The European Convention for Constructional Steelwork – ECCS

Organisation - Activities

Structural Safety - past advancements and future challenges

JCSS Workshop Prague

May 22nd 2024

Univ.-Prof. Dr.-Ing. Markus Feldmann
Kevin Wolters, M.Sc.

The ECCS
Origins

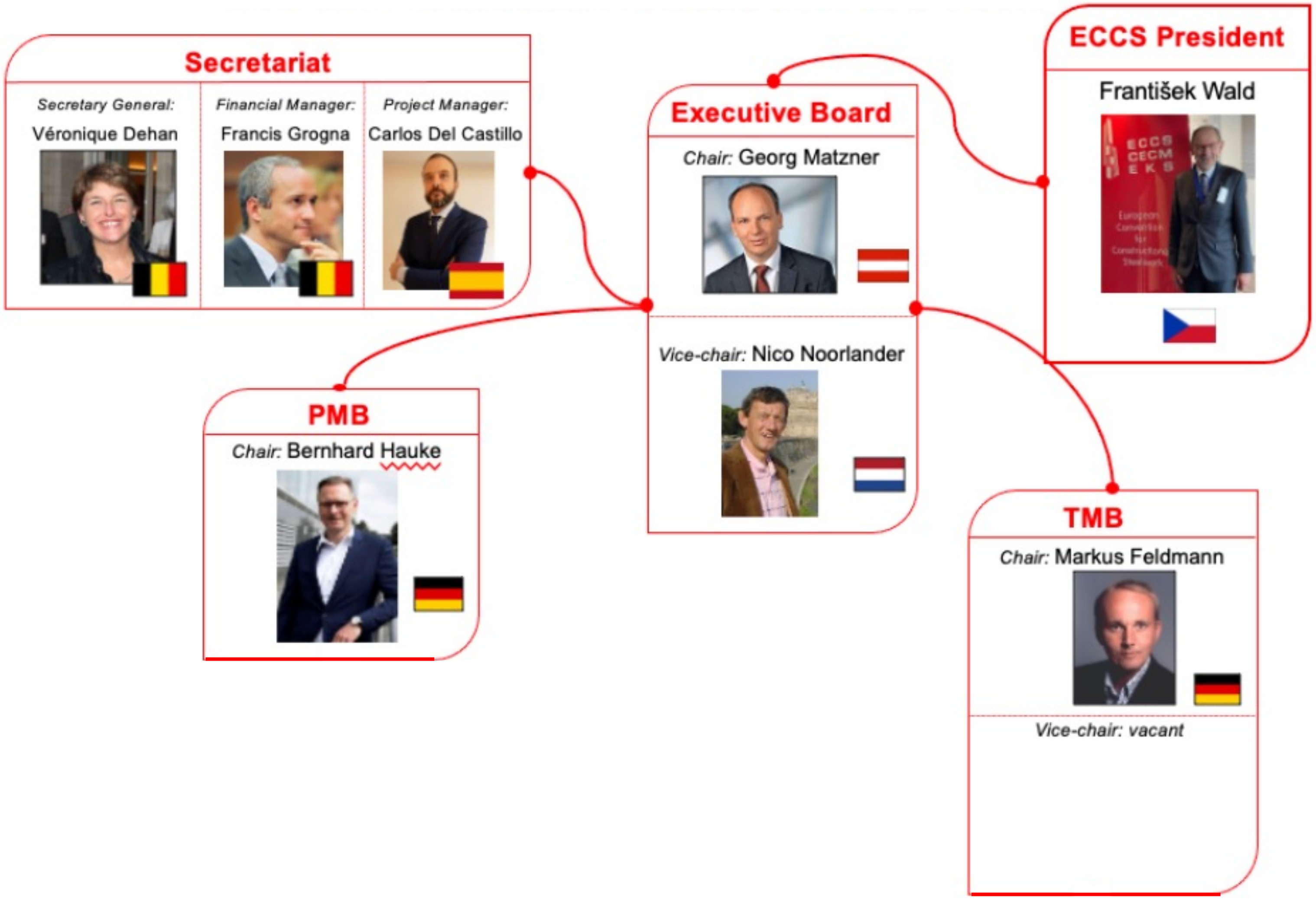
- Set up in 1955 in parallel with the European Coal and Steel Community (ECSC)
- Federation of 16 National Associations (Full Members) + 14 Associate Members
- ECCS = THE sole European Platform gathering
  - steel producers
  - steelwork contractors
  - European research organisations
  - and the academic world

The ECCS
Mission

- To develop an effective **technical and promotional network** for sustainable use of steel in the construction sector through our 10 TCs and two ACs in close collaboration with CEN and ISO
- To improve **competitiveness and innovation** in the construction through a series of **research projects**
- To **represent the profession** and continue to be the **reliable partner** on European and International level through the presence on various platforms at European and Global level (ECCREDI, CEN, ISO, DG GROW, etc)

- To **develop the markets** for constructional steel by the application of practical **standards and codes**.
- To propose **research and development** to the benefit of the industry within the frame of the commercial interests of the fabrication industry.
- Early specification of steel structures through **education, training, project tracking**, partnerships with all parties involved in the **construction process**.

The ECCS
Governance

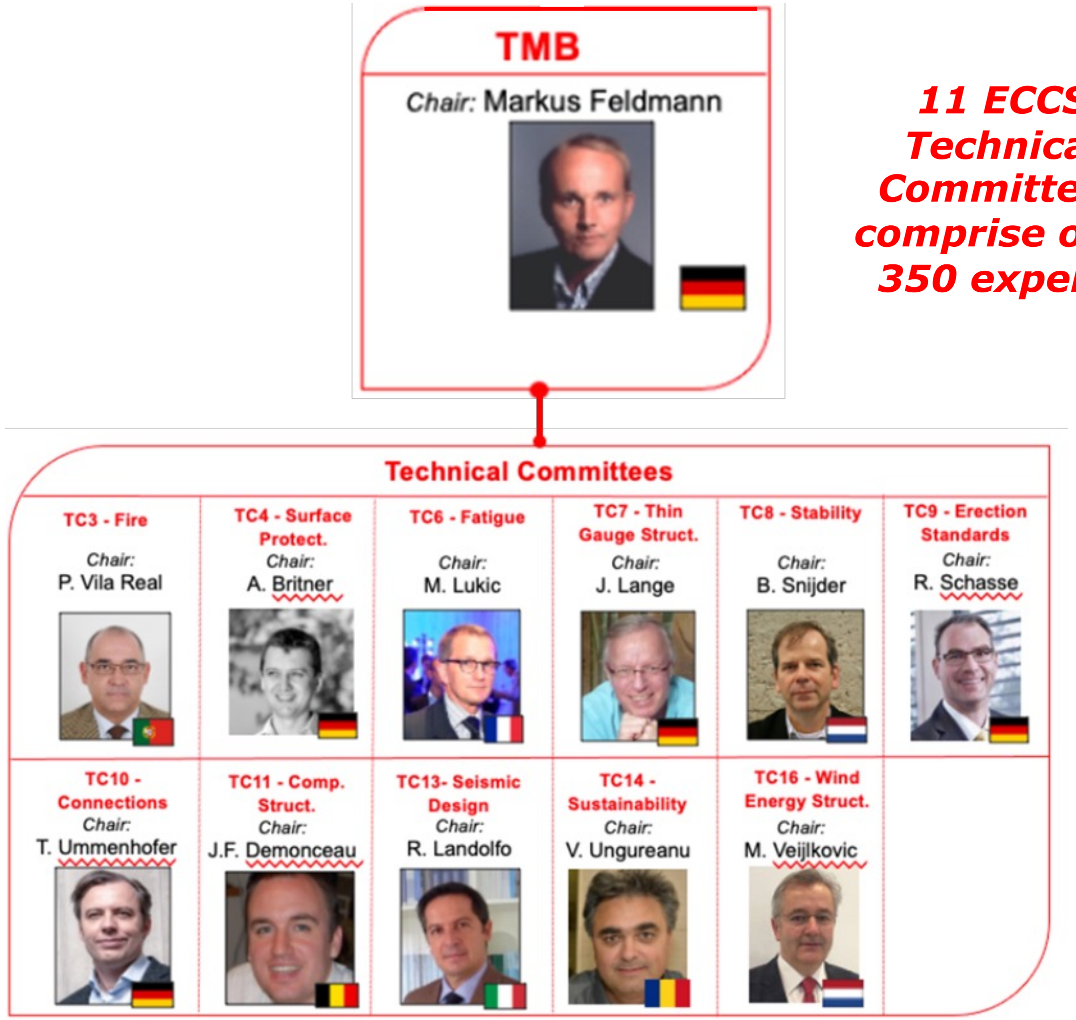


The ECCS
Governance

The ECCS
Technical Committees

TMB Technical Management Board

- **TC 4 – Surface Protection**
- **TC 6 - Fatigue**
  - TWG 6.1 – Assessment of Existing Structures
  - TWG 6.2 - Extended Fatigue Approach
  - TWG 6.3 - Statistical Analysis of Fatigue Data
  - TWG B - Hollow Sections
- **TC 7 - Thin Gauge Structures**
  - TWG 7.5 - Practical Improvement of Design
  - TWG 7.9 - Sandwich Panels
  - TWG 7.10 - Connect. in Cold-formed Structures
- **TC 8 - Stability**
  - TWG 8.3 - Plate Buckling
  - TWG 8.4 - Shell Buckling
- **TC 9 – Manufacturing and Erection standards**
- **TC 10 - Connections**
- **TC 11 - Composite Structures**
- **TC 13 - Seismic Design**
- **TC 14 - Sustaina. & Eco-Efficiency**
- **TC 16 Energy Support Structures**



11 ECCS Technical Committees comprise over 350 experts

The ECCS
Exchange of experts

EVOLUITON/ WORKING GROUPS

- **Working Group EN 1993-1-1** B. Snijder
- **Working Group EN 1993-1-2** P. Schaumann
- **Working Group EN 1993-1-5** U. Kuhlmann
- **Working Group EN 1993-1-8** T. Ummenhofer
- **Working Group EN 1993-1-9** M.Lukic

TECHNICAL COMMITTEES

- **TC 3** FIRE
- **TC 6** FATIGUE
- **TC 7** THIN GAUGE STRUCT.
- **TC 8** STABILITY
- **TC 10** CONNECTION

Exchange of experts - Common meetings, use of ECCS-Internet-Platform, common dissemination, common research projects

The ECCS
Publications

- ECCS Eurocode Design Manuals
- ECCS Training Courses/webinars
- Coordination/participation in EU research projects
- Online Bookstore: www.steelconstruct.com

NEW SKIN

2023-2025
ADVANCE
ACCOMPANYING MEASURE FOR DISSEMINATION, VALORISATION AND COLLABORATIVE EXPLOITATION OF CIRCULARITY OF CONSTRUCTIONAL STEEL PRODUCTS

GREENVESTS

The ECCS
Conferences

- International Symposium on Steel Bridges

- Eurosteel → www.eurosteel2023.org

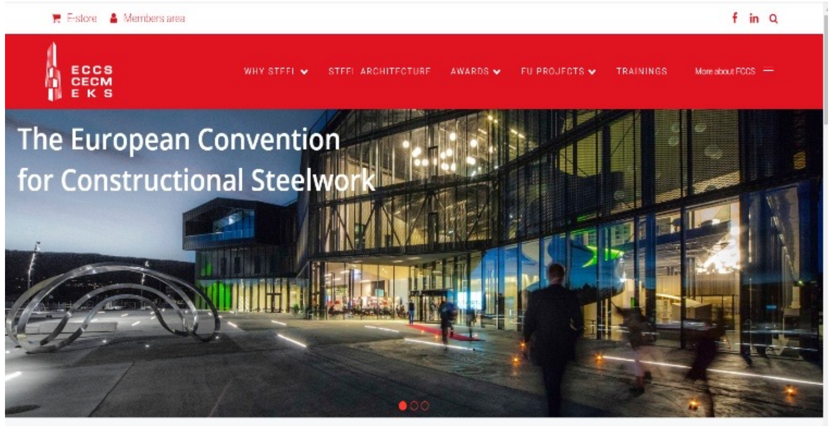
eurosteel

The ECCS
Awards

- European Steel Design Awards
- European Steel Bridge Awards
- European Student Architectural Award
- Charles Massonnet Award

The ECCS
Dissemination of Knowledge

- Website: www.steelconstruct.com



- Electronical newsletter: **Steelconstruct.com**

- Journal: **Steel Construction** - Design and Research

The ECCS
Webinars & Workshops

The ECCS
Networking

- ECCREDI
- ESTEP
- ECTP
- LIAISON COMMITTEE
- EUROFER
- WORLDSTEEL
- JRC, CEN and ISO

EUROPEAN CONSTRUCTION TECHNOLOGY PLATFORM

EUROFER The European Steel Association

worldsteel ASSOCIATION

JRC EUROPEAN COMMISSION

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

International Organization for Standardization

Avenue des Ombrages 32, bte 20
B-1200 Brussels

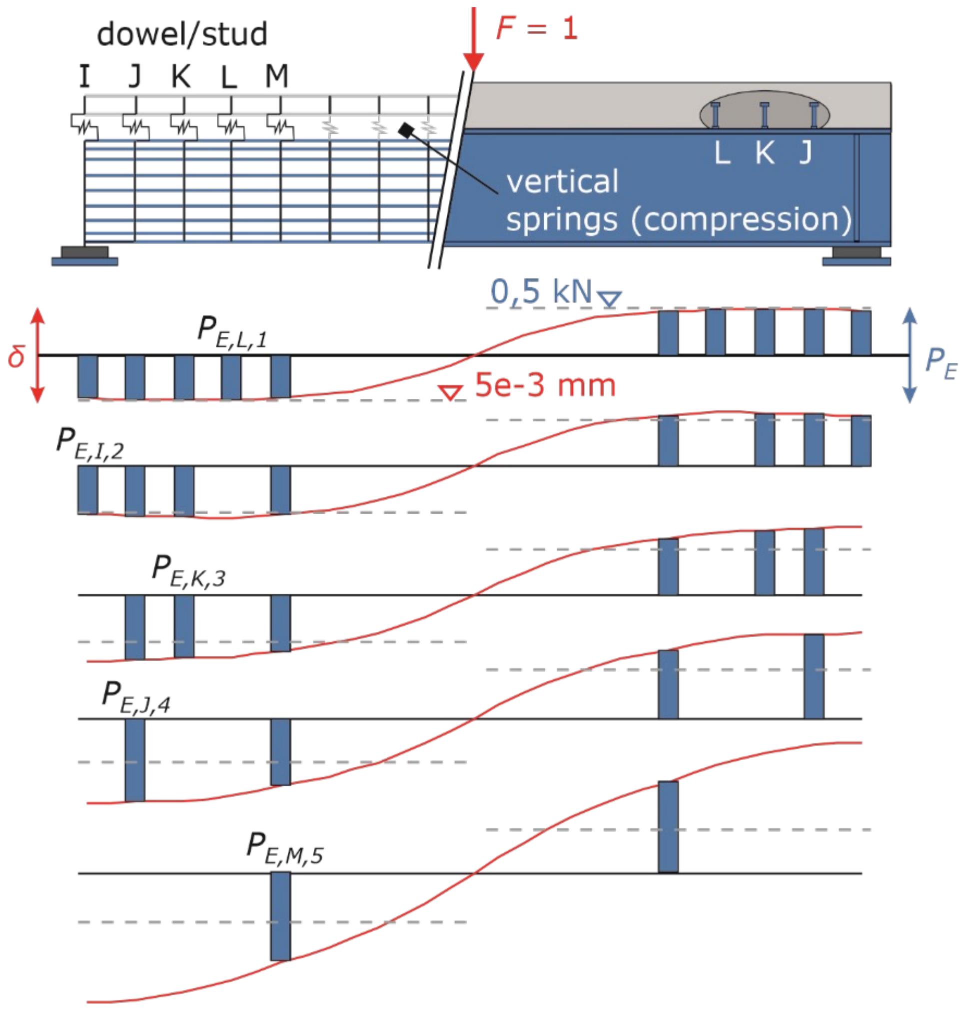
Tel: +32 2 762 04 29

Contact: Véronique Dehan
Secretary General

Email: eccs@steelconstruct.com

Website: www.steelconstruct.com

Investigations on the system reliability of composite beams



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Institute of Steel Construction

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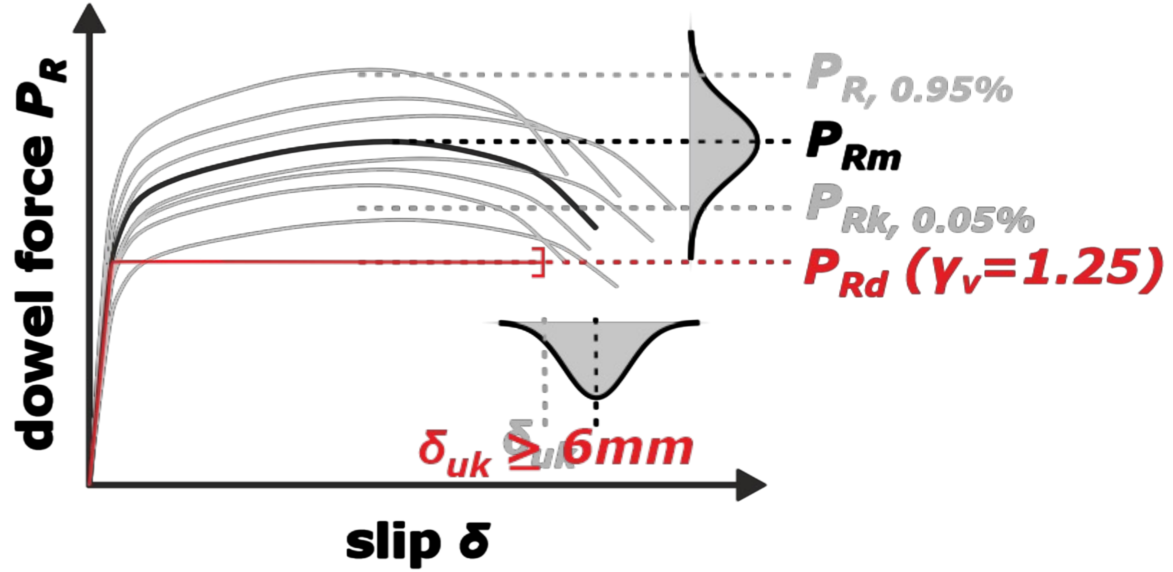
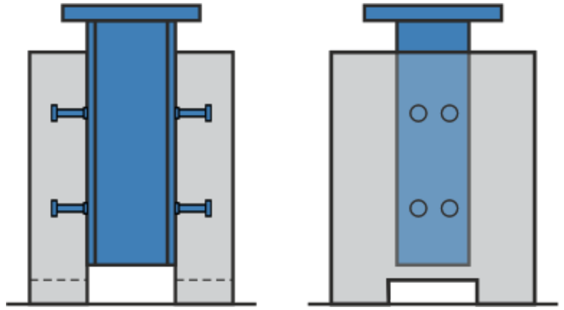
Motivation
Variation of dowel capacity





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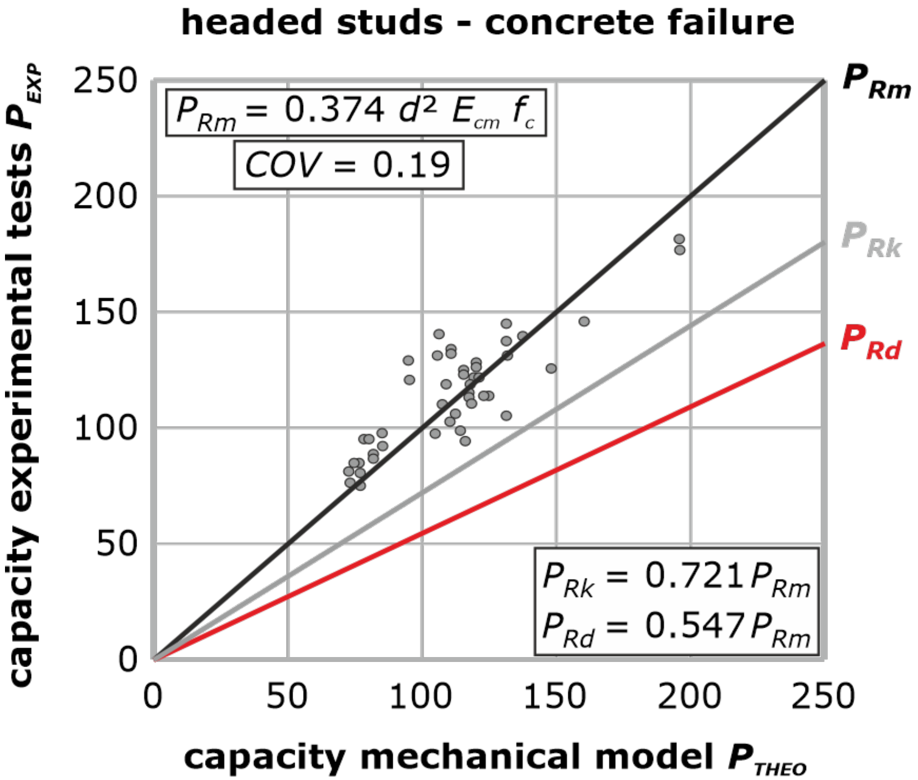
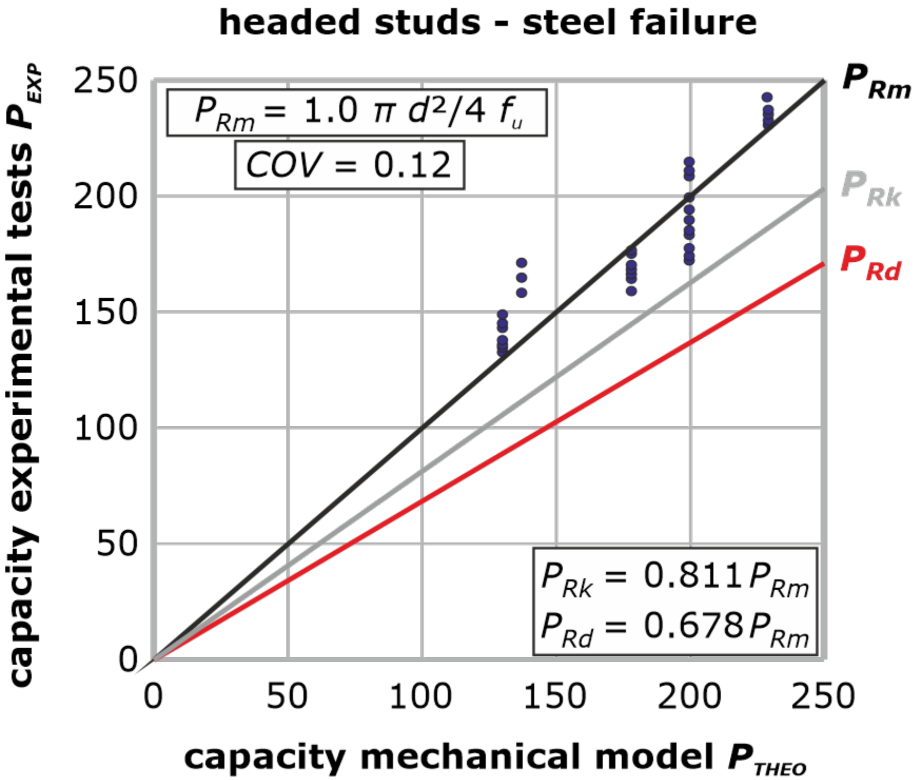
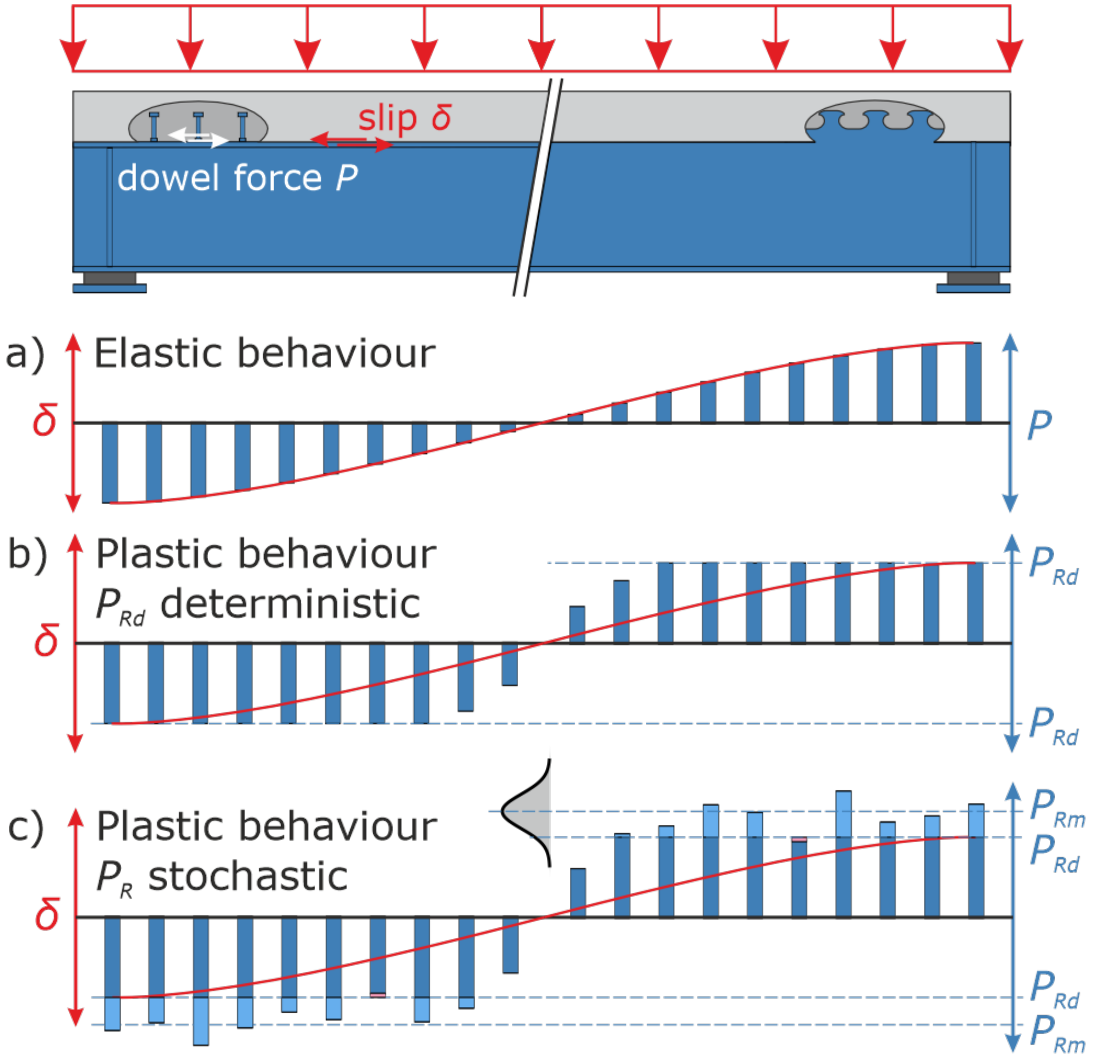
Motivation
Variation of dowel capacity





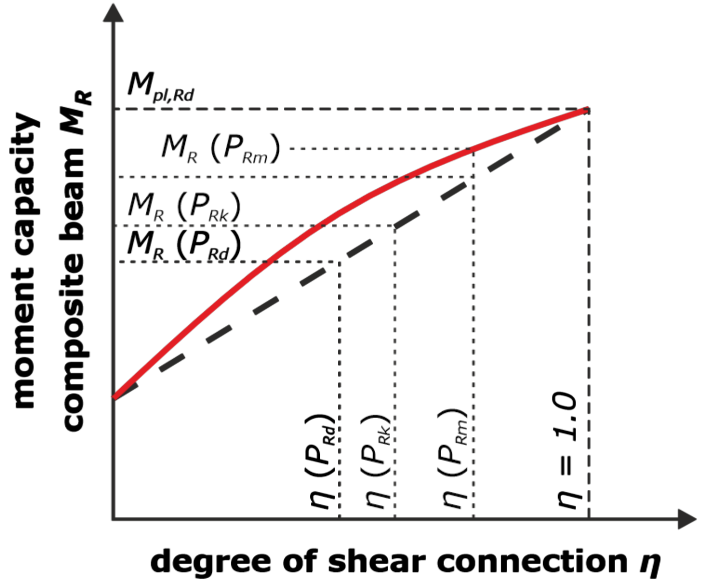
[101 Push-Specimens, Oehlers 1981]

Motivation
Dowel capacity in composite beam design



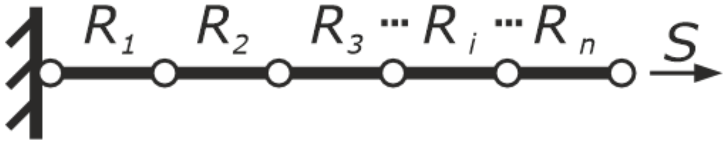
Possible effect on load bearing behaviour of composite beams:

$$\eta = \frac{n \cdot P_{Rd}}{\min\{N_c; N_{pl,a}\}} = \frac{\sum P_{R,i}}{\min\{N_c; N_{pl,a}\}}$$



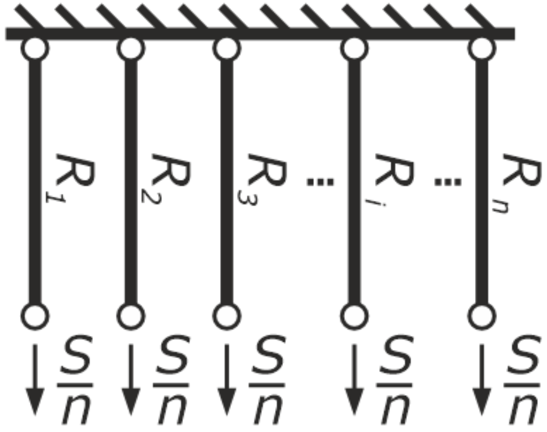
Can we raise the design level for shear connectors?

Series system



→ **system failure, as soon as one component fails**

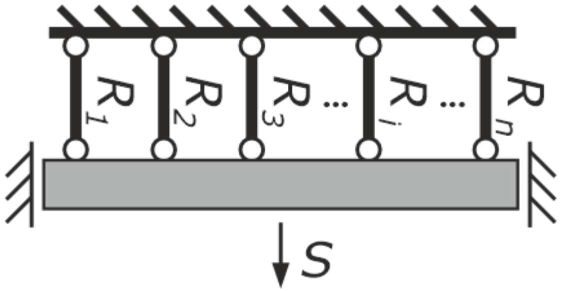
Parallel system



→ **system failure, as soon as all components fail;**

→ **no redistribution of forces**

DANIEL's system

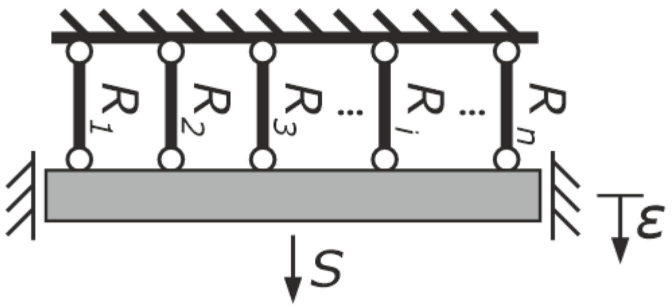


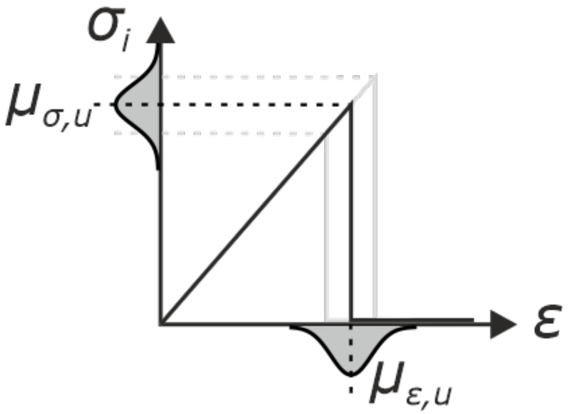
→ **system failure, as soon as all components fail;**

→ **redistribution of forces**

Theoretical background
The ideal DANIEL‘s system

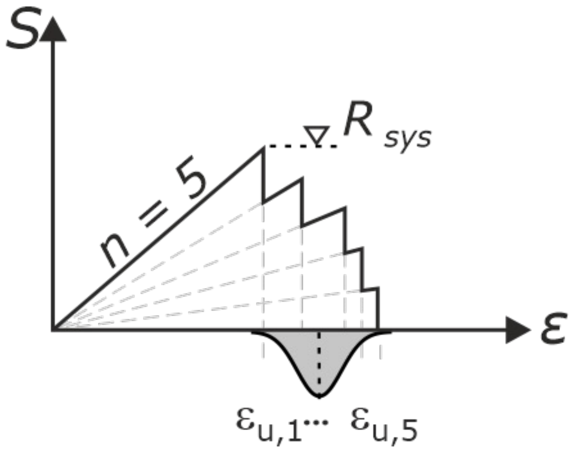
DANIEL’s system

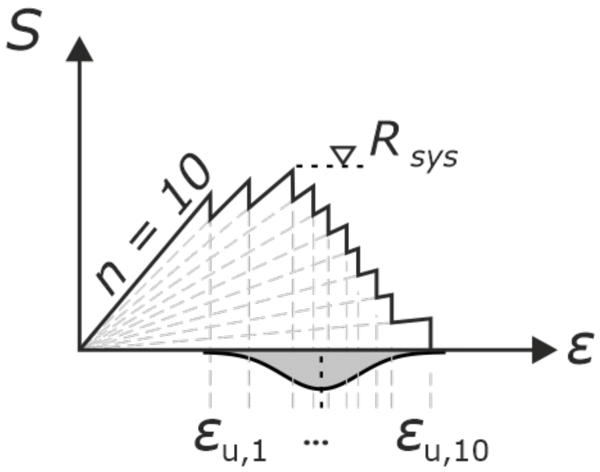




ideal brittle material law

few components; small scatter → system failure at first component is very likely





more components; larger scatter → forces might be redistributed to remaining components

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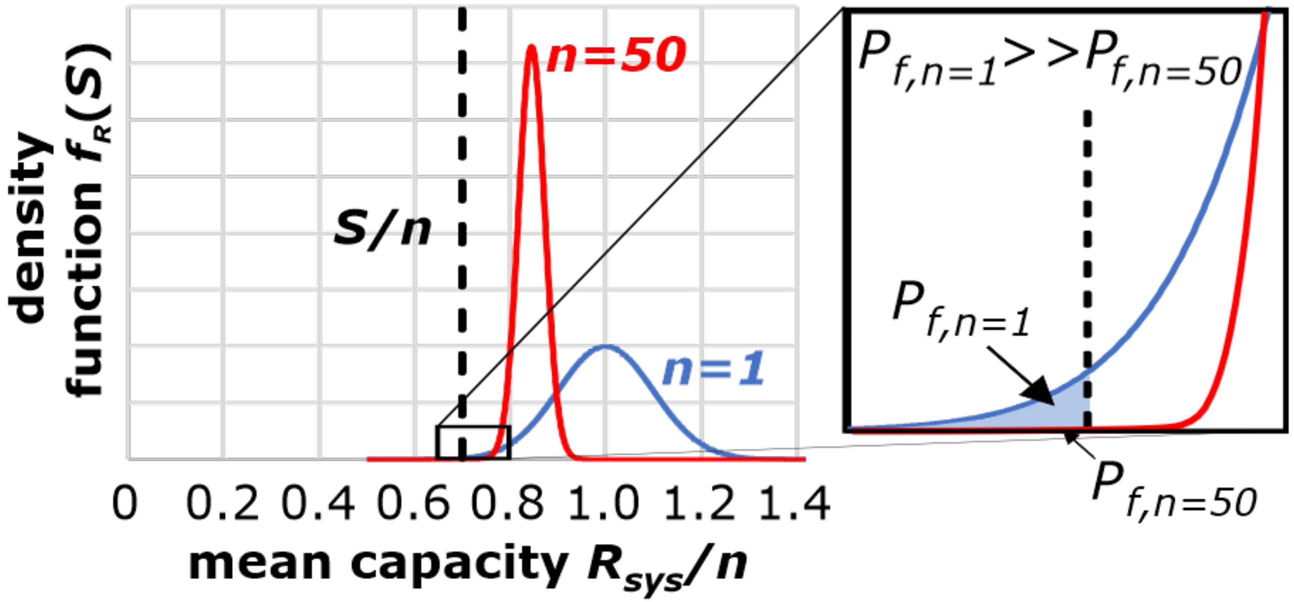
Theoretical background
The ideal DANIEL's system

DANIEL's effect



mean value decreases; variation decreases

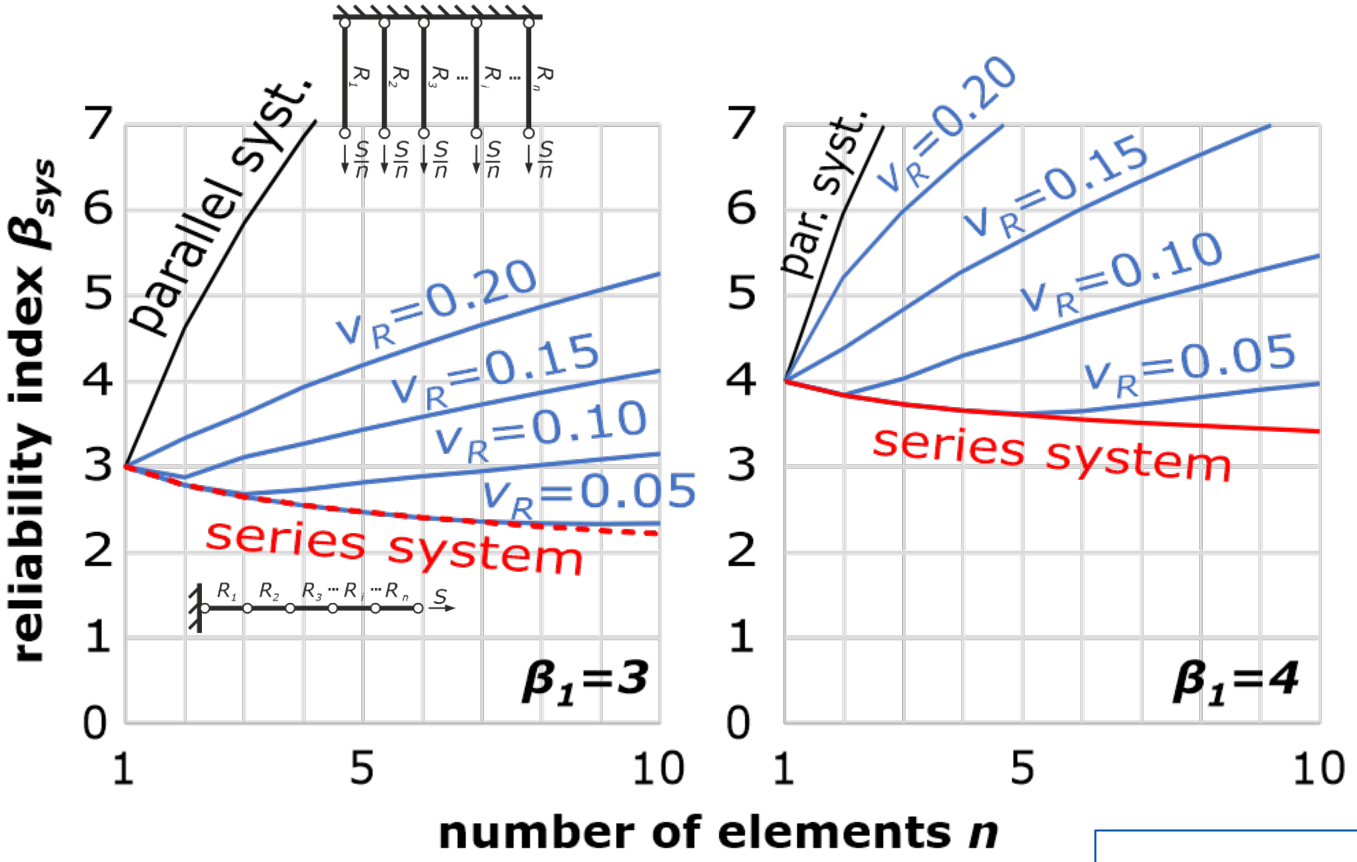
→ probability of failure decreases; system reliability increases

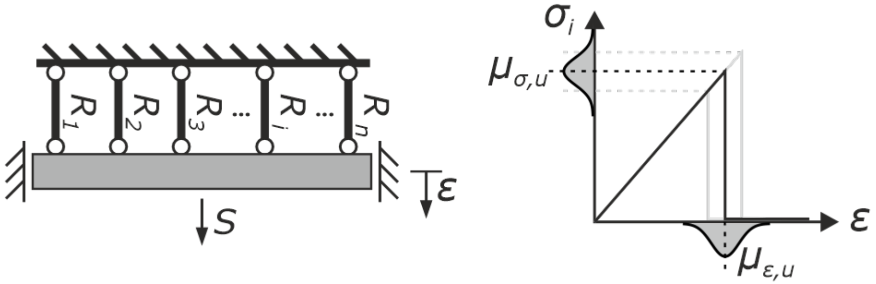
Reference value of the effect

- Choose $\boldsymbol{S}$ in a way that the systems are comparable for different component numbers $\boldsymbol{n}$
- $\boldsymbol{\beta_1}$ is the reference value of system reliability for $\boldsymbol{n}$=1

$$\boldsymbol{S = n \cdot (\mu_R - \beta_1 \cdot \sigma_R)}$$

Theoretical background
The ideal DANIEL's system



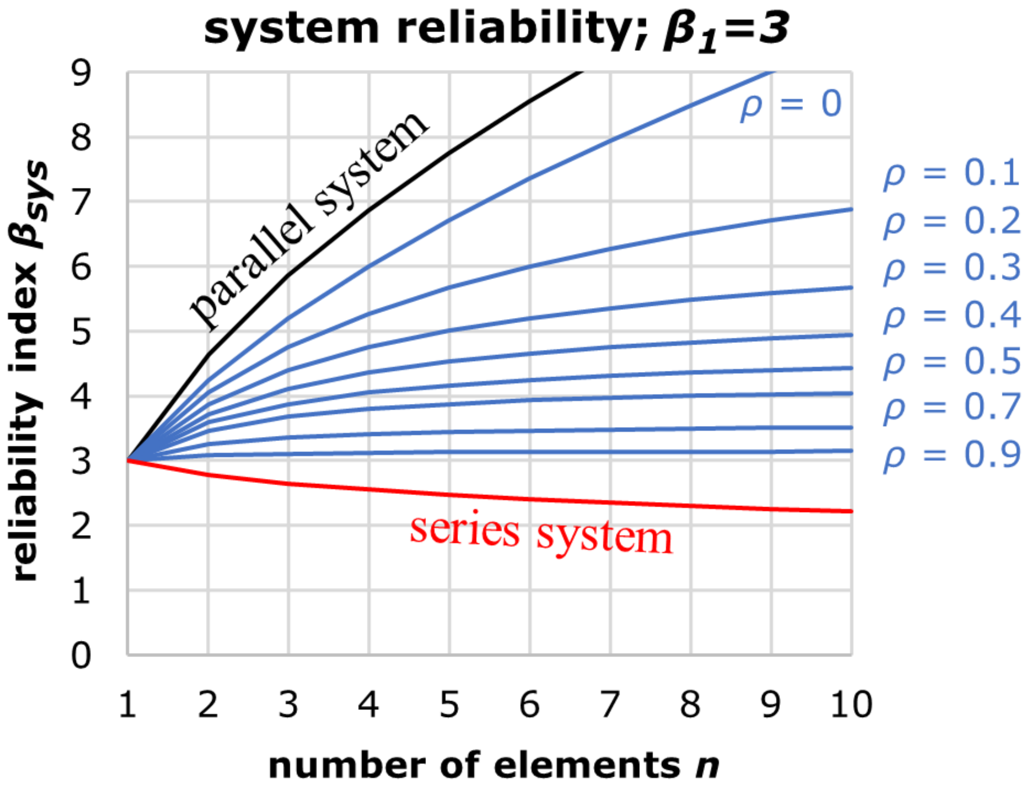


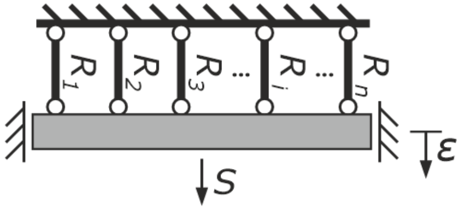
Influences on system reliability

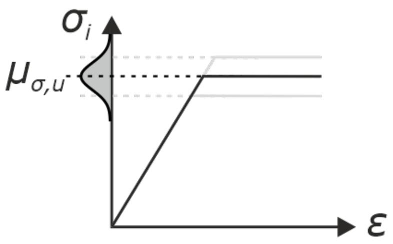
- reference value for reliability β_1
- variation of component capacity v_R
- component number n

$$P_{f,sys} = (-1)^{n+1} \cdot F_R^n\left(\frac{S}{n}\right) - \sum_{i=1}^{n-1}\left[(-1)^i \cdot \binom{n}{i} \cdot F_R^i\left(\frac{S}{n}\right) \cdot F_{R,sys,n-1}(S)\right]$$

Theoretical background
The ductile DANIEL's system







Influences on system reliability

- reference value for reliability β_1
- correlation of component capacity ρ
- component number n

$$P_{f,sys} = \Phi\left(\frac{S - n \cdot \mu_R}{\sqrt{n} \cdot \sigma_R} \cdot \frac{1}{\sqrt{1 + \rho \cdot (n-1)}}\right)$$

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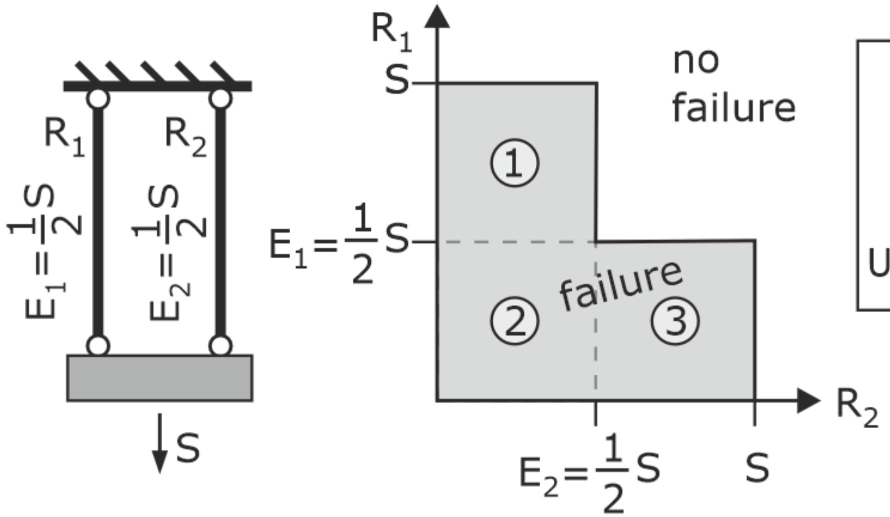
Theoretical background
Generalized brittle systems

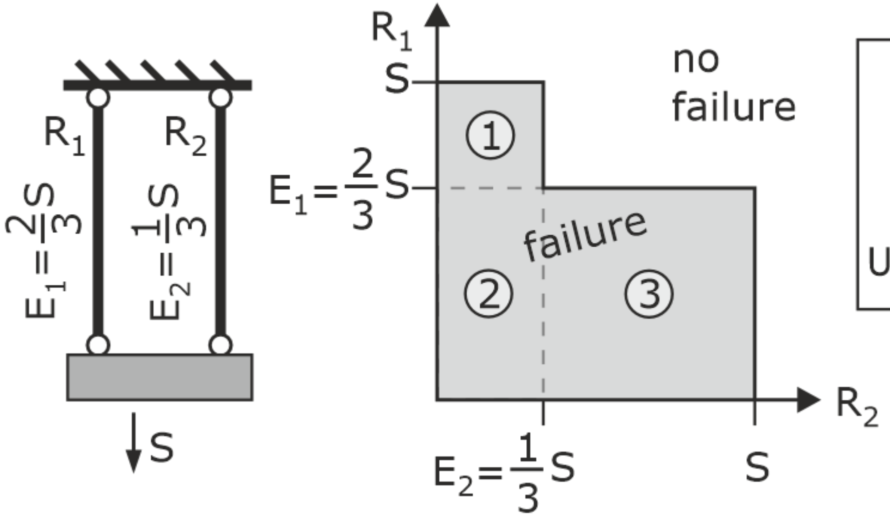


failure region:

$$[R_1 < \tfrac{1}{2}S \cap R_2 < S]$$
$$\cup\, [R_2 < \tfrac{1}{2}S \cap R_1 < S]$$

$$\begin{aligned} P_{f,sys} = &\left[\left(\mathrm{F}_{R,1}(S) - \mathrm{F}_{R,1}\left(\tfrac{1}{2}S\right)\right)\cdot\left(\mathrm{F}_{R,2}\left(\tfrac{1}{2}S\right) - \mathrm{F}_{R,2}(0)\right)\right] \quad 1 \\ &+ \left[\left(\mathrm{F}_{R,1}\left(\tfrac{1}{2}S\right) - \mathrm{F}_{R,1}(0)\right)\cdot\left(\mathrm{F}_{R,2}\left(\tfrac{1}{2}S\right) - \mathrm{F}_{R,2}(0)\right)\right] \quad 2 \\ &+ \left[\left(\mathrm{F}_{R,1}\left(\tfrac{1}{2}S\right) - \mathrm{F}_{R,1}(0)\right)\cdot\left(\mathrm{F}_{R,2}(S) - \mathrm{F}_{R,2}\left(\tfrac{1}{2}S\right)\right)\right] \quad 3 \end{aligned}$$

$$\boxed{P_{f,sys} = (-1)^{n+1}\cdot F_R^n\left(\frac{S}{n}\right) - \sum_{i=1}^{n-1}\left[(-1)^i\cdot\binom{n}{i}\cdot F_R^i\left(\frac{S}{n}\right)\cdot F_{R,sys,n-1}(S)\right]}$$

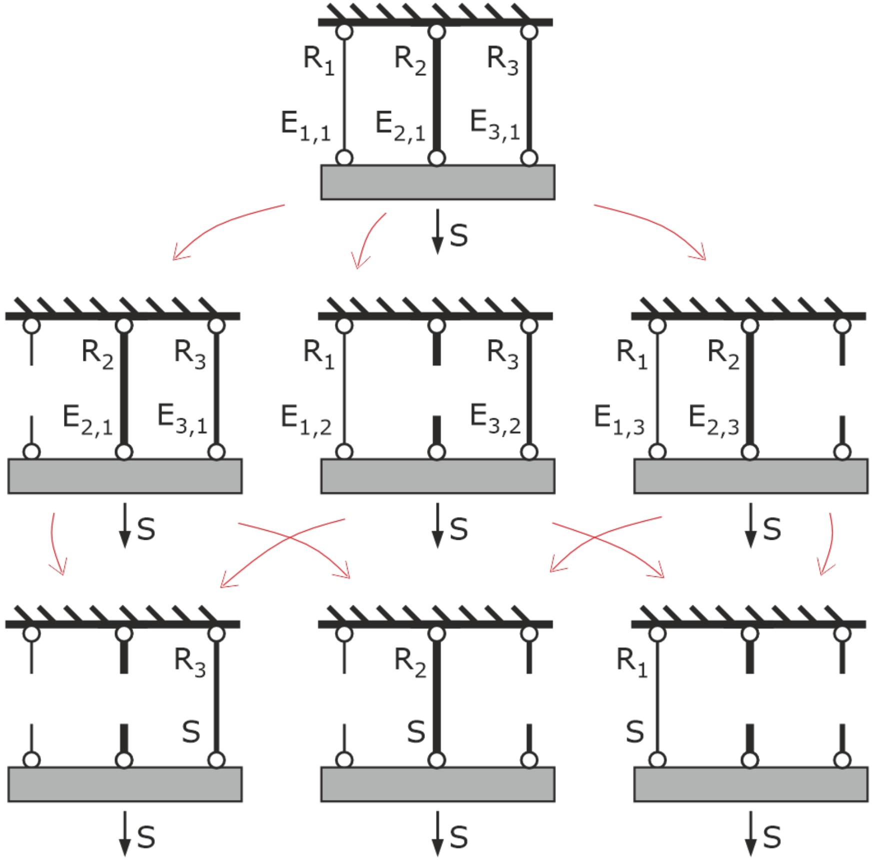


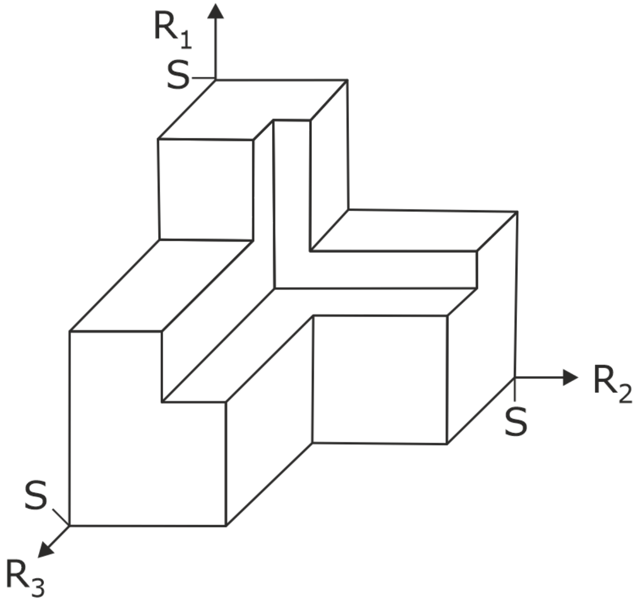
failure region:

$$[R_1 < \tfrac{2}{3}S \cap R_2 < S]$$
$$\cup\, [R_2 < \tfrac{1}{3}S \cap R_1 < S]$$

$$\begin{aligned} P_{f,sys} = &\left[\left(\mathrm{F}_{R,1}(S) - \mathrm{F}_{R,1}\left(\tfrac{2}{3}S\right)\right)\cdot\left(\mathrm{F}_{R,2}\left(\tfrac{1}{3}S\right) - \mathrm{F}_{R,2}(0)\right)\right] \quad 1 \\ &+ \left[\left(\mathrm{F}_{R,1}\left(\tfrac{2}{3}S\right) - \mathrm{F}_{R,1}(0)\right)\cdot\left(\mathrm{F}_{R,2}\left(\tfrac{1}{3}S\right) - \mathrm{F}_{R,2}(0)\right)\right] \quad 2 \\ &+ \left[\left(\mathrm{F}_{R,1}\left(\tfrac{2}{3}S\right) - \mathrm{F}_{R,1}(0)\right)\cdot\left(\mathrm{F}_{R,2}(S) - \mathrm{F}_{R,2}\left(\tfrac{1}{3}S\right)\right)\right] \quad 3 \end{aligned}$$

Theoretical background
Generalized systems





Generalized systems with $n \geq 3$

- n-dimensional calculation
- $n!$ possible failure sequences
- 2^{n-1} different values for E_i
- $2^{(n-1)^n}$ possible failure regions ("Hypercubes")

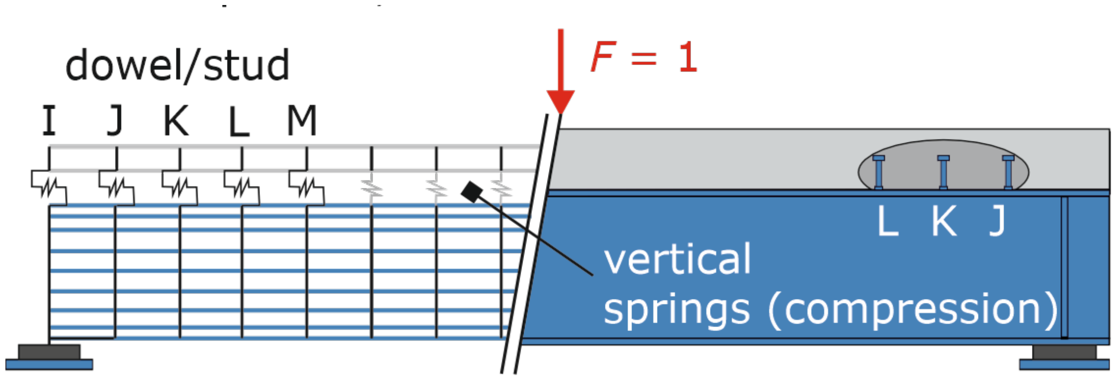
→ $n = 6$: 720 possible failure sequences; 1.07 billion possible failure regions

→ method limited by computational power

Composite beams with brittle shear connectors
"Lamella model"

Beam-spring-model

- Matlab-Code
- composite beam discretized into several lamellas, coupled by stiff bars
- user defined springs for shear connectors
  - 3 degrees of freedom (*UX, UZ, RotZ*)
  - brittle/ductile
  - deterministic or random



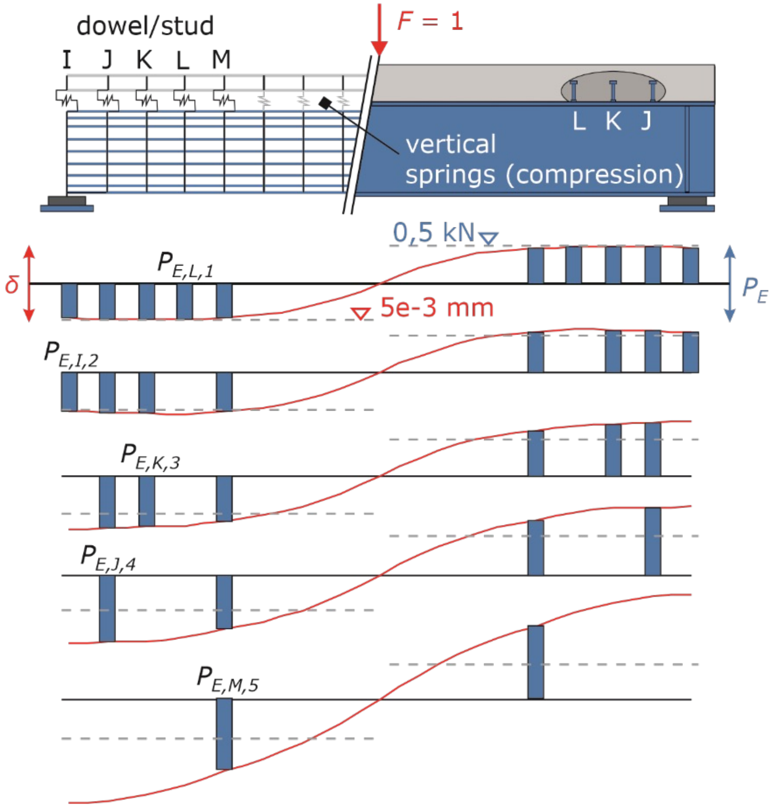
Composite beams with brittle shear connectors
Generalized system "shear connection"

Beam-spring-model

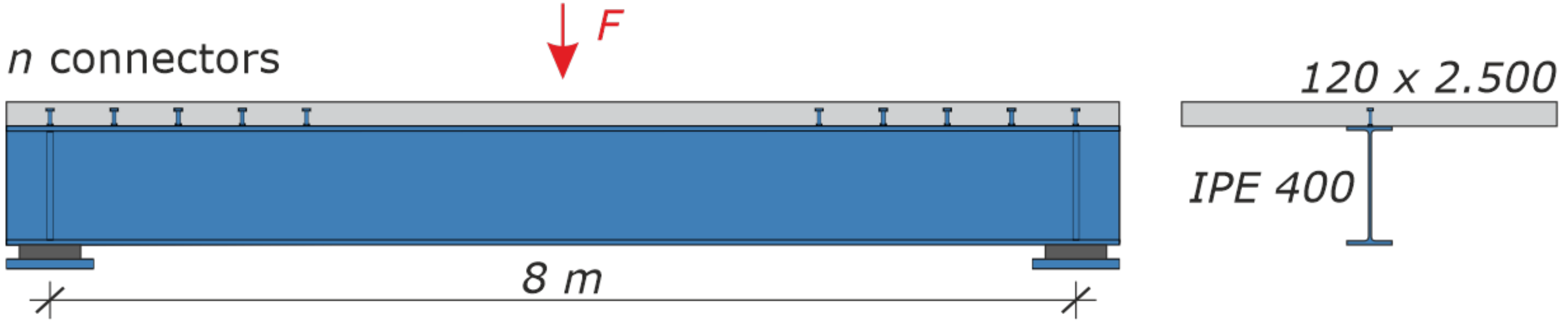
- Matlab-Code
- composite beam discretized into several lamellas, coupled by stiff bars
- user defined springs for shear connectors
    - 3 degrees of freedom (*UX, UZ, RotZ*)
    - brittle/ductile
    - deterministic or random
- used to determine dowel forces for each failure sequence
- scale F, so that $\sum P_{E,i} = n \cdot (\mu_{P,R} - \beta_1 \cdot \sigma_{P,R})$
- probability of system failure by union of all sequences, here:

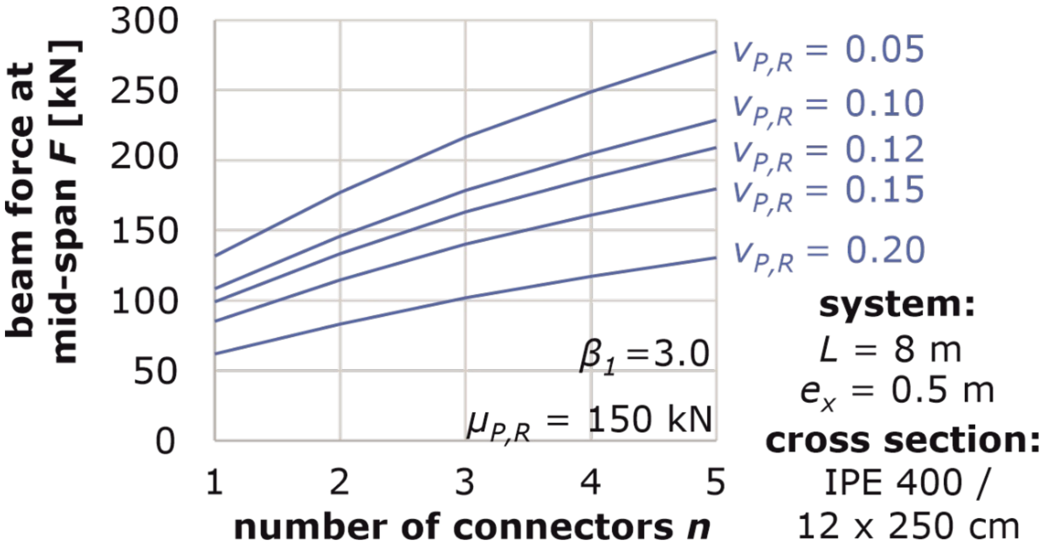
$$P_{R,L} \leq P_{E,L,1} \cap P_{R,I} \leq P_{E,I,2} \cap P_{R,K} \leq P_{E,K,3} \cap P_{R,J} \leq P_{E,J,4} \cap P_{R,M} \leq P_{E,M,5}$$

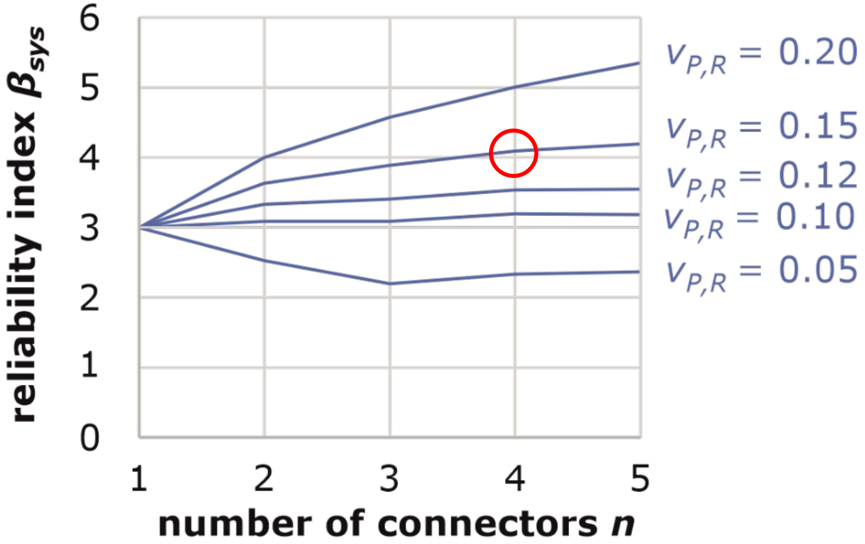
1.) calculation with beam-spring-model and *F=1*; determination of shear forces in connectors of *n!* possible failure sequences; here L - I - K - J - M



Composite beams with brittle shear connectors
System reliability of the shear connection





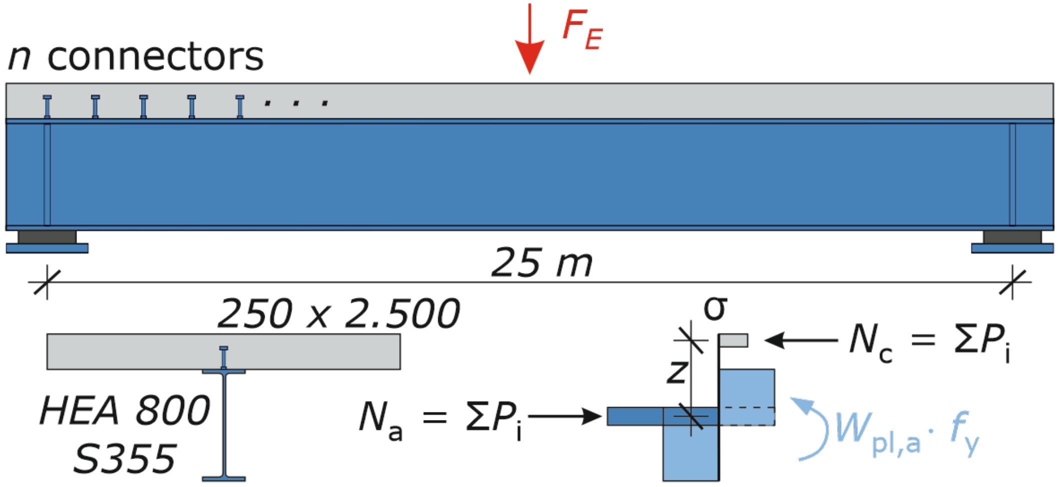


β	P_f
2	$2{,}28 \cdot 10^{-2}$
3	$1{,}35 \cdot 10^{-3}$
4	$3{,}17 \cdot 10^{-5}$
5	$2{,}87 \cdot 10^{-7}$

· 43

- scale F, so that $\sum P_{E,i} = n \cdot (\mu_{P,R} - \beta_1 \cdot \sigma_{P,R})$

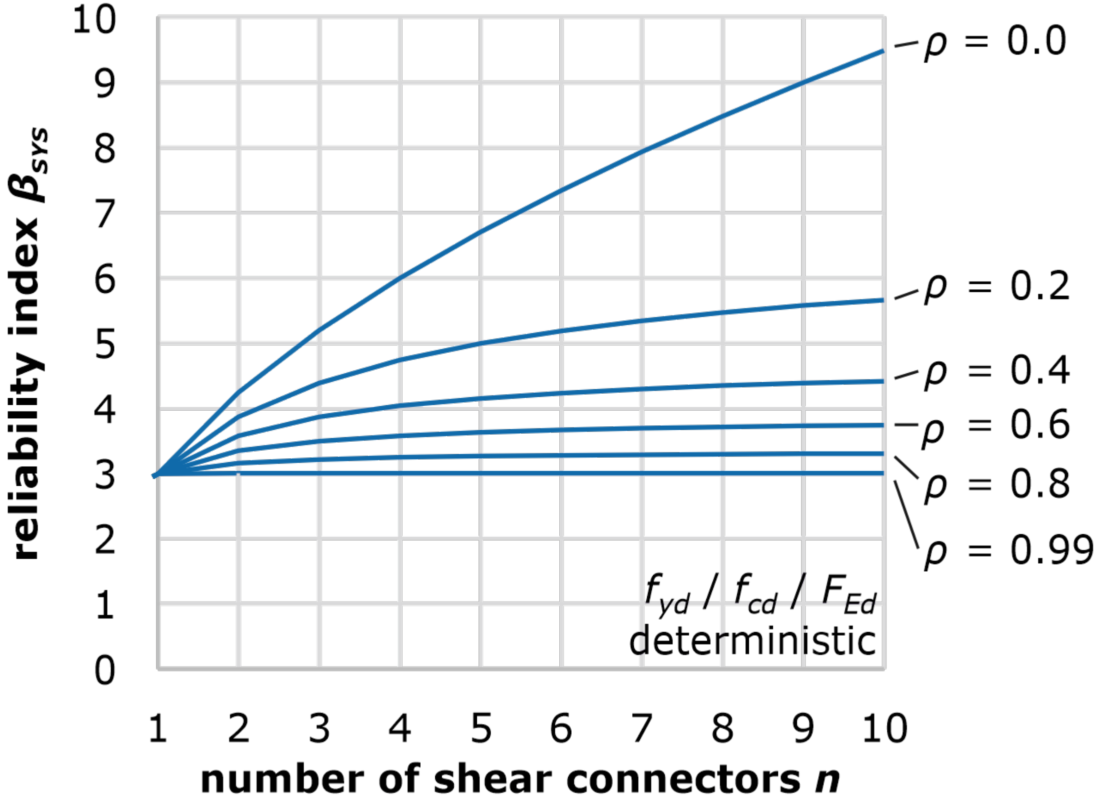
Composite beams with ductile shear connectors
System reliability of the shear connection



$$g = M_R - M_E = W_{pl,a} \cdot f_y + \sum P_i \cdot z - \frac{F_E \cdot L}{4}$$

$$z = \frac{h_a}{2} + h_c - \frac{1}{2} \cdot \frac{\sum P_i}{b_c \cdot (\alpha_{cc} \cdot f_c)} - \frac{1}{2} \cdot \frac{\sum P_i}{2 \cdot t_w \cdot f_y}$$

Calculation with *FORM*



(F_{Ed} scaled, so that $M_{Ed} = M_{Rd}$)

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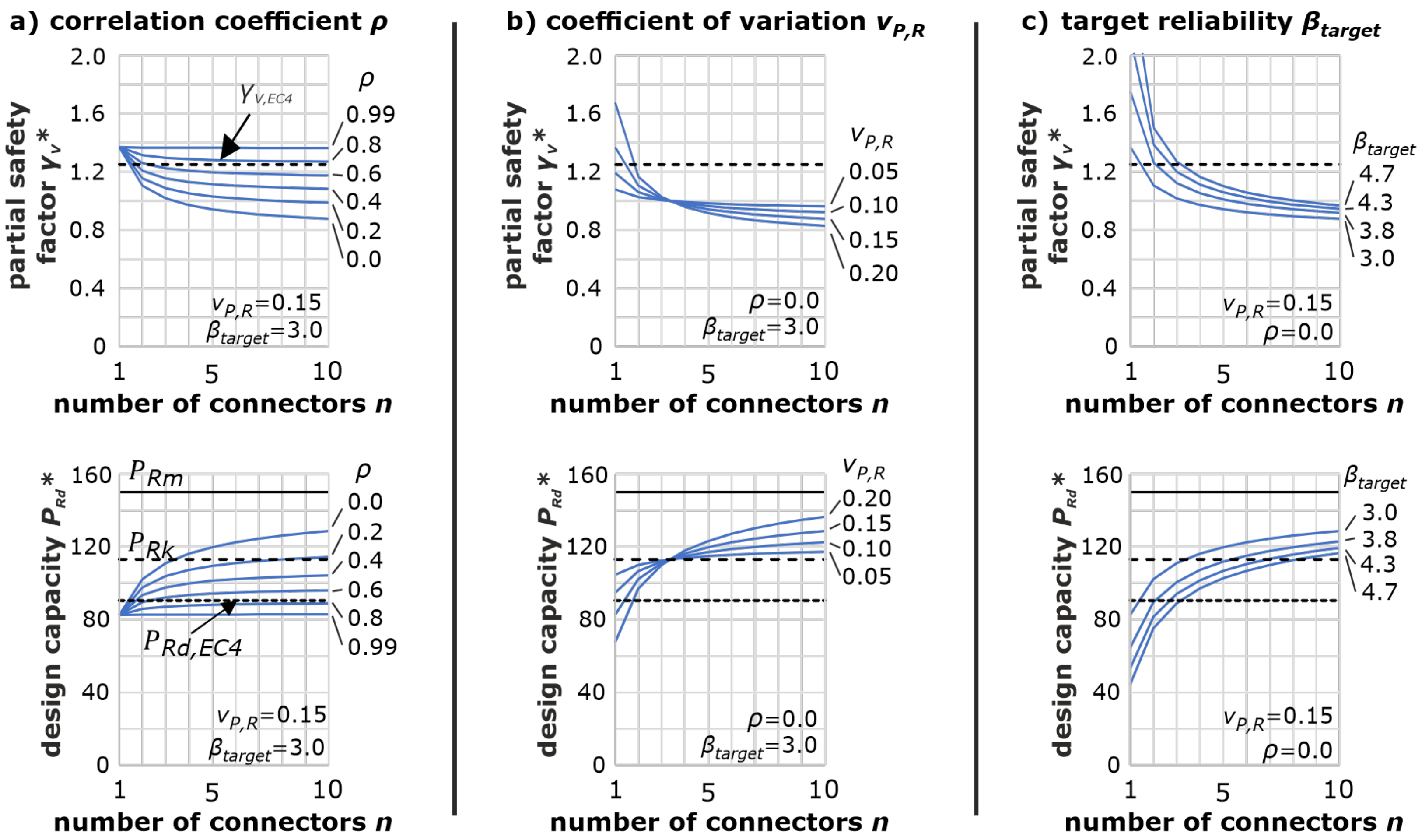
Composite beams with ductile shear connectors
System reliability of the shear connection

Can we raise the design level for shear connectors?

more connectors
→ higher safety level

OR

Keep safety level (β_{target})
→ recalibrate design level
P^*_{Rd} via γ^*_V



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Composite beams with ductile shear connectors

System reliability of the shear connection

Can we raise the design level for shear connectors?

more connectors
→ higher safety level

OR

Keep safety level (β_{target})
→ recalibrate design level
P^*_{Rd} via γ^*_V

$$\boxed{\gamma^*_V = \frac{1 - 1{,}645 \cdot \nu_{P,R}}{1 - \frac{1}{\sqrt{n}} \cdot \beta_{target} \cdot \nu_{P,R} \cdot \sqrt{1 + \rho \cdot (n-1)}}}$$

$$\boxed{n \geq \left(\frac{\beta_{target}}{1{,}645}\right)^2 \rightarrow \gamma^*_V \leq 1{,}0}$$

(for $\rho = 0$)

Conclusion and Outlook

System reliability of the shear connection

- In usual cases (moderate variation of dowel capacity; target reliability $\beta \geq 3$) significant increase of system reliability

- For ductile but also for brittle shear connectors

- Dependant on boundary conditions, assumptions, limit state functions

- Further investigations needed for a wide range of cross sections, material properties, stochastic assumptions of shear connector behaviour (variation, correlation, etc.), limit state functions

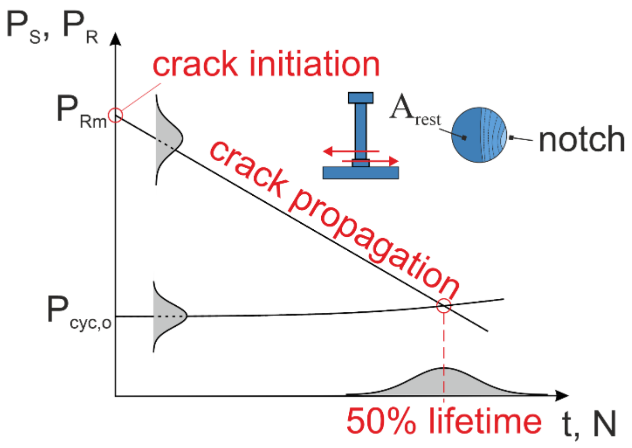
- Develop concept for hidden safeties in composite beams (recalculations existing structures, reach minimum degree of shear connection, etc.)

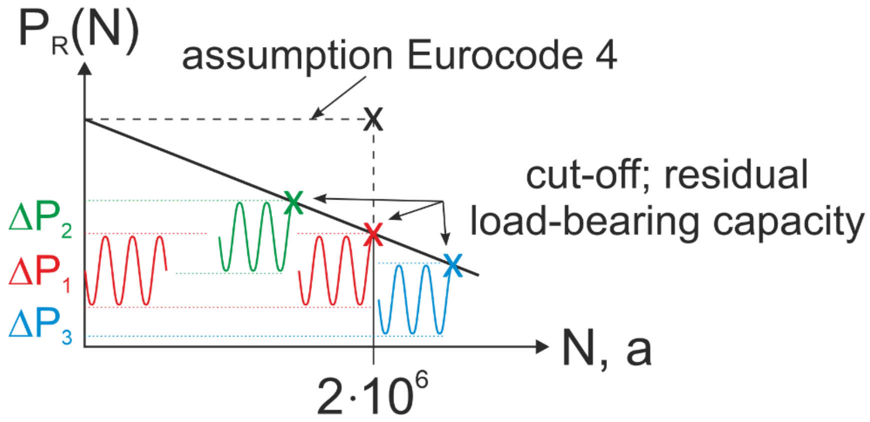
- Fatigue limit state

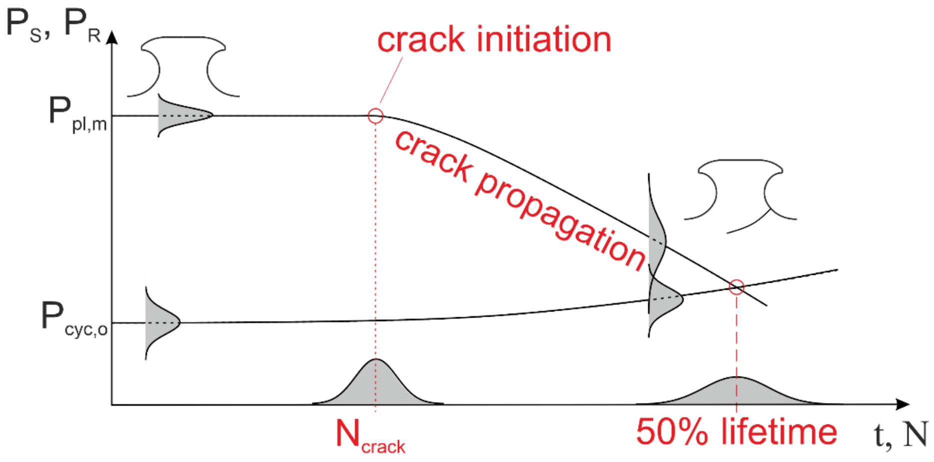
Conclusion and Outlook

Fatigue limit state

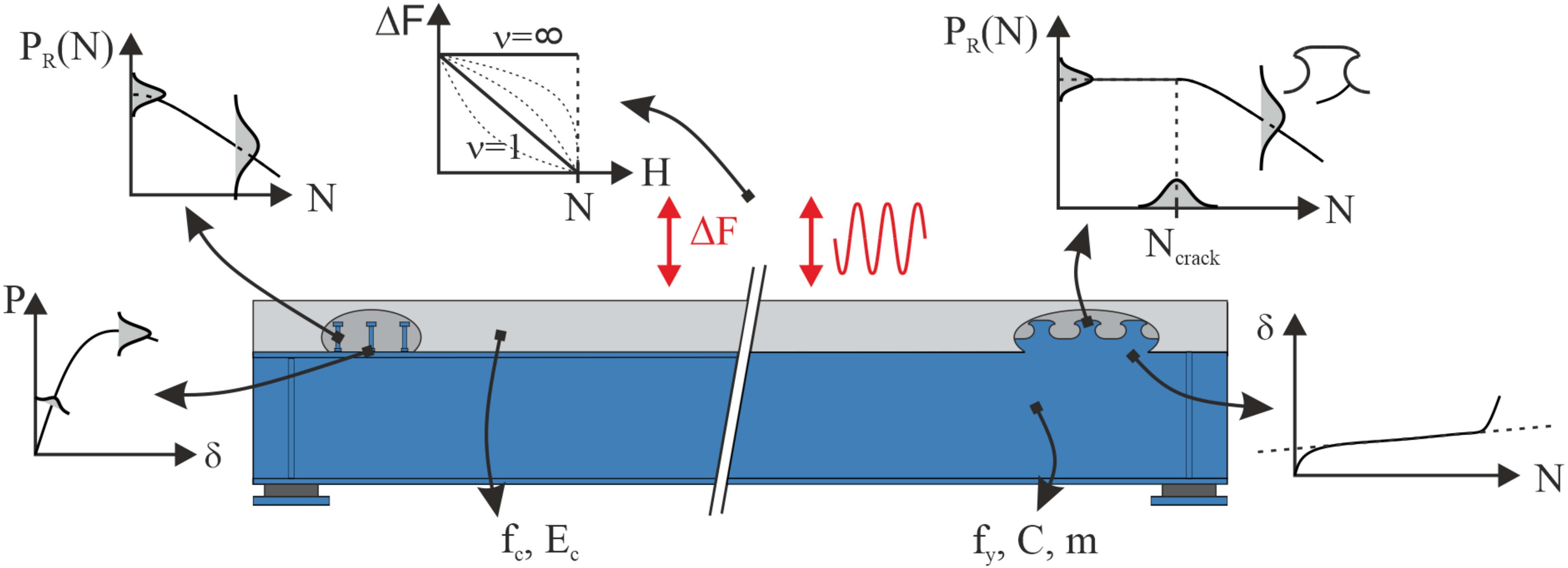
- Residual load-bearing capacity of composite dowels and headed studs after crack propagation







Thank you for your attention!



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