Timber-Concrete Composites Slabs

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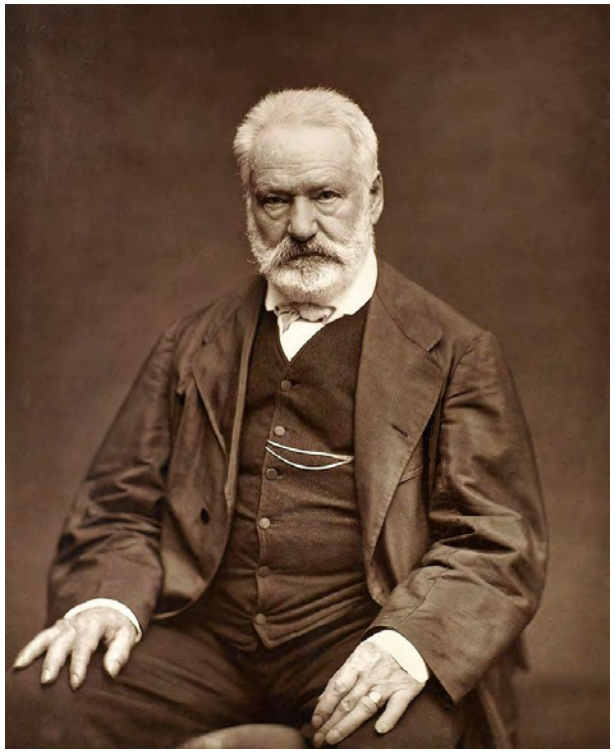
Nothing is as powerful as an idea whose time has come
(Victor Hugo)



Content

- Point of departure
- Materials
- Connections
- Local Behaviour
- Global Behaviour
- Long Term Behaviour
- Prefabrication
- Relied Issues

Point of departure

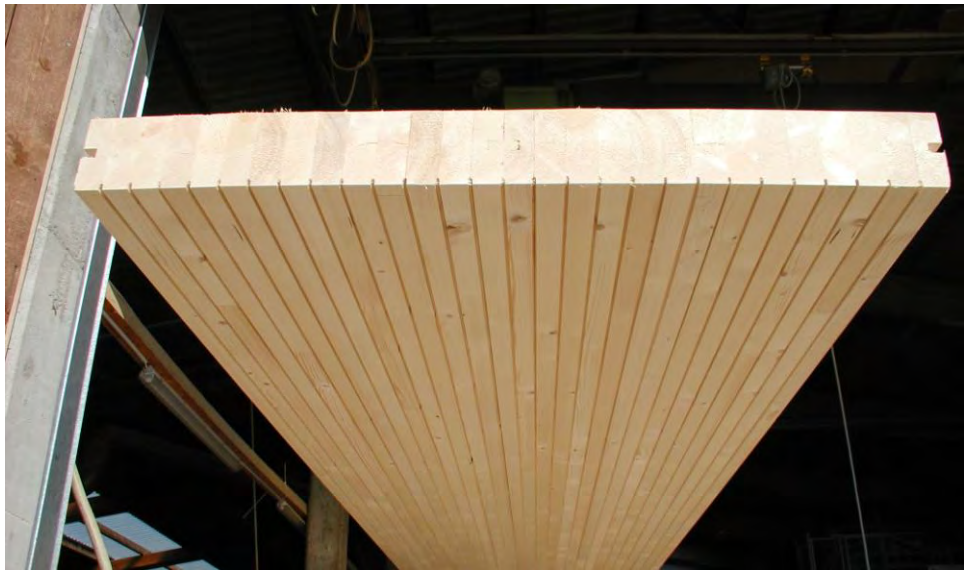
- Low competitiveness of the construction method
- Difficult connectors
- No link between overall conditions (vibration, acoustic) and static requirements
- Humidity (dry construction side)
- Acceleration of execution

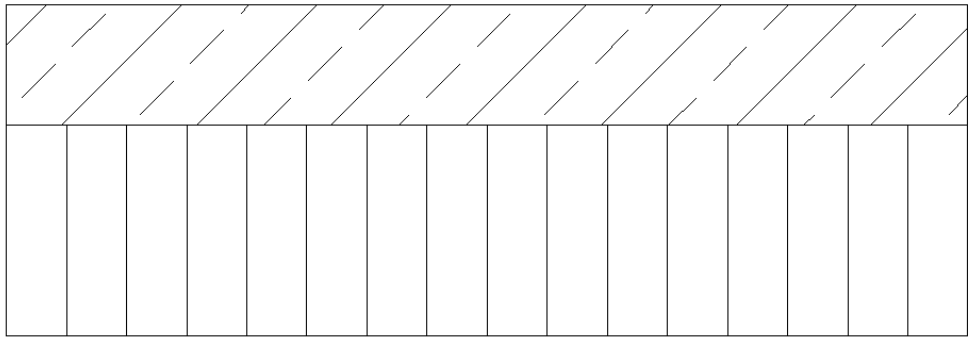
Targets

- Simple connectors
- Quality controlled materials
- Industrial production
- Dry construction side
- High properties in use

Materials

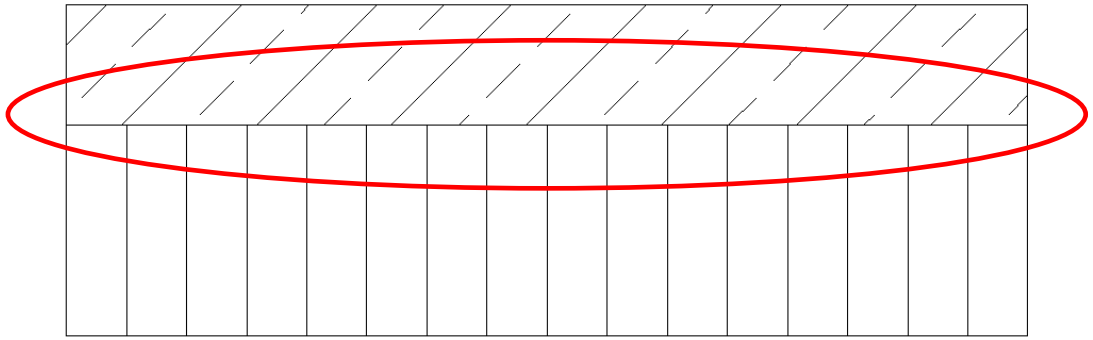
- Glulam panel in horizontal position
- Reinforced concrete (steel-bars or fibres)
- Industrial fabrication of connectors



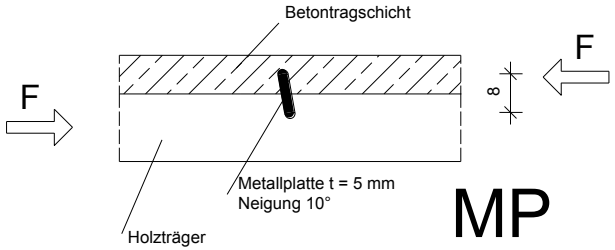


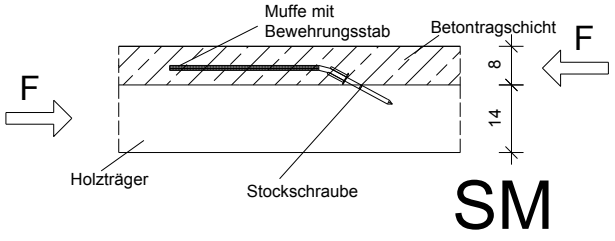
Materials

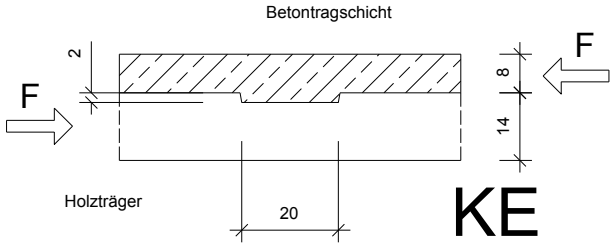
- Glulam panel in horizontal position
- Reinforced concrete (steel-bars or fibres)
- Industrial fabrication of connectors

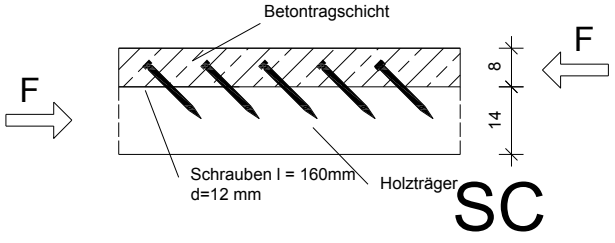


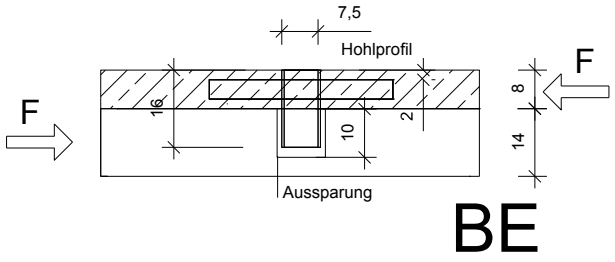
Test series connector

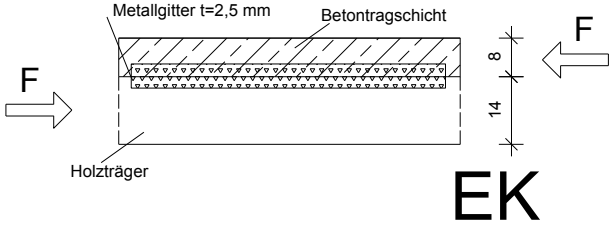




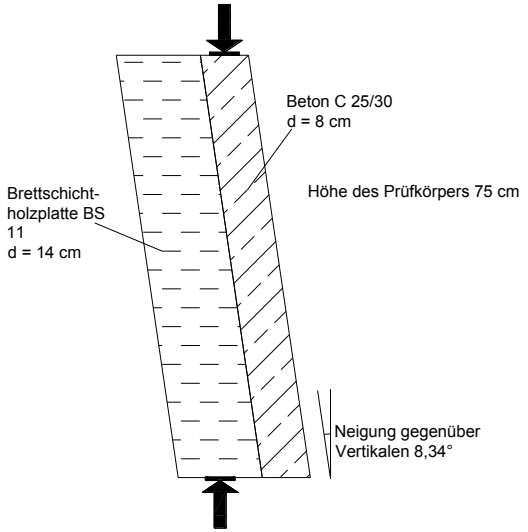


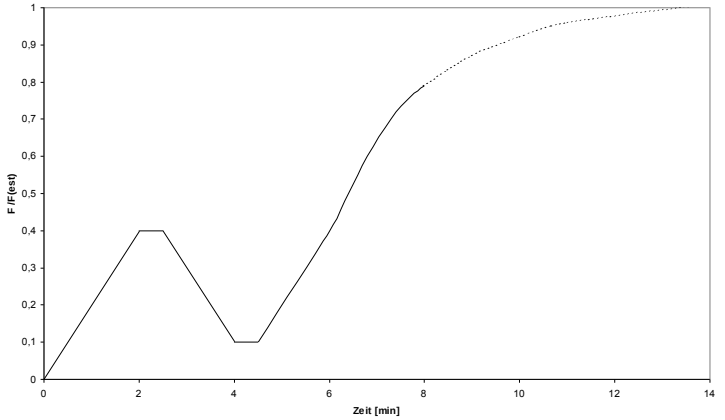




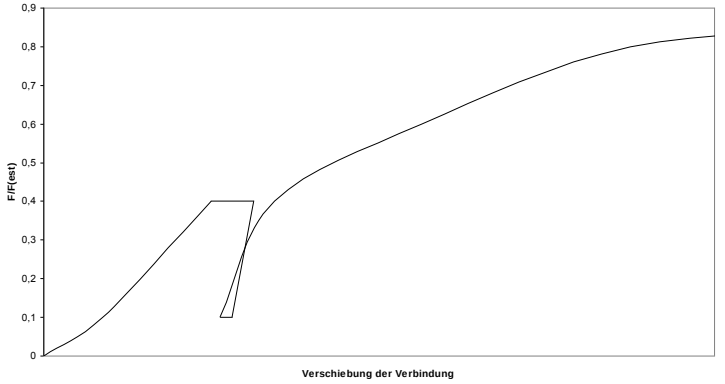


Test methods

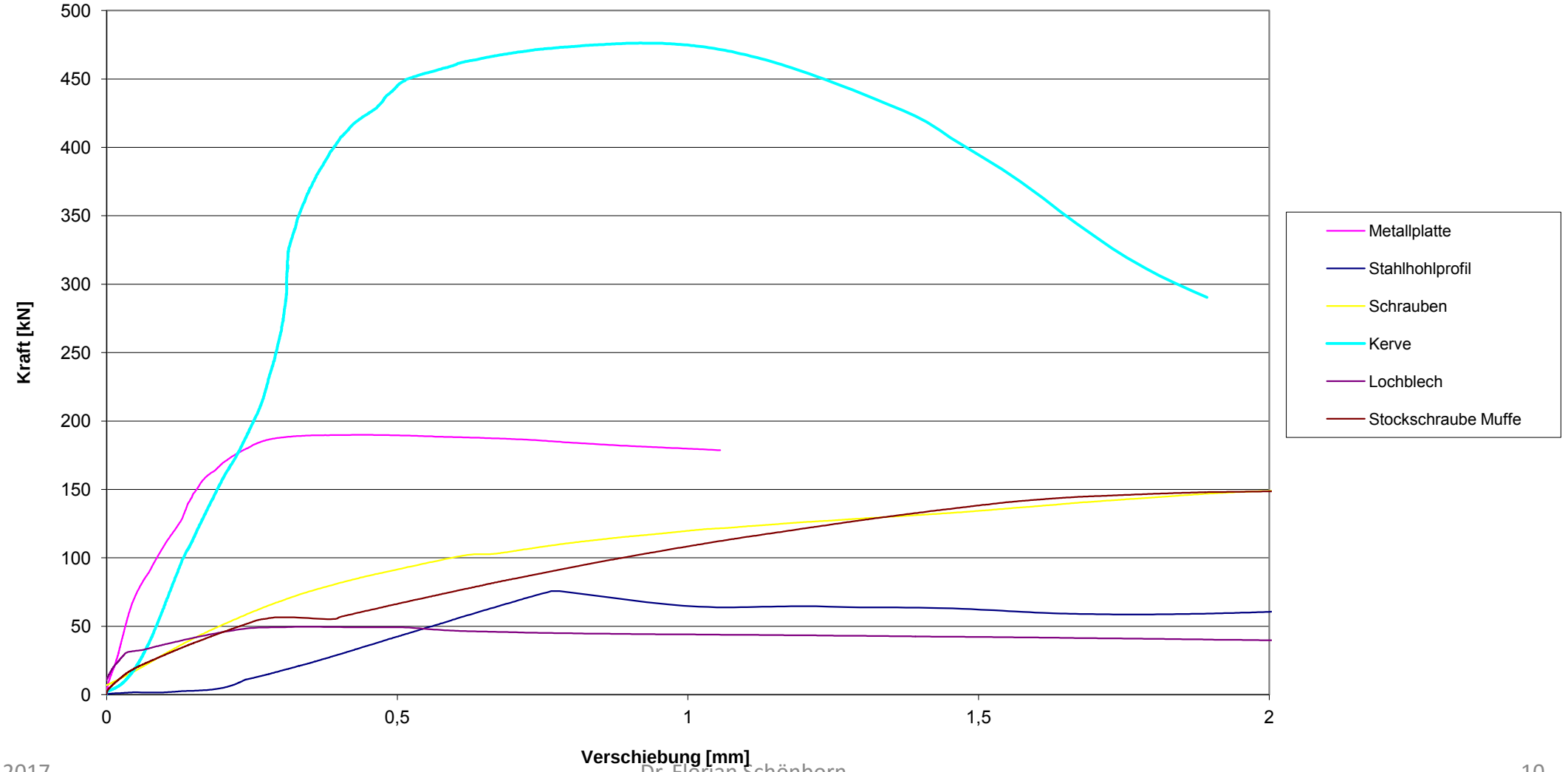




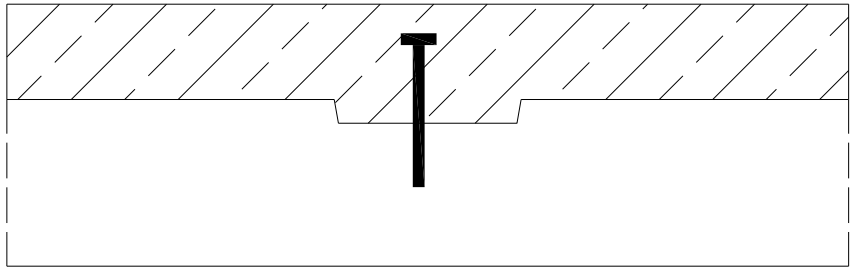
Idealisierte Last-Verschiebungskurve



Results

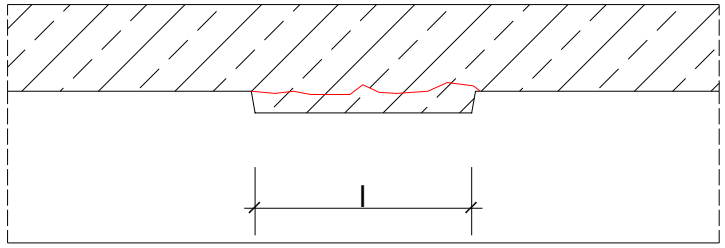

500
450
400
350
300
250
200
150
100
50
0
Kraft [kN]
0
0,5
1
1,5
2
Verschiebung [mm]
Metallplatte
Stahlhohlprofil
Schrauben
Kerve
Lochblech
Stockschraube Muffe

Notches - Grooves

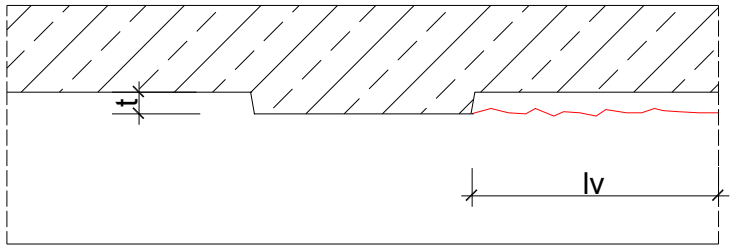


- High stiffness
- 4 Failure loads
- Ductile failure mode
- Screw not for static reasons (for the effect of shrinkage)
- K_s= 1135 MN/m per m (SLS)
- K_s= 2/3 K_s= 757 MN/m per m (ULS)
- $K_{s,0,05}$ = 424 MN/m per m

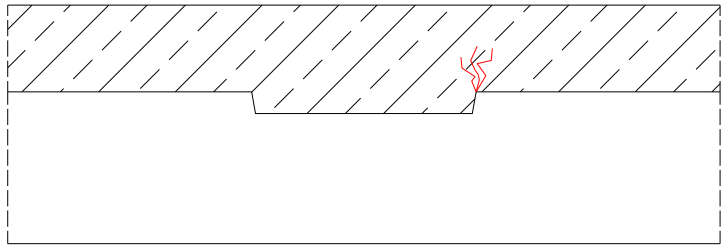
Failure Modes



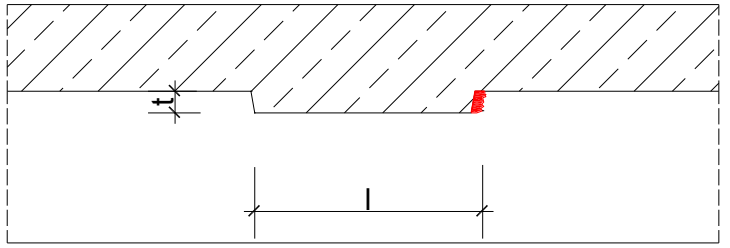
Shearing of concrete



Timber snatch-off



Cracking of concrete



Crushing of timber

Failure Modes

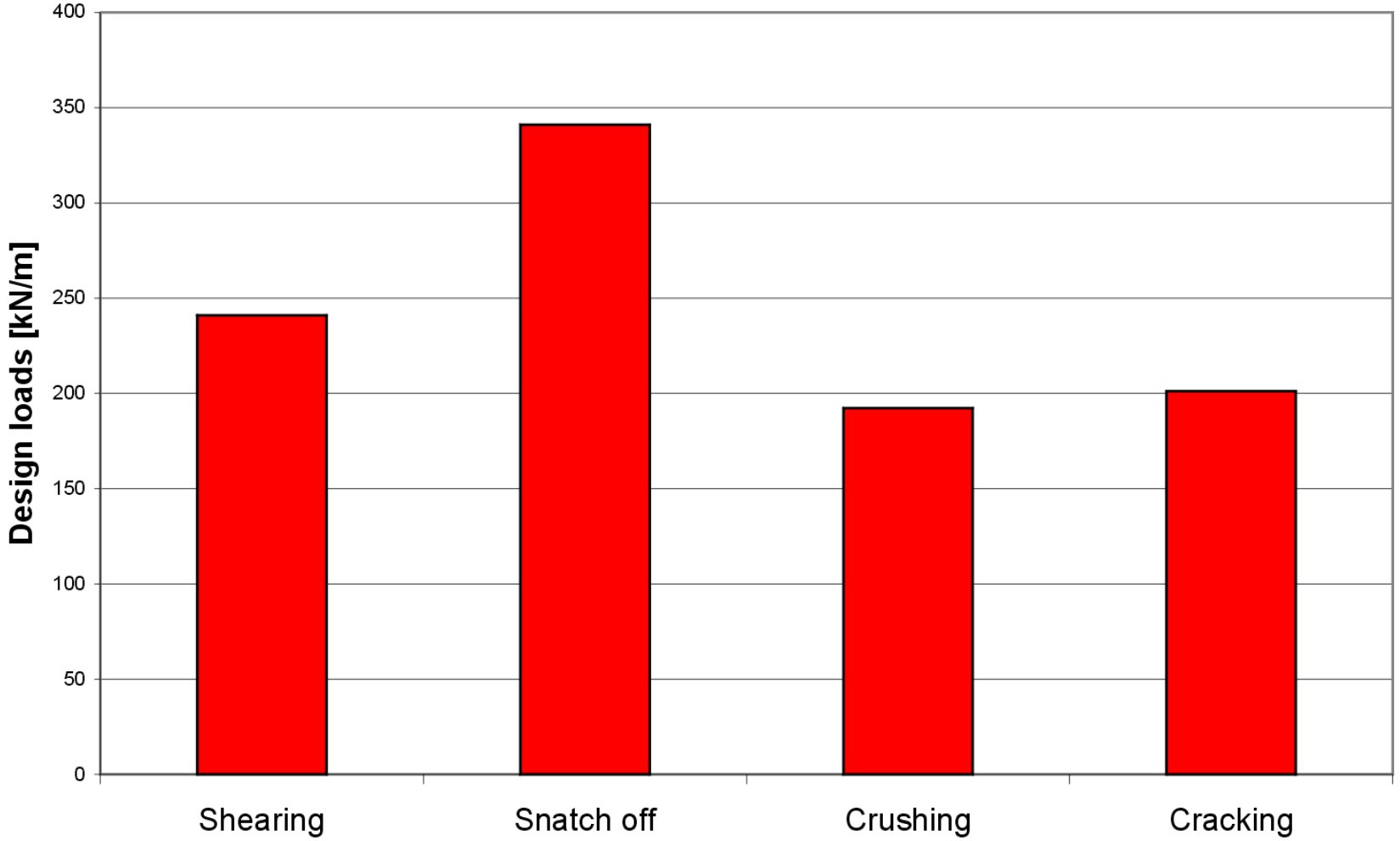
Shearing of concrete

Timber snatch-off

Cracking of concrete

Crushing of timber

Design Loads



Calculation Formular

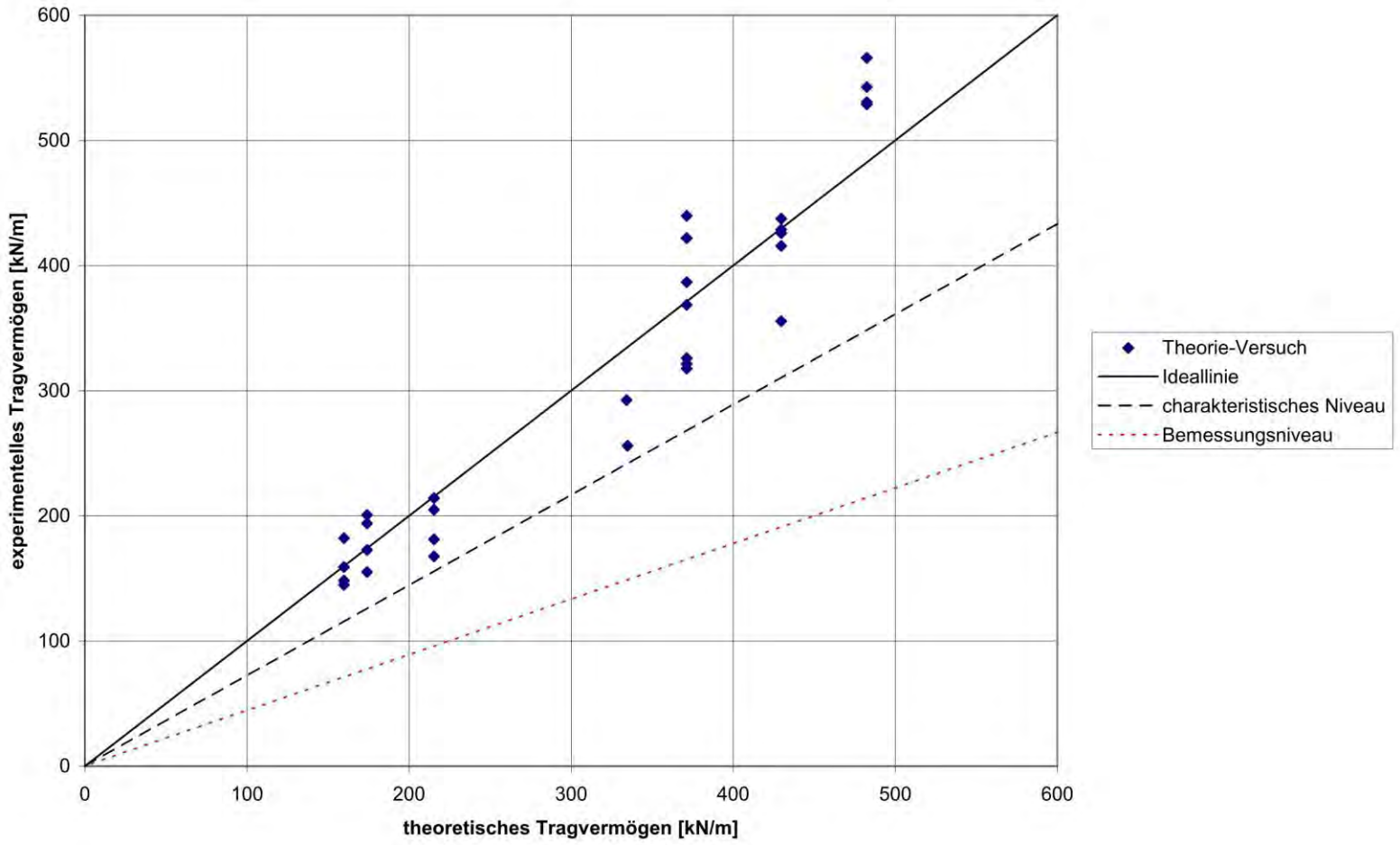
Shearing: $F_{Rd} = 2{,}55 \cdot 2, 4 \cdot A_h \cdot \tau_{Rd}$

Snatch-off: $F_k = 1 \cdot b_v \cdot t_v \cdot 8 \cdot f_{v,k}$

Crushing: $F_k = 1{,}2 \cdot A_{Connection} \cdot f_{c,a,d}$ ka

Cracking: $$F = 2{,}25 * t * b * f_{ck}^{2/3} * \frac{l}{180}$$

Calculation Formular – Crushing



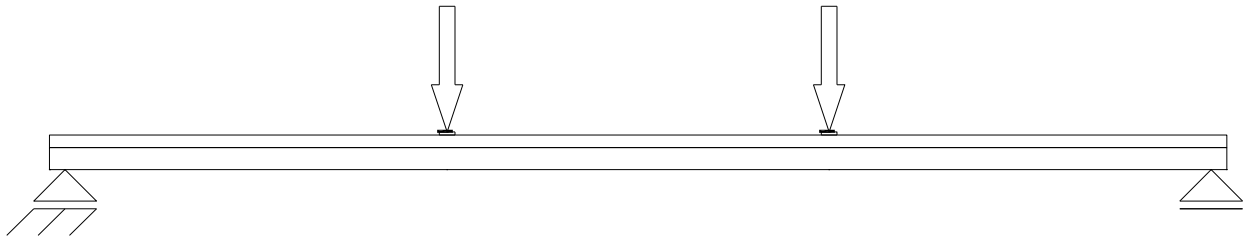
Calculation Formular – Results for design

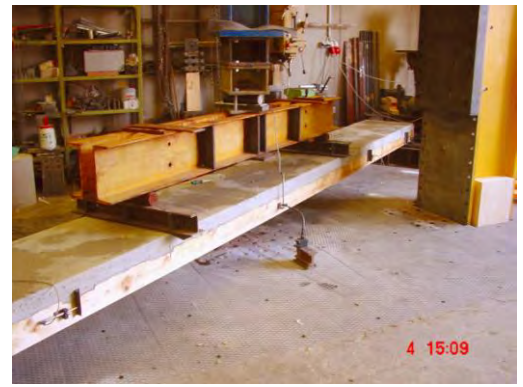
- Concrete: C 25/30 or better
- Length: 13 cm .... 20 cm
- Distance: $l_v + 12{,}5 * t_v$
- Angel: 5° ... 20°
- Depth: t_v = 20 mm ... 25 mm

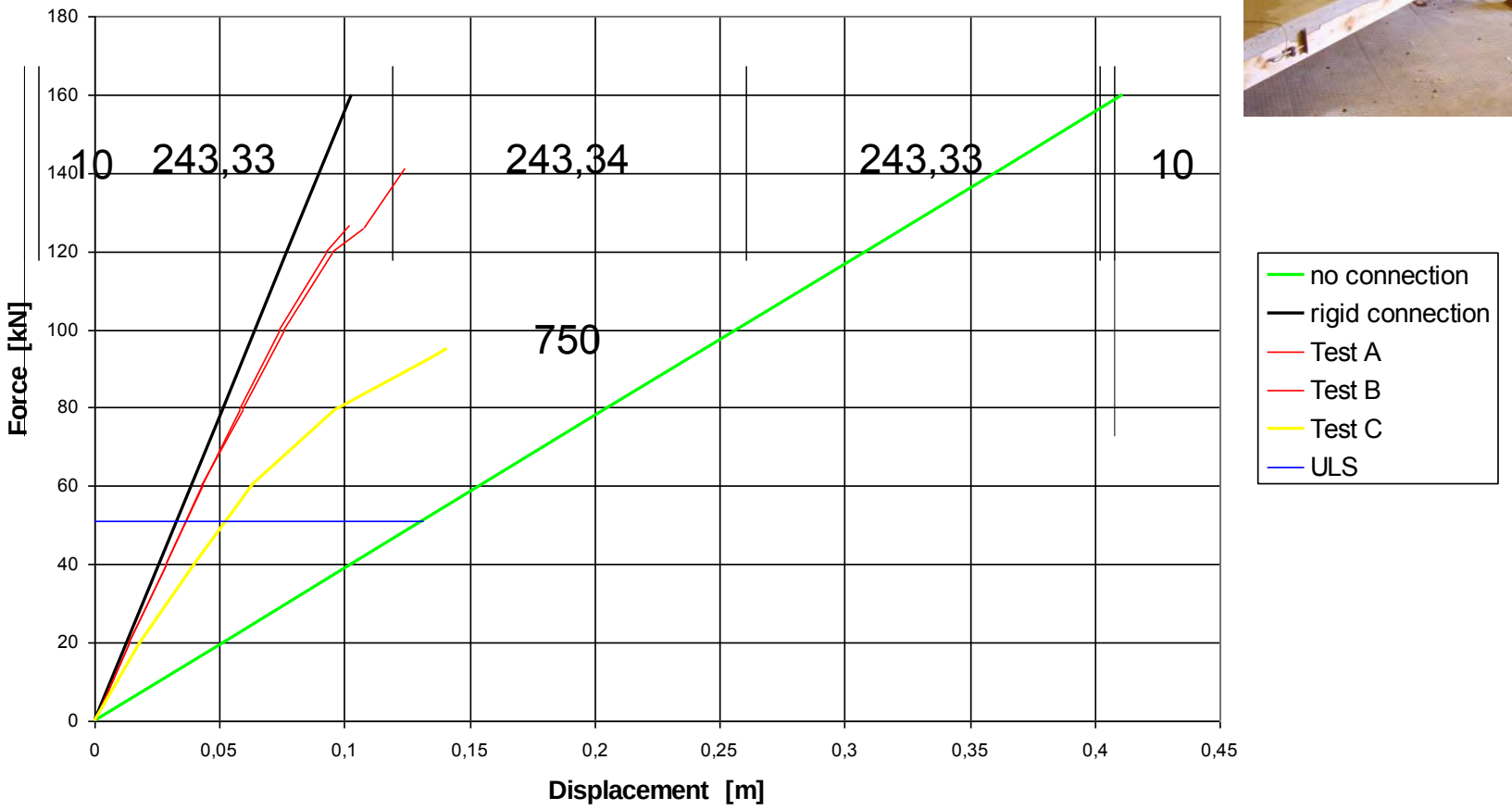
Gobal Behavoir:Bending tests - aims

- Rely local and global behaviour
- Analyse global failure
- Detect slenderness ratio
- Find ideal position of connectors
- Determine rules for a simplified calculation

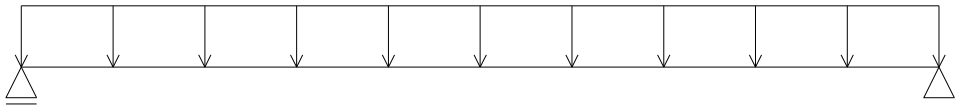
Bending Tests



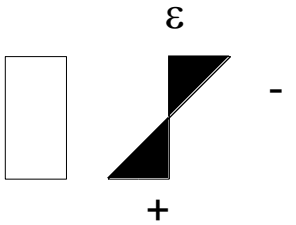




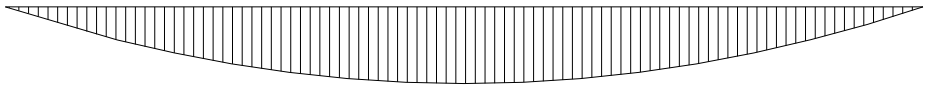
Mechanics



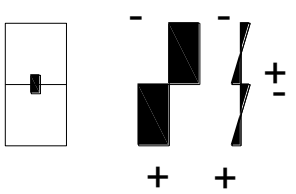
Gesamtquerschnitt:



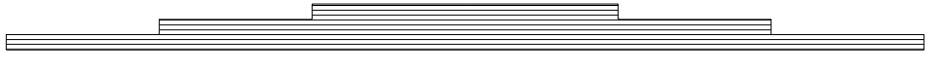
M:



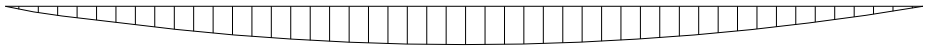
Teilquerschnitte:



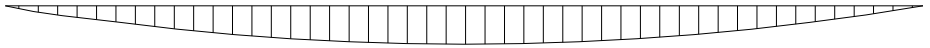
N:



M:



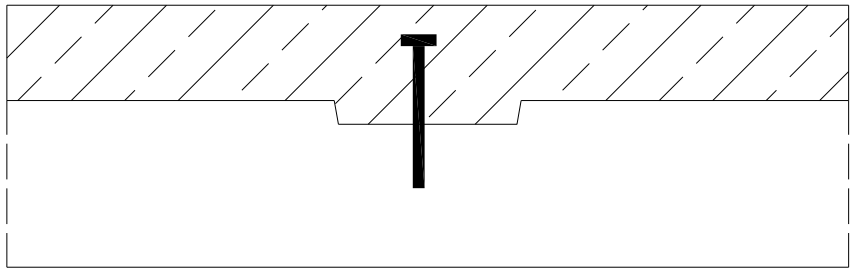
M:

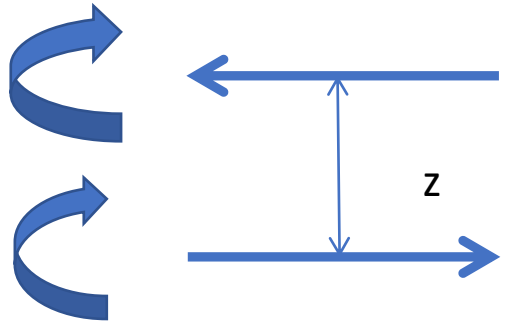


N:

Simplified Calculation

M_d





$$N_d = Y * \frac{M_d}{0{,}5 * (h_{concrete} + h_{Timber})}$$

$$EI_{rigid,\ t=0} = \Sigma\ (E_i I_i + E_i A_i * a_i^2)$$

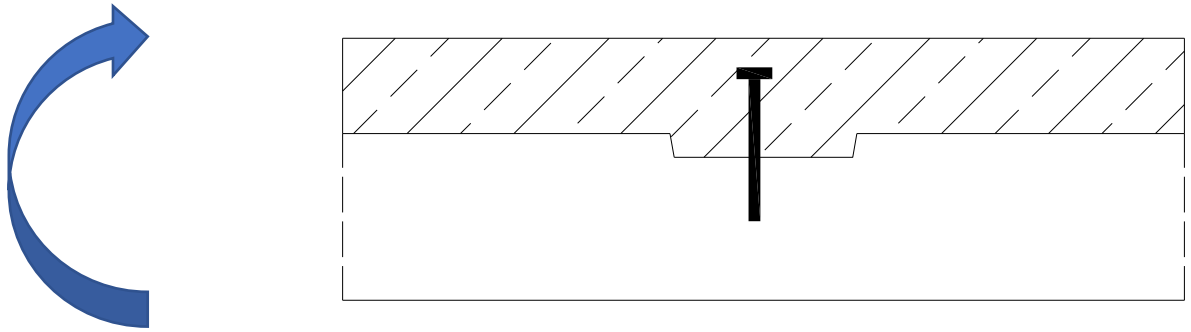
$$EI_{tc} = X * EI_{rigid}$$

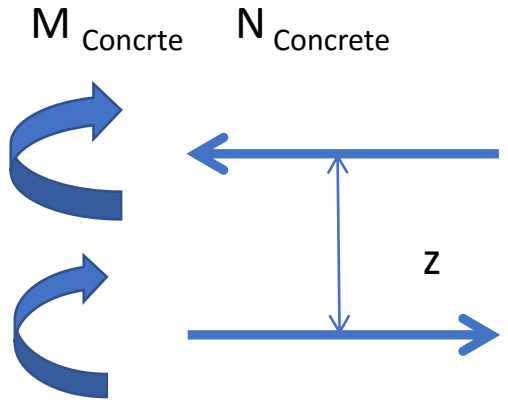
$$M_{d,Timber} = (1-Y) * M_d * \frac{EI_{Timber}}{EI_{Timber} + EI_{Concrete}}$$

$$M_{d,Concrete} = (1-Y) * M_d * \frac{EI_{Concrete}}{EI_{Timber} + EI_{Concrete}}$$

Simplified Calculation

M_d





$$N_{groove,max} = \frac{N_{Desing}}{n_{grooves}} * 0,8264 * e^{0,0011 \cdot l}$$

Calculation Formular - Bending (t= 0)

$EI_{rigid,\ t=0} = \Sigma\ (E_i I_i + E_i A_i * a_i^2)$

$EI_{tc} = 0{,}9 *\ EI_{rigid}$

$$w_{t=0} = \frac{5 * q * l^4}{384 * EI_{tc,t=0}}$$

$$N_d = 0{,}718 * \frac{M_d}{0{,}5 * (h_{concrete} + h_{Timber})}$$

$$M_{d,Timber} = (1 - 0{,}664) * M_d * \frac{EI_{Timber}}{EI_{Timber} + EI_{Concrete}}$$

$$M_{d,Concrete} = (1 - 0{,}664) * M_d * \frac{EI_{Concrete}}{EI_{Timber} + EI_{Concrete}}$$

Further Issues – long-term behaviour

Calculation Formular – Long term behaviour

Timber: $\varphi = 1{,}8$

Concrete: $\varphi = 2{,}4$

Connection: $\varphi = 1{,}6$

$$E_{Timber,t=\infty} = \frac{E_{Timber,t=0}}{1+\varphi_{Timber}}$$

$$E_{Concrete,t=\infty} = \frac{E_{Concrete,t=0}}{1+\varphi_{Concrete}}$$

$$K_{S,mean,t=\infty} = \frac{K_{S,mean,t=0}}{1+\varphi_{Connection}}$$

Calculation Formular - Bending (t= ∞)

$EI_{rigid,\ t=\infty} = \Sigma\ (E_{i,\ t=\infty}\ I_i + E_{i,t=\infty}\ A_i * a_i^2)$

$$N_{d,t=\infty} = 0{,}671 * \frac{M_d}{0{,}5 * (h_{concrete} + h_{Timber})}$$

$EI_{tc,\ t=\infty} = 0{,}88 * EI_{rigid,\ t=\infty}$

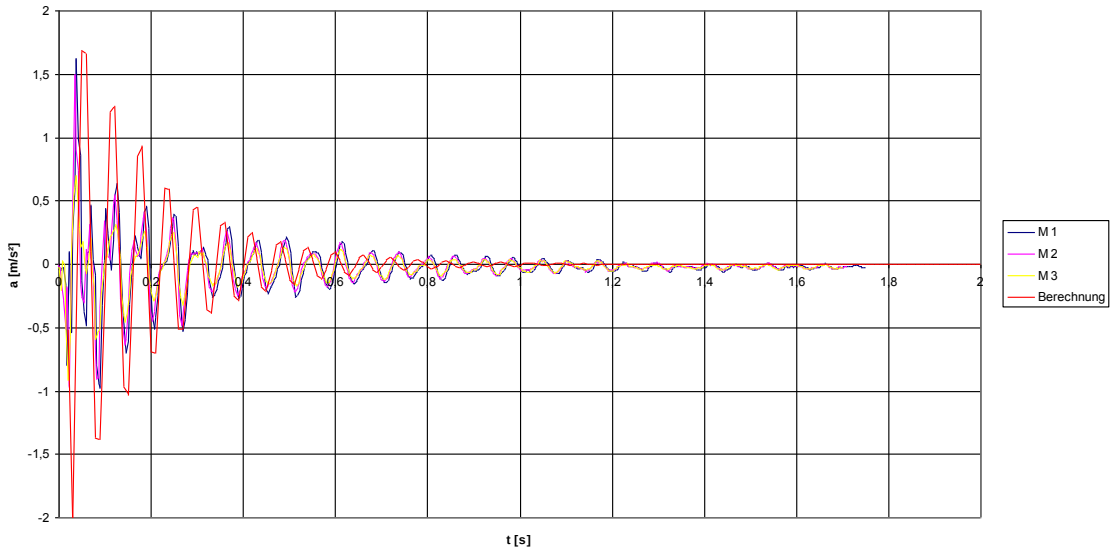
$$M_{d,Timber,t=\infty} = (1 - 0{,}614) * M_d * \frac{EI_{Timber,t=\infty}}{EI_{Timber,t=\infty} + EI_{Concrete,t=\infty}}$$

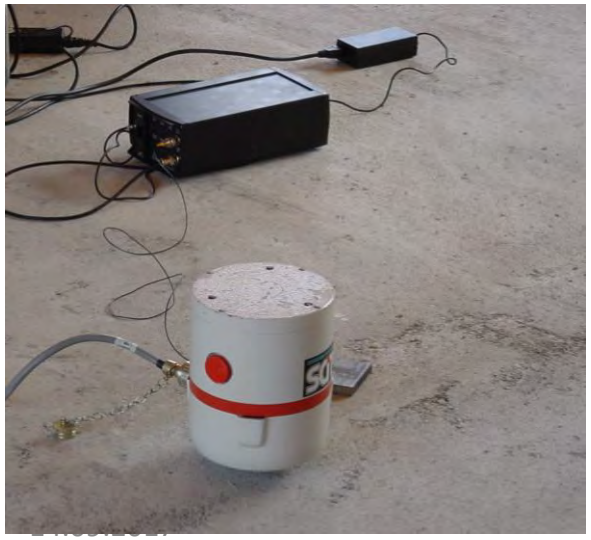
$$w_{t=\infty} = \frac{5 * q * l^4}{384 * EI_{tc,t=\infty}}$$

$$M_{d,Concrete,t=\infty} = (1 - 0{,}664) * M_d * \frac{EI_{Concrete,t=\infty}}{EI_{Timber,t=\infty} + EI_{Concrete,t=\infty}}$$

Dynamic Behavior

g_a +p [kN/m²]	2,5	3	4	5	6	7
slenderness λ= l/d						
Stat. calculation	32	31	30	29	29	28
Dyn. cacculation	30	29	29	29	28	27





Calculation

- Limitation of strains (timber)
- Limitation of strains (tension concrete)
- Check deflection
- Check resistance towards vibrations
- Check stresses on notches

$$h_{total} = \frac{l}{\lambda}$$

$$h_{timber} = 0{,}636 * h_{total}$$

$$h_{concrete} = (1 - 0{,}636) * h_{total}$$

Adivce: Neutral axis shoud be next to the joint

$0,92 \leq h_{concrete} / z_{stotal} \leq 1,08$

z_s: distance between to of section and balance Point (rigid section)

Calculation

Number of grooves:

$n_{Grooves}$ = Integer ($l \cdot 0,006 + 0,99$)
$n_{Grooves}$: Number of grooves (Par support side=
l: Span [cm]

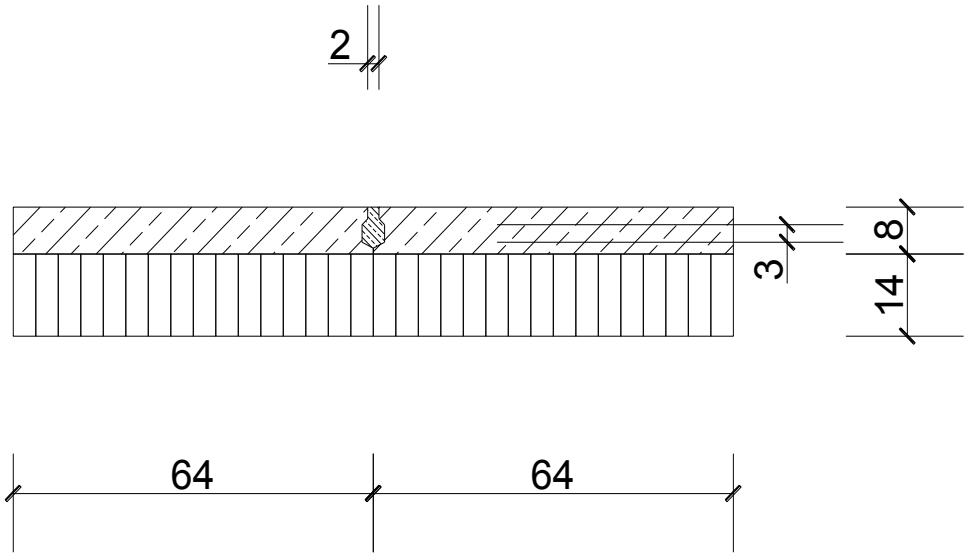
$$N_{groove,\max} = \frac{N_{Desing}}{n_{grooves}} * 0,8264 * e^{0,0011 \cdot l}$$

Relied Issues

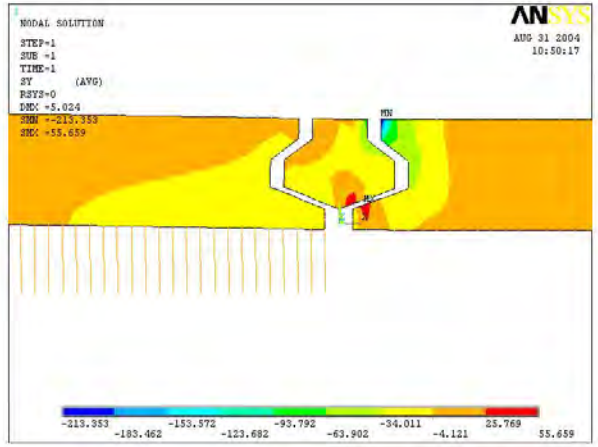
- Fabrication
- Seismic behavoir
- Accoustic behaviour
- Fire
- Humidity

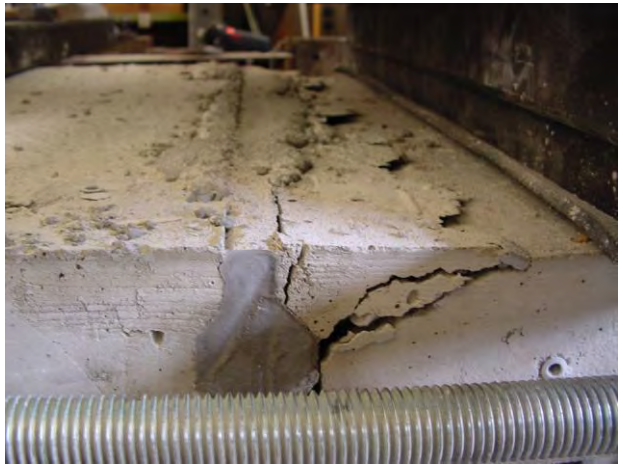
Further Issues - Prefabrication

Transversal connectior

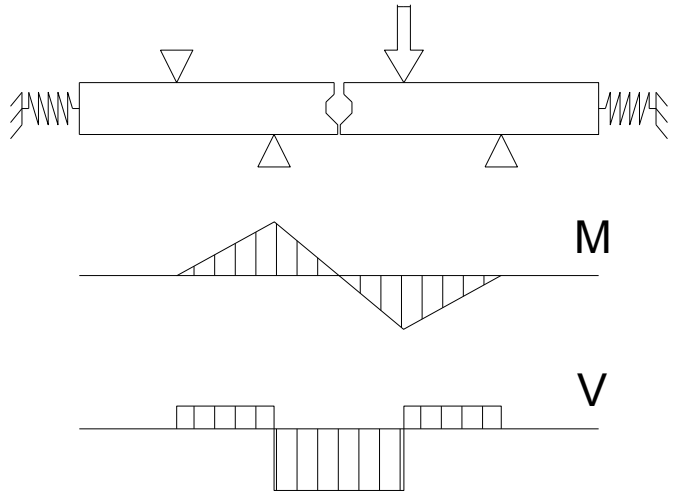


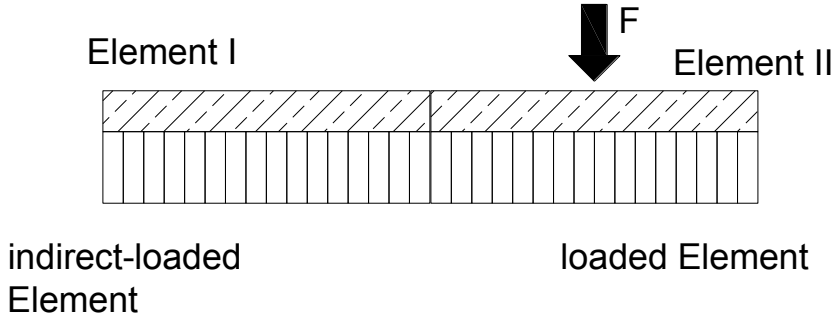
- Grouting of the concrete layer
- Steel connector in the concrete layer combined with welding
- Overlap of the layers
- Connection of the wood elements with spring groove profiles



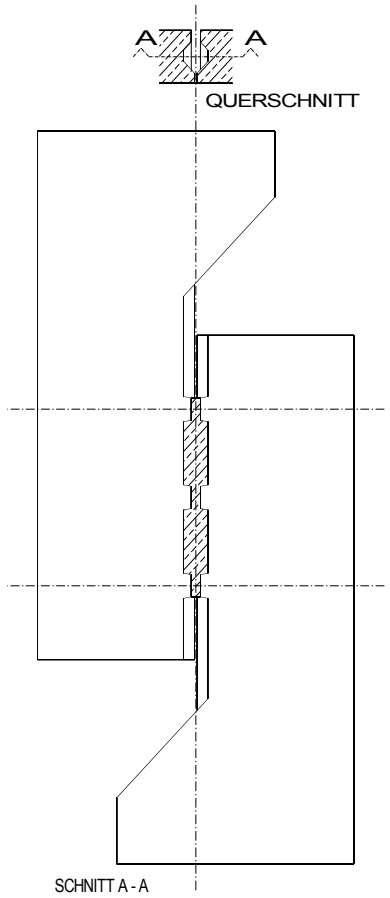


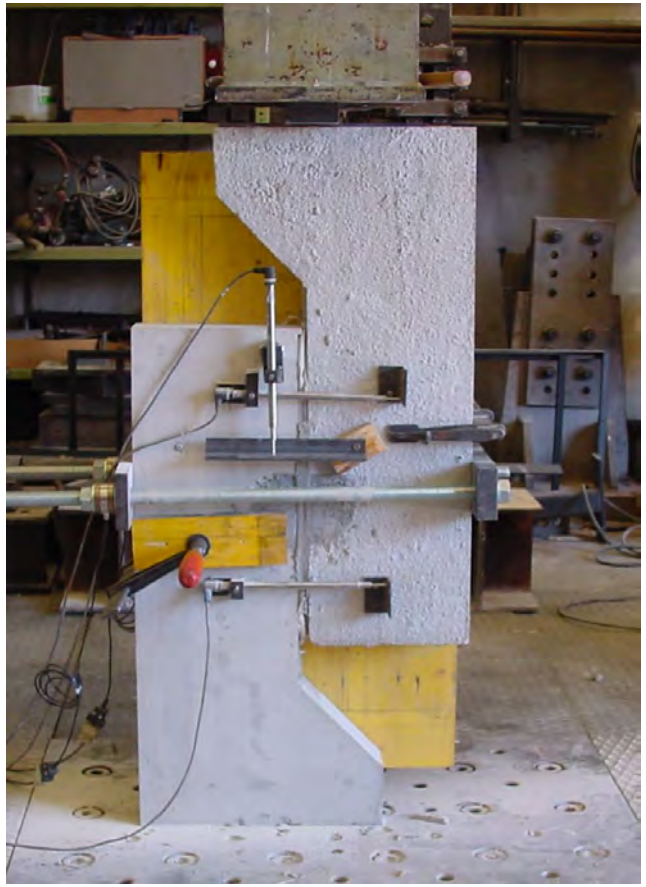
Test series


M
V

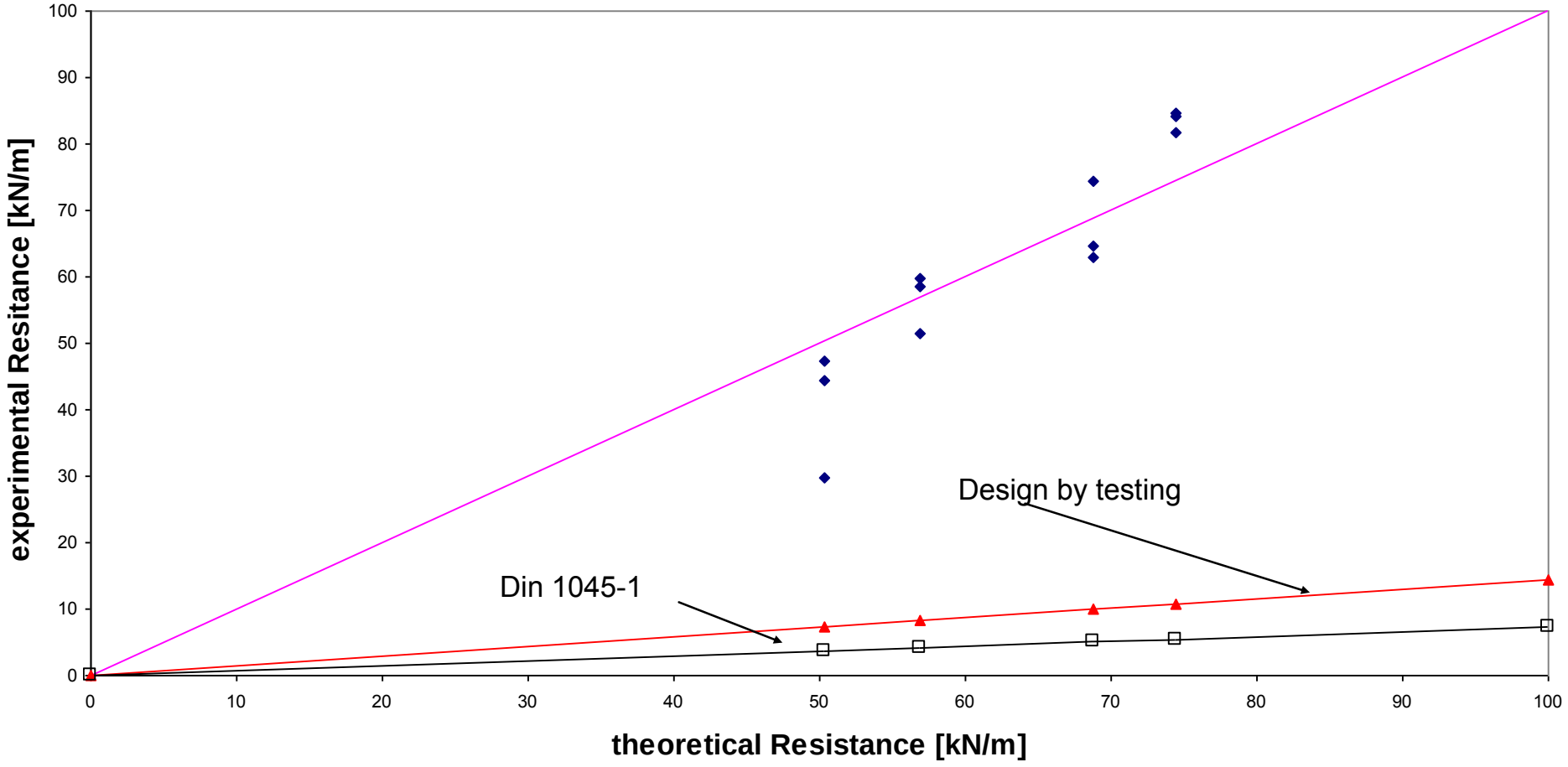

F
Element I
Element II
indirect-loaded Element
loaded Element

Test series

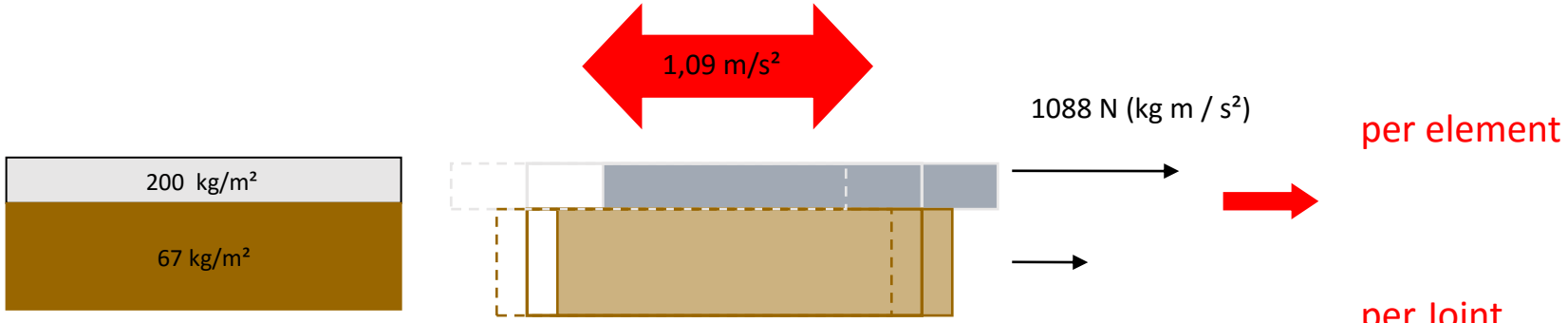




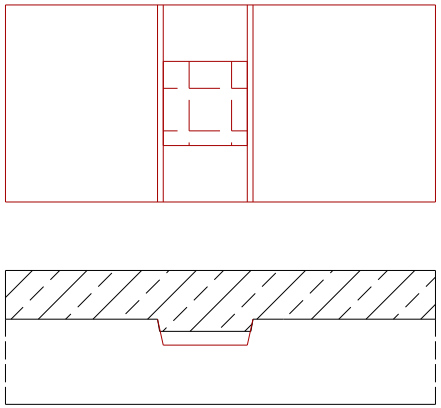
Test - Series


experimental Resitance [kN/m]
theoretical Resistance [kN/m]
Design by testing
Din 1045-1
0
10
20
30
40
50
60
70
80
90
100

Seismic Bahviour



Seismic Device



Bridge Crestawald (CH)
1996