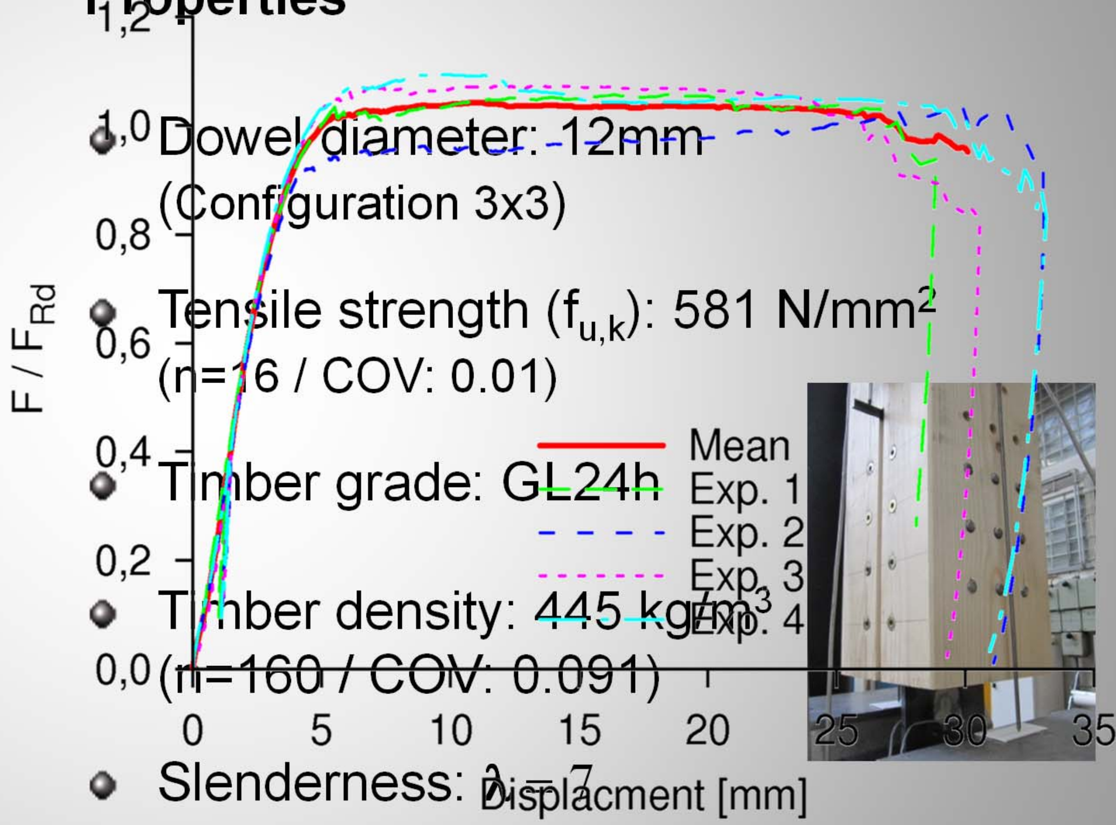


$$k_{mat} \cdot \varphi_{req} \leq \varphi_{con}$$
$$k_{mat} = 1{,}10$$

Ductile behavior of joints

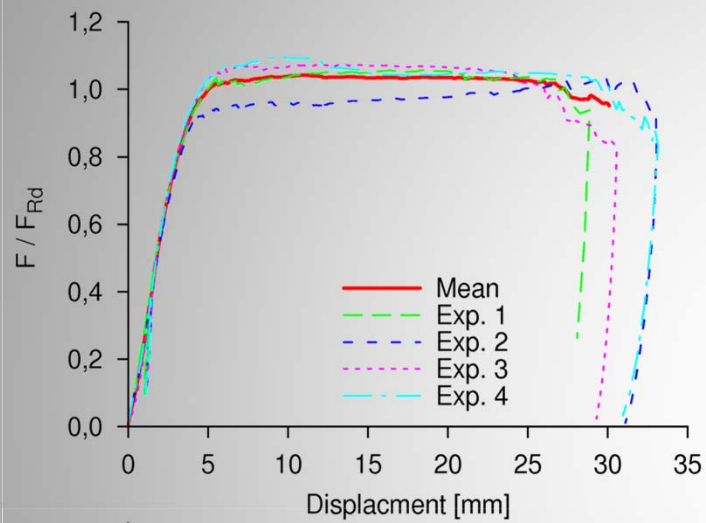
Properties

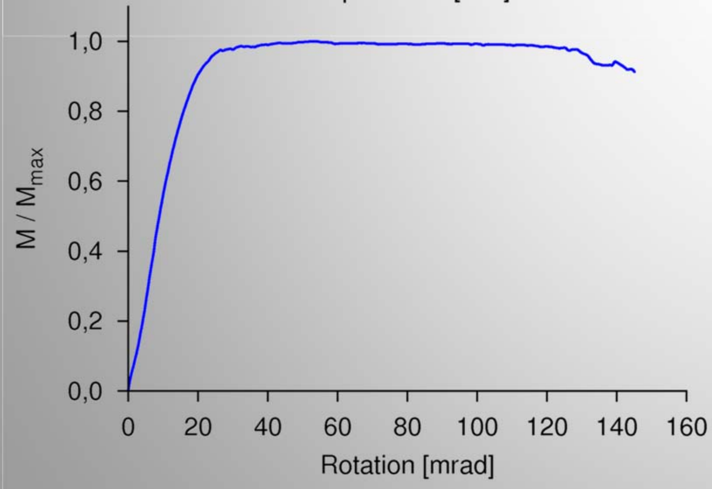
- Dowel diameter: 12mm (Configuration 3x3)
- Tensile strength ($f_{u,k}$): 581 N/mm²
  (n=16 / COV: 0.01)
- Timber grade: GL24h
- Timber density: 445 kg/m³
  (n=160 / COV: 0.091)
- Slenderness: λ = 7
- Reinforced connection

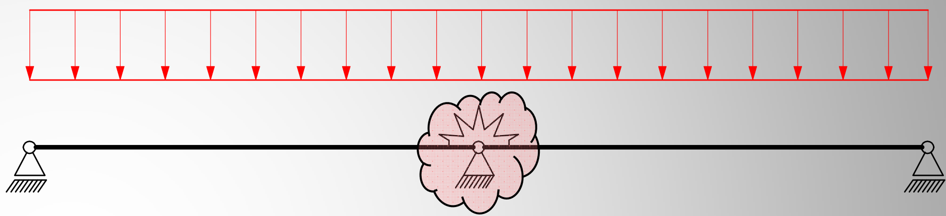


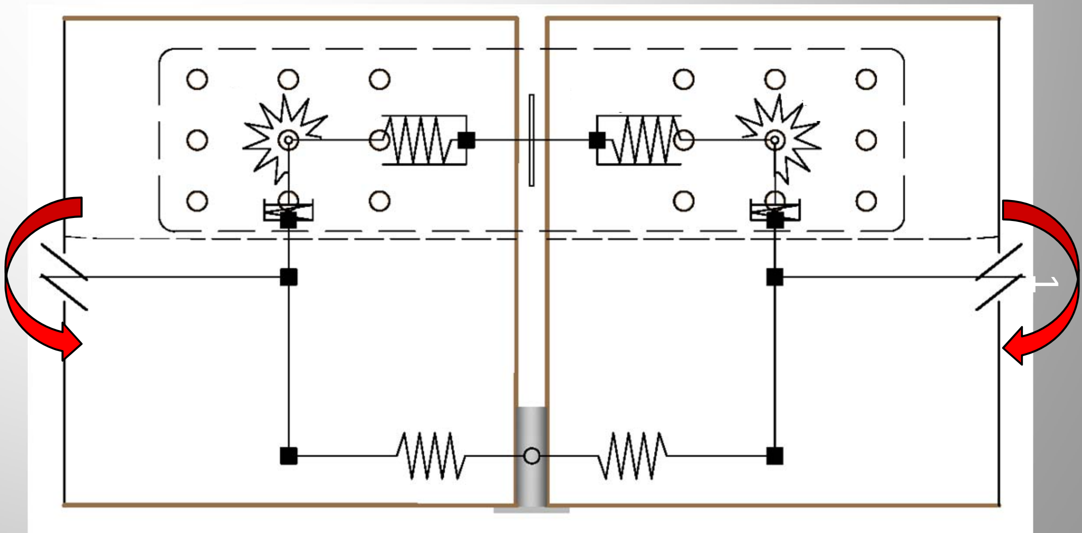
Tension test of a dowelled type connection

Plasticity by implementing ductile joints

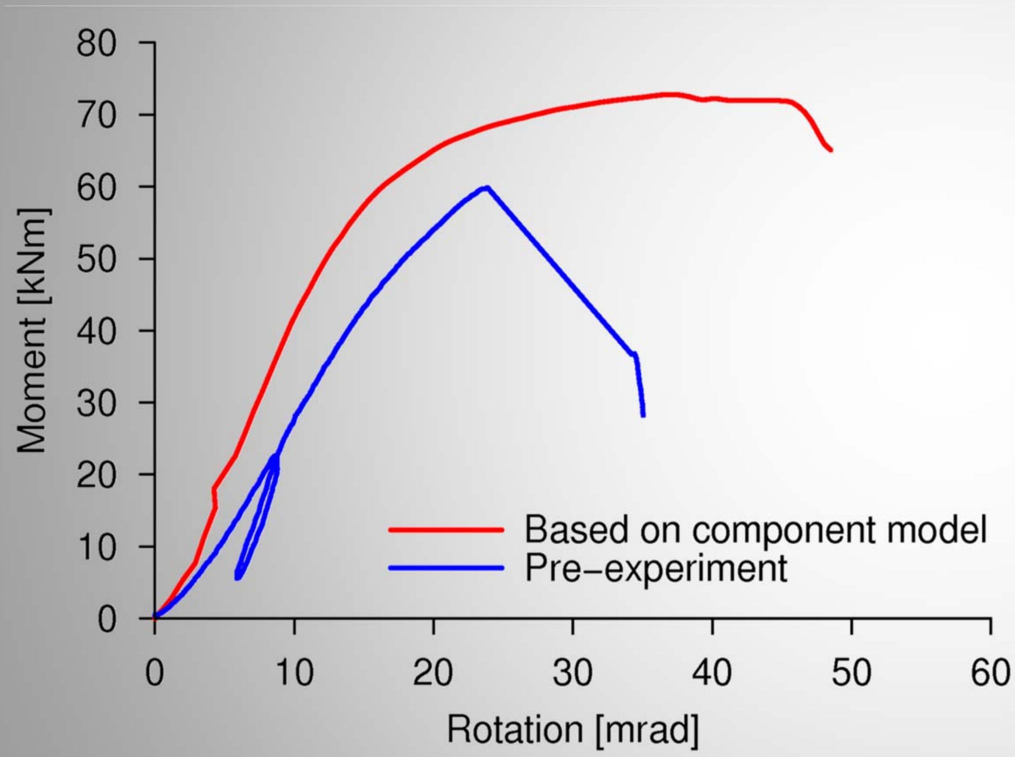








Pre-test

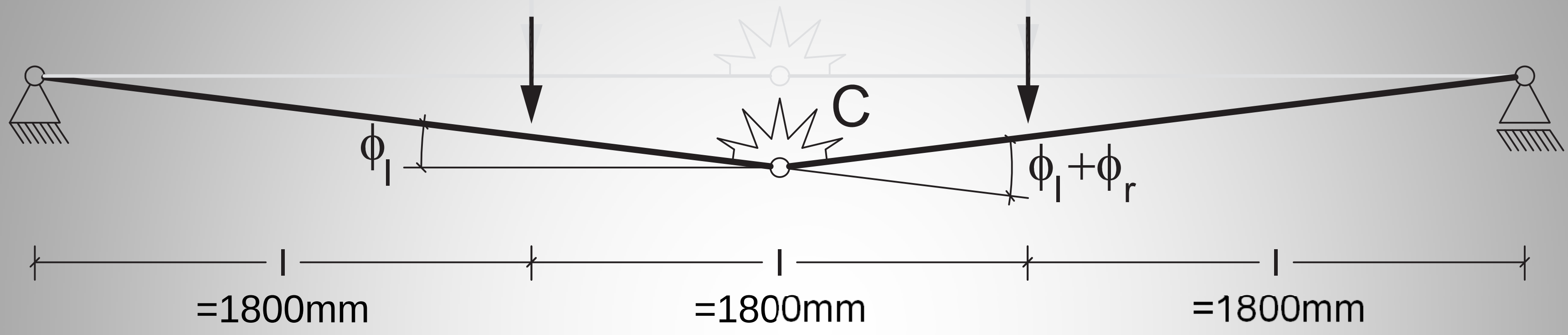


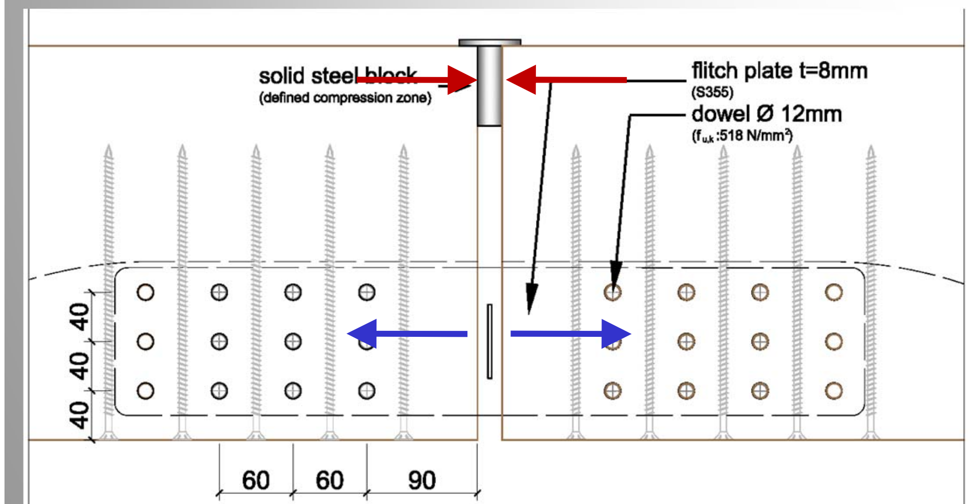
Gained knowledge due to pre-tests

- The compression zone has an influence on the stiffness.
- Occurence of tension perpendicular to the grain, due to the joint rotation.

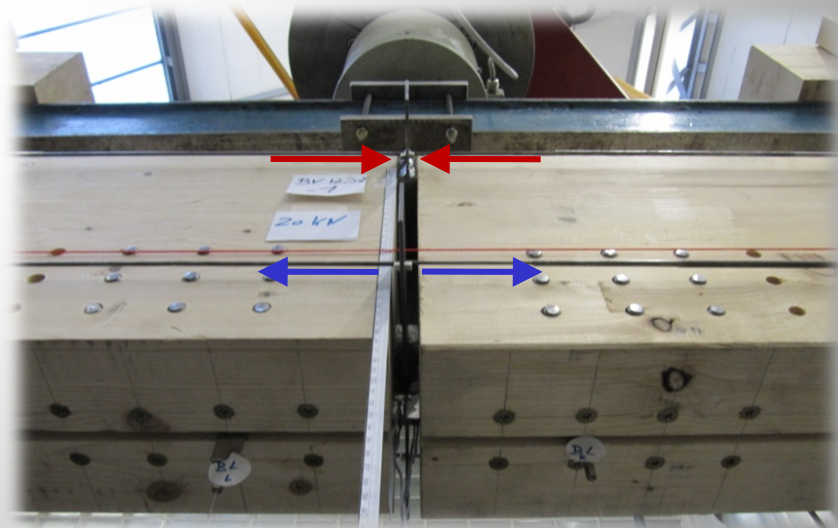
Rotation capacity

Test setup





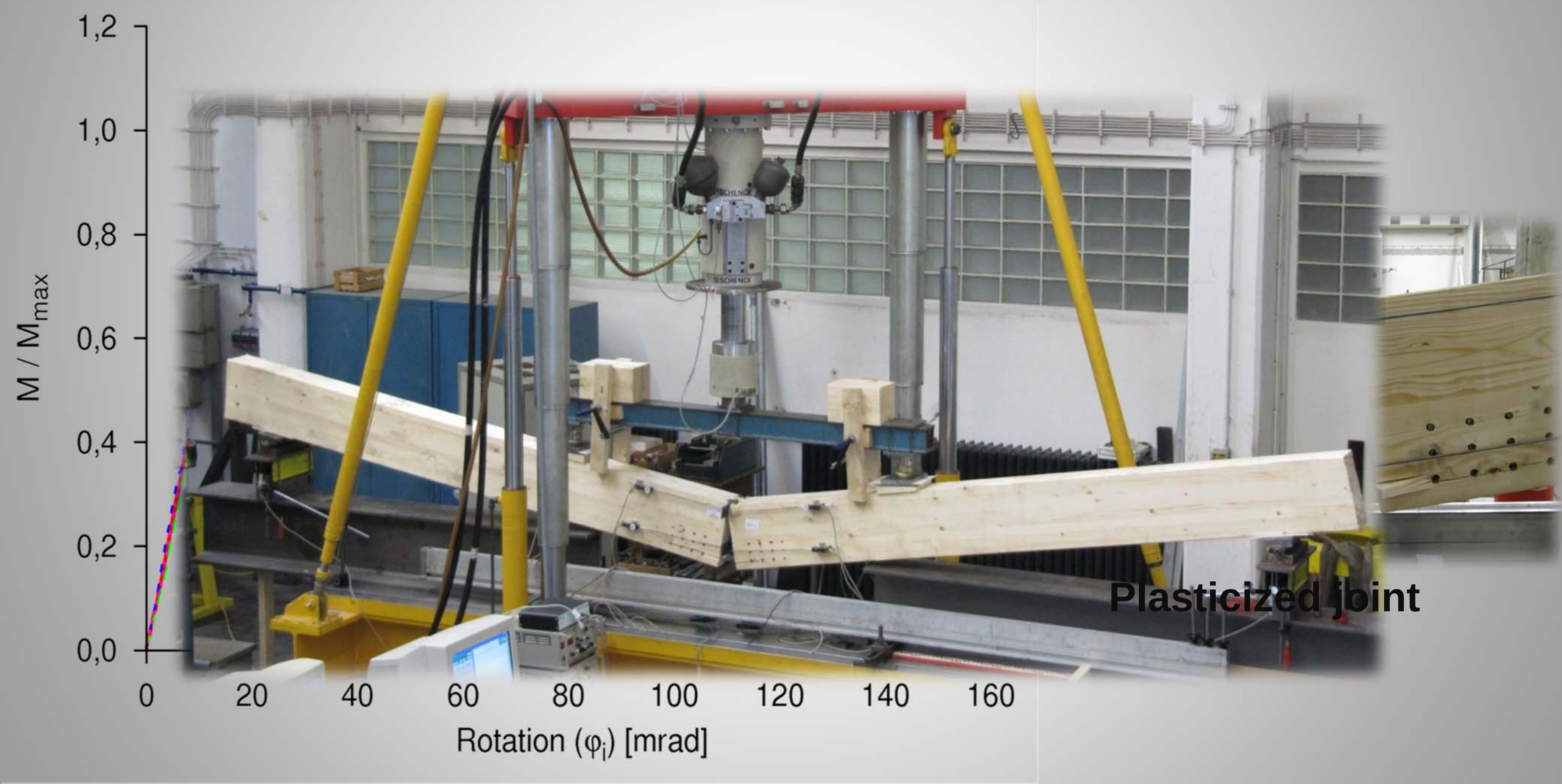
Revised draft of the joint



Joint in the Test setup

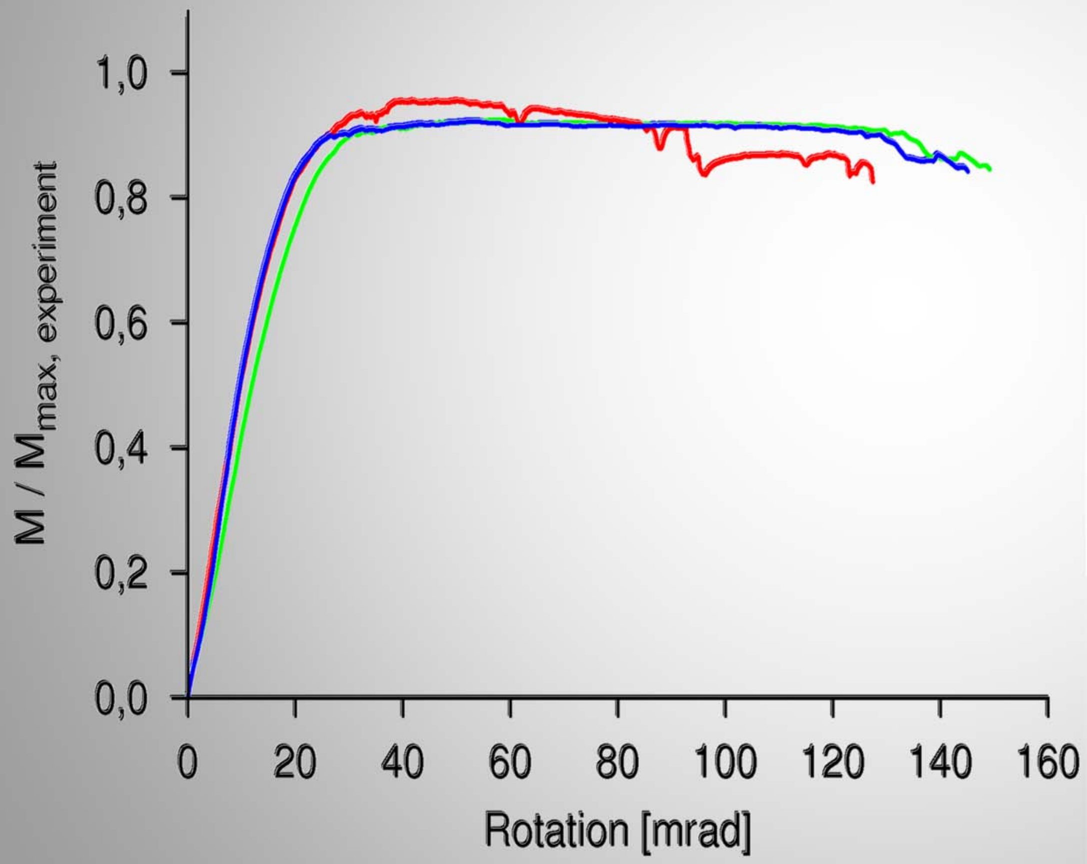
Rotation capacity

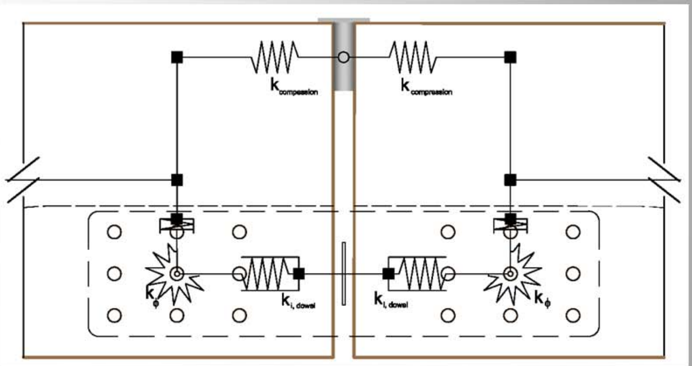
Test setup



Rotation capacity

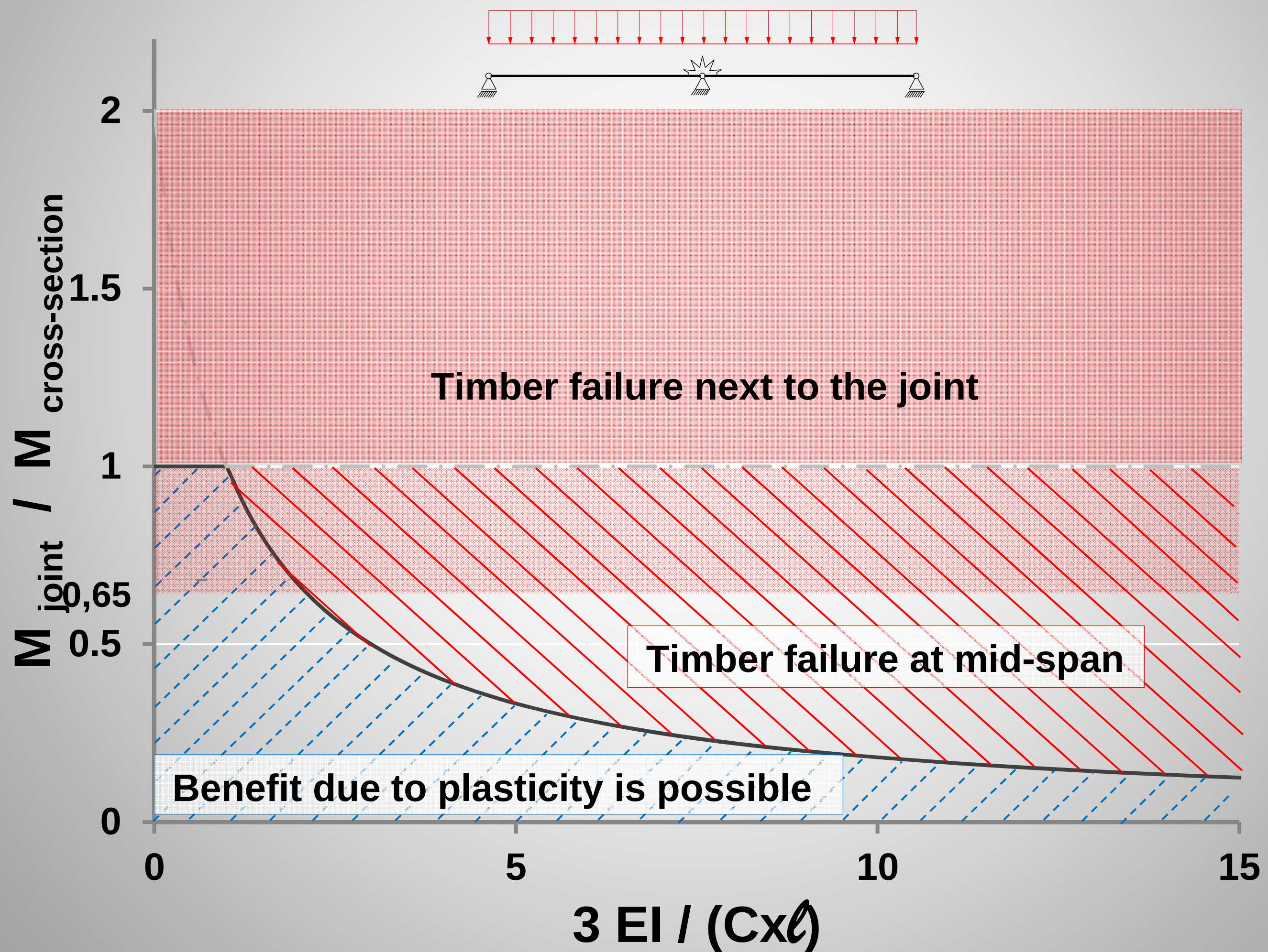
First veryfication of the component model



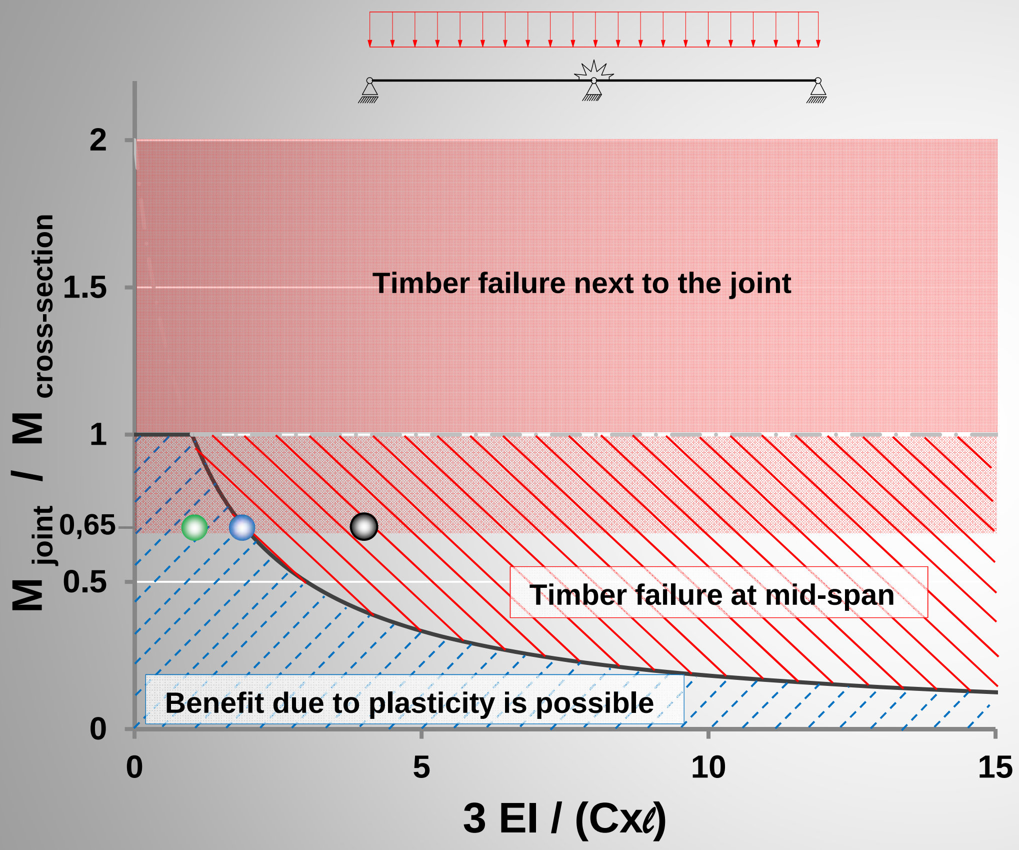


Joint Stiffness

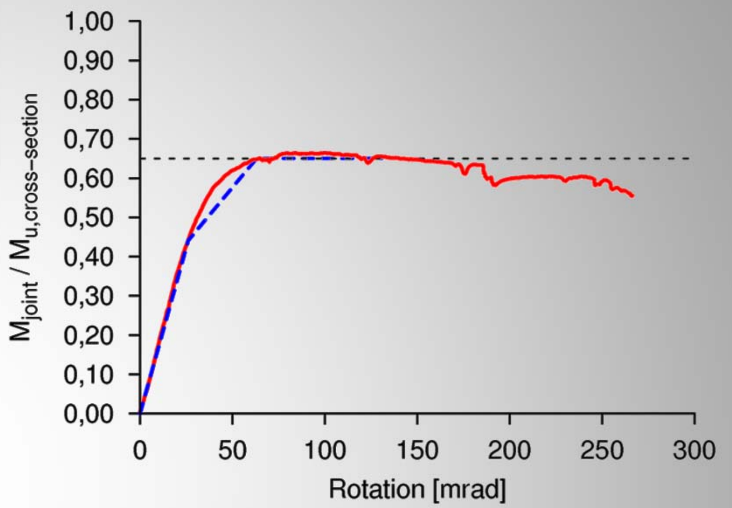
Minimum stiffness of the joint (two-span beam)



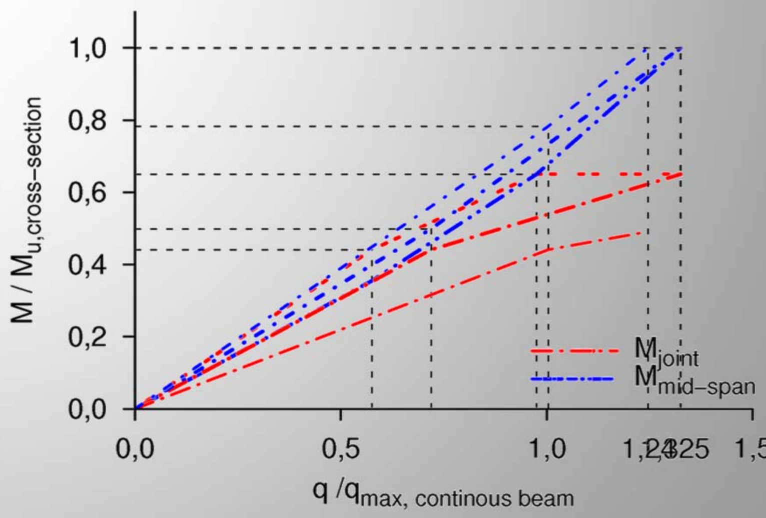
Joint Stiffness



Joint behavior



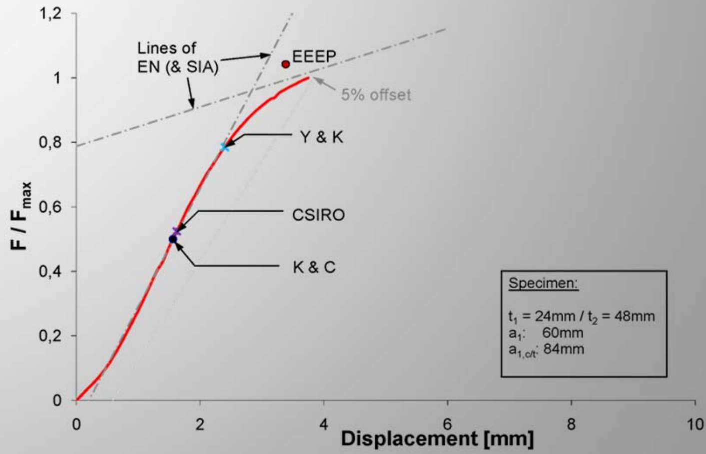
Moment distribution



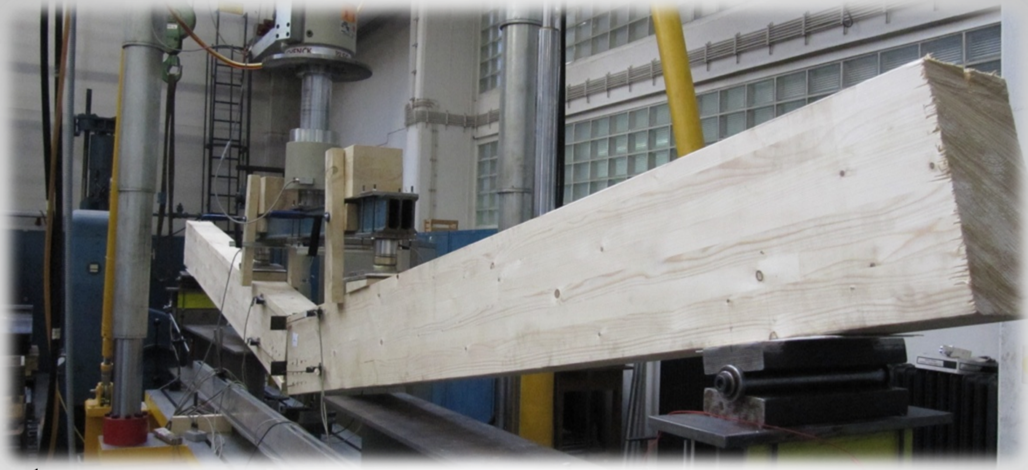
Summary / Outlook

- Reinforced dowelled typ fasteners show a significant ductile behavior.
- Scattering of the modulus of elasticity has an influence of the required rotation (φ_{req}).

- Influence of the scattering of the density on the bearing resistance.
- Proof of a possible component model to develop the moment – rotation behaviour of connections.
- Evaluation of the ductility is required.



Thank you for your attention



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Further thank to

AiF Ideen eine Zukunft geben

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