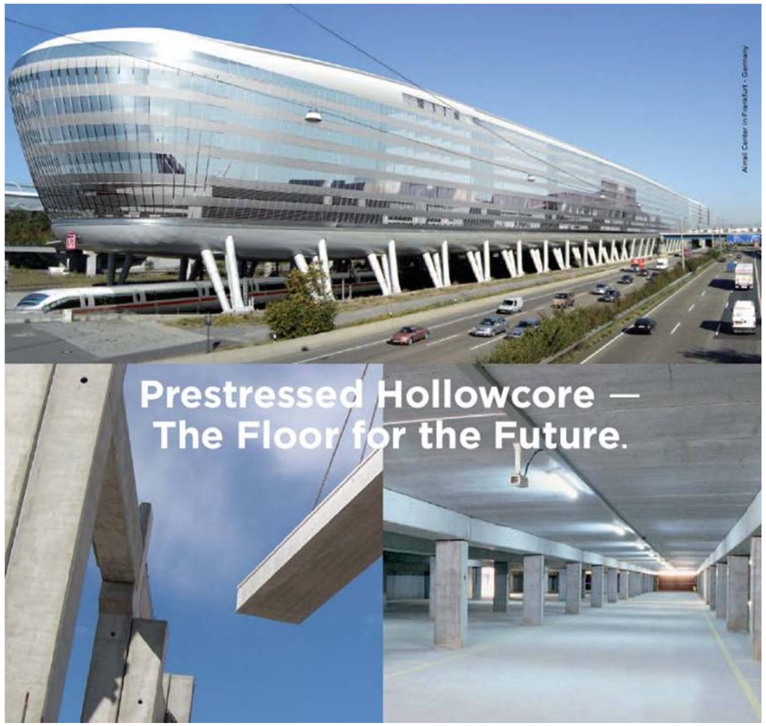
INTERNATIONAL PRESTRESSED
HOLLOWCORE ASSOCIATION

Hegger + Partner
Ingenieurbüro für Tragwerksplanung
und Bauberatung

Shear resistance of hollow core slabs
Testing and Design

Technical Seminar in Aachen 26./27.10.2011



Dipl.-Ing. Hans-Peter Doser

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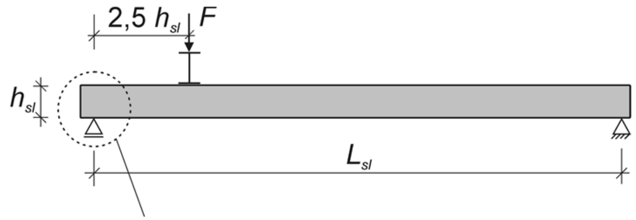
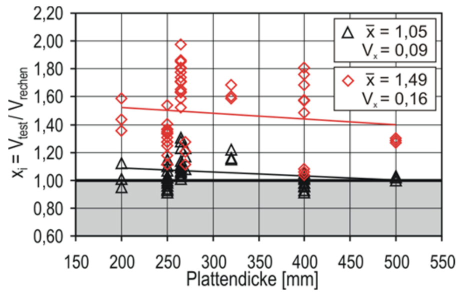


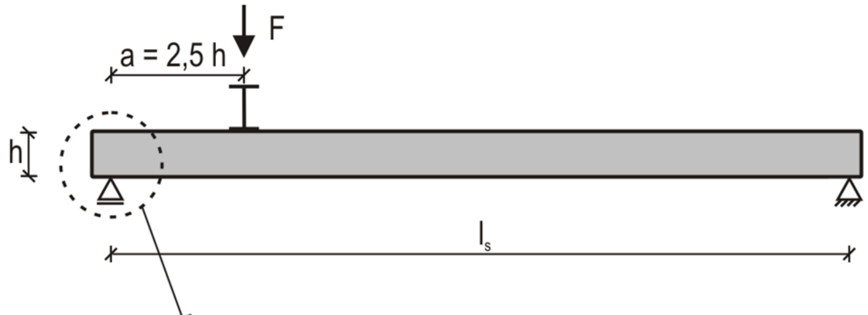
- testing evaluation
  - German approvals
  - EN 1168:2009

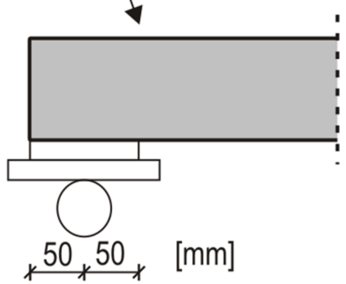
$$V_{Rd,ct} = f \cdot \frac{I_y \cdot b_w}{S_y} \left(\sqrt{\left(\frac{f_{ctk;0,05}}{\gamma_c} \right)^2 - \alpha_1 \cdot \sigma_{cd} \cdot \frac{f_{ctk;0,05}}{\gamma_c}} - \alpha_p \cdot \tau_{cpd} \right)$$

- data base and statistical evaluation



Testing arrangement





- According to EN 1168 (one line loading)
- Length of specimen: l = 15 x h; min = 4,0 m
- Distance of load: a = 2,5 x h
- Load application via stiff girder on gypsum

Pictures of test

Testing execution

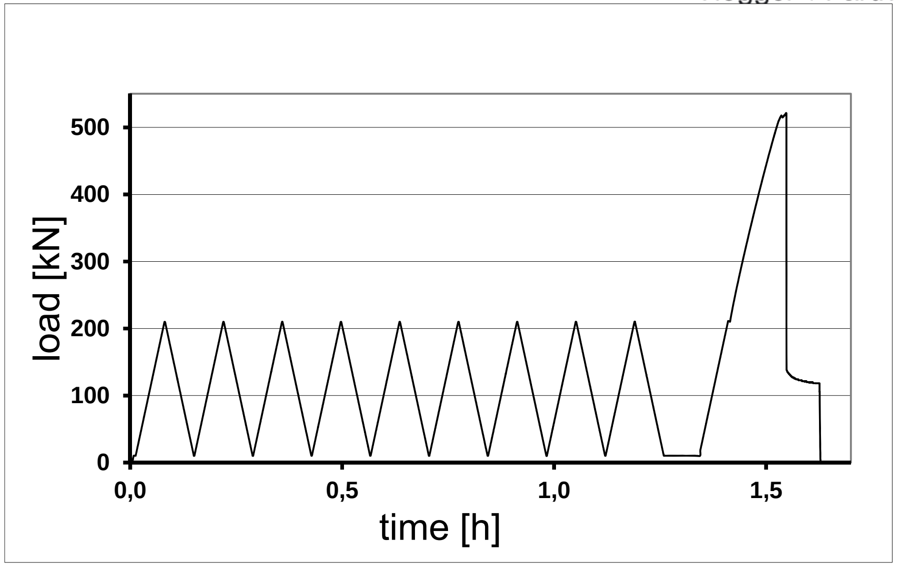
German approval

9 load cycles up to 0,91 x $V_{Rd,ctm}$

$V_{Rd,ctm}(f_{ctm}, \gamma=1{,}8)$

Increasing load to failure

$V_{Rk,ctm}(f_{ctm}, \gamma=1{,}0)$



EN 1168

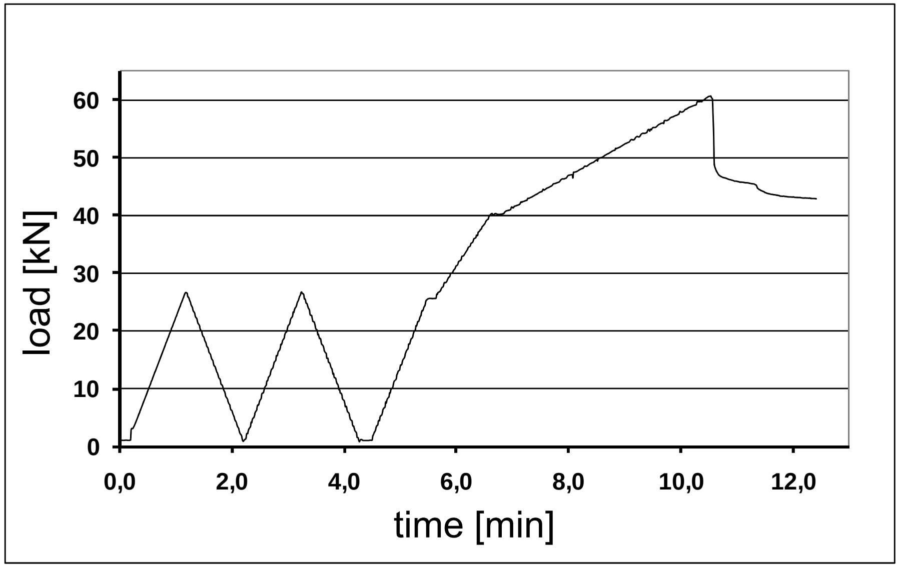
2 load cycles up to 0,70 x $V_{Rd,ct}$

$V_{Rd,ct}(f_{ctk;0,05}, \gamma=1{,}8)$

Stepwise increasing load

50% $V_{Rk,ctm}$ – 75% $V_{Rk,ctm}$ – failure

$V_{Rk,ctm}(f_{ctm}, \gamma=1{,}0)$



Material samples

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- Concrete cubes 150x150x150mm
- Drill cores taken vertically out of the webs

Material properties

Determination of tensile strength

drilled cores

i-section
(„dog bones“)

Adhesive tensile
strength

design equations

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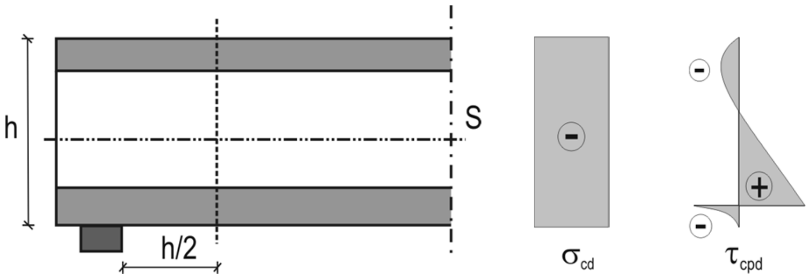
German approvals (DIBt)

$$V_{Rd,ct} = f \cdot \frac{I_y \cdot b_w}{S_y}\left(\sqrt{\left(\frac{f_{ctk;0,05}}{\gamma_c}\right)^2 - \alpha_1 \cdot \sigma_{cd} \cdot \frac{f_{ctk;0,05}}{\gamma_c}} - \alpha_p \cdot \tau_{cpd}\right)$$



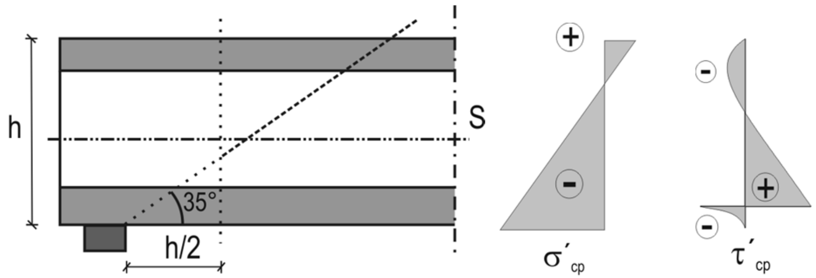
calculation of stress components

$$\sigma_{cd} = \frac{N_{Ed}}{A}$$

$$\tau_{cpd} = \frac{T_{M-M}}{I_{bpd} \cdot b_{M-M}} \qquad T_{M-M} = \sum \sigma_{x,p} \cdot h_m \cdot b_i$$

DIN EN 1168

$$V_{Rd,c} = \frac{I_y \cdot b_w}{S_y}\left(\sqrt{f_{ctd}^2 + \sigma'_{cp} \cdot f_{ctd}} - \tau'_{cp}\right)$$



calculation of stress components

$$\sigma'_{cp} = \sum_{i=1}^{n}\left[\alpha_i \cdot \left(\frac{P_{xi}}{A} + \frac{P_{xi} \cdot e_i}{I_y} \cdot z\right)\right] + \frac{M_{Ed}}{I_y} \cdot z$$

$$\tau'_{cp} = \frac{1}{b_w}\sum_{i=1}^{n}\left[\frac{dP_{xi}}{dx} \cdot \left(\frac{A_0}{A} - \frac{S_y \cdot e_i}{I_y} - C_{pt}\right)\right]$$

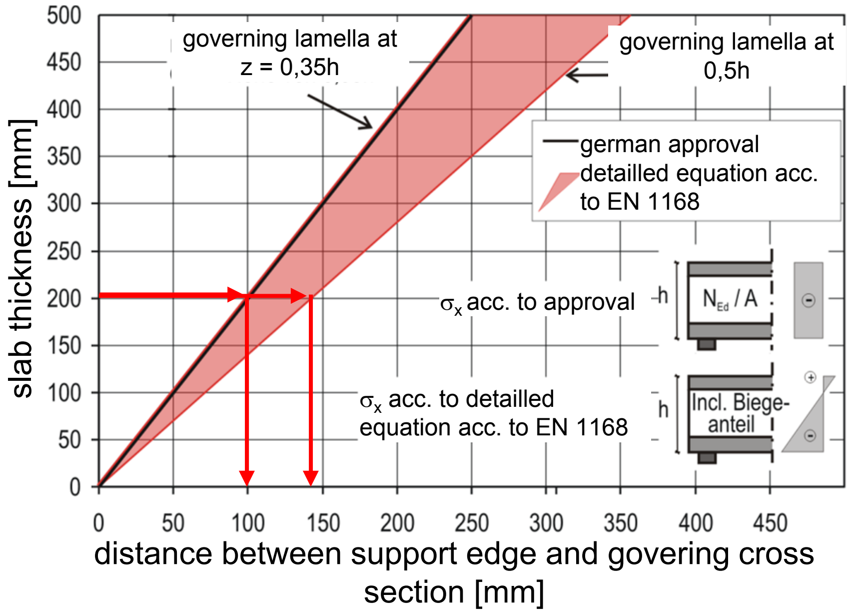
simplified equation:

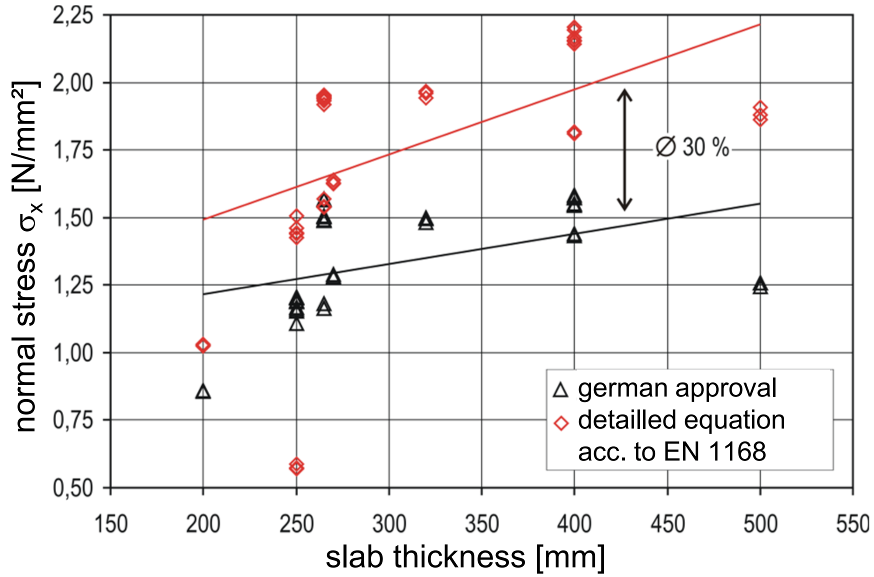
$$V_{Rd,c} = \varphi \cdot \frac{I_y \cdot b_w}{S_y}\sqrt{f_{ctd}^2 + \beta \cdot \alpha_l \cdot \sigma_{cp} \cdot f_{ctd}}$$

Normal stress σ_{cd}

Differences in calculating σ_{cd}

- Constant normal stress in gov. cross section (approval)
- Linearely distr. normal stress (consideration of bending moments due to prestress) (DIN EN 1168)
- Consideration of increasing prestressing force





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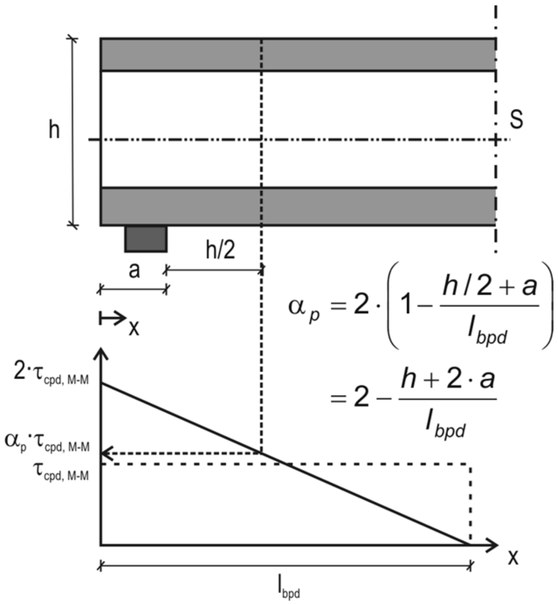
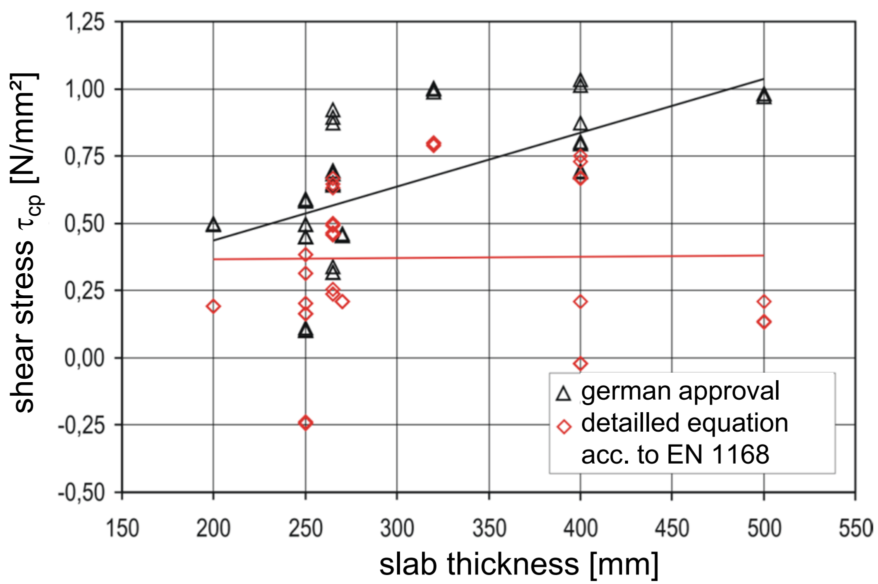
shear stress τ_{cp}

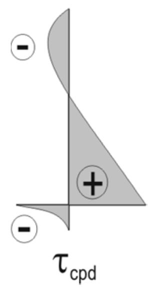
Differences in consideration of τ_{cp}

- modification factor α_p increases τ_{cpd} in most cases (for $(a + h/2) < 0{,}5\ l_{bpd}$)
- EN 1168 considers τ_{cpd} independent of the distance to bearing
- Vertical distance to critical point determines value of τ_{cpd}



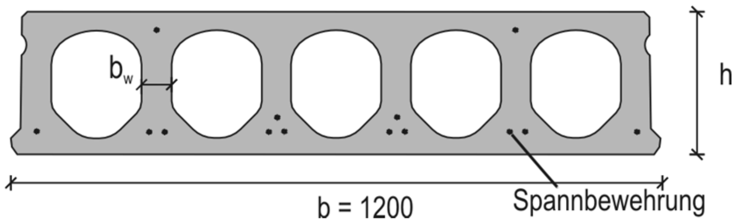
$$\alpha_p = 2 \cdot \left(1 - \frac{h/2 + a}{l_{bpd}}\right) = 2 - \frac{h + 2 \cdot a}{l_{bpd}}$$





data base

cross section



h ~ 200 - 500 mm

$\Sigma b_w/b$ ~ 0,2 - 0,4

prestress steel

number of strands

loss of prestress

material properties

concrete class C45/55

test results tension (n≈250)

test parameters

slab length

ultimate loads

~70 tests carried through by H+P at imb

48 test with shear tension failure

12	Goldbeck SPA 250	250-0,20-3	250	4,10	43	42	6	253	279	1,10	258	276	1,07	237
19	VMM SCD 40/120	400-0,27-4	400	6,10	45	57	7	327	331	1,01	349	363	1,04	327

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Safety factor

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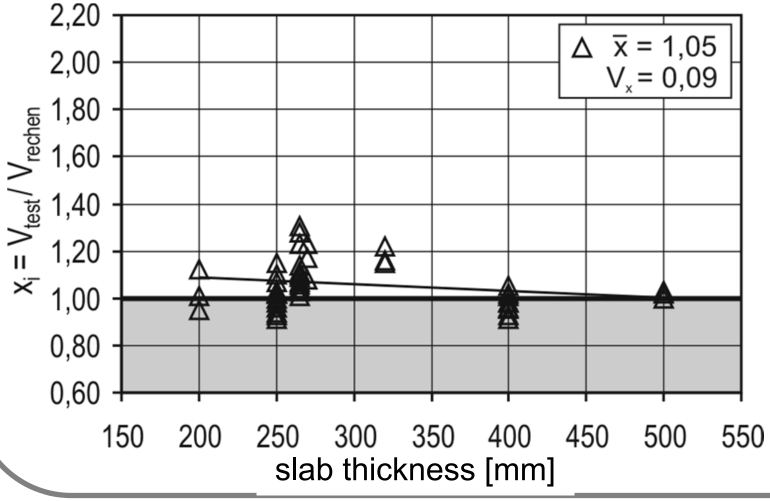
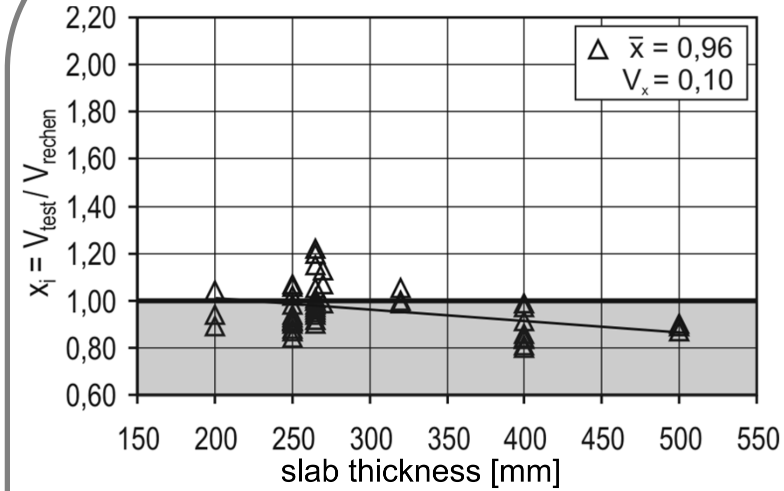
German approval (DIBt)



$x_i = V_{test}/V_{calc}$, i = 1,...,48

Δ V_{calc} with $f_{ctm, test}$

DIN EN 1168



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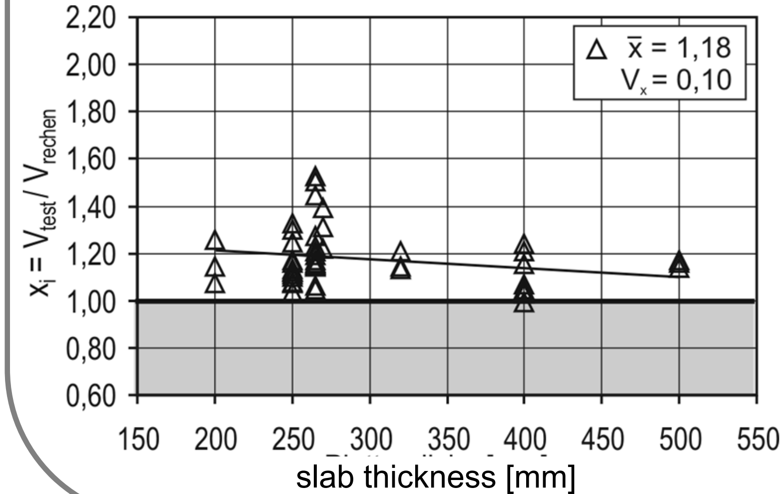

simplified