Thinking About Hidden Safety When Assessing Existing Structures

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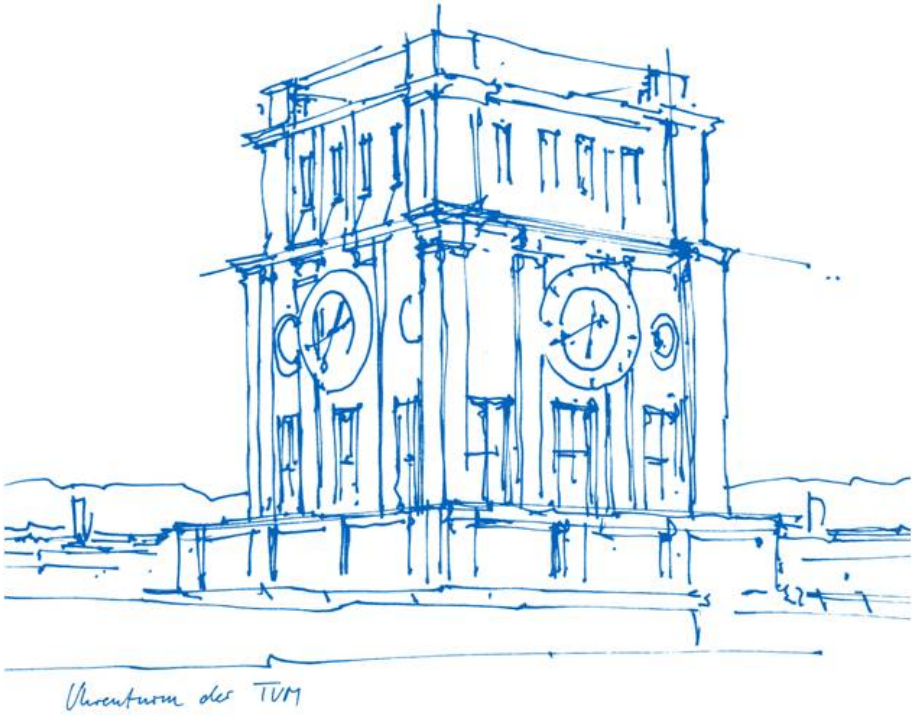
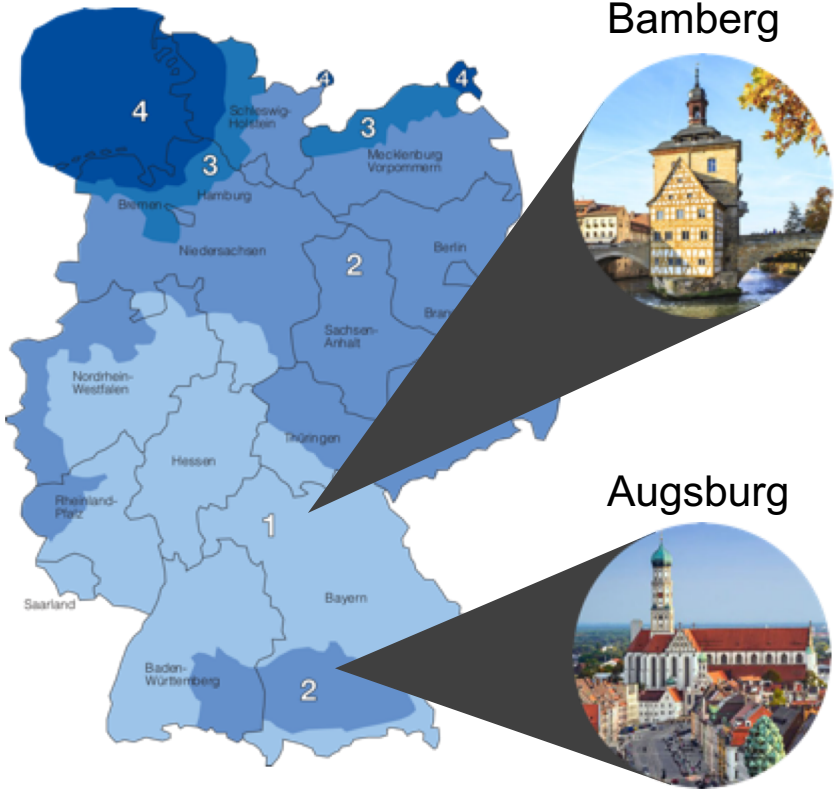


Hidden Safety

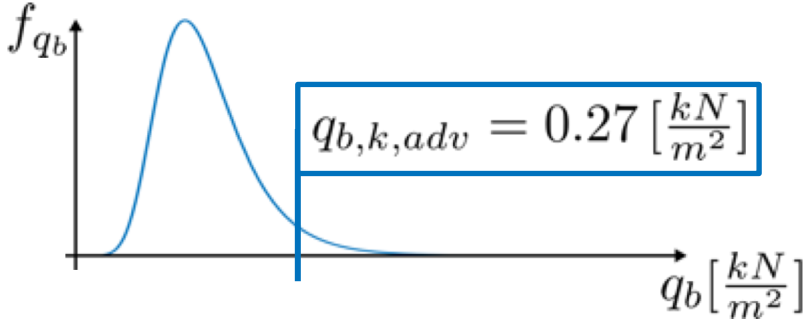
- Standard semi-probabilistic design codes include simplified models for ease-of-use
- Such simpler models are typically associated with a larger uncertainty
- To compensate for this uncertainty, model parameters are typically selected conservatively.
- This leads to a bias, which is referred to as Hidden Safety

Hidden safety: Wind load model of the Eurocode



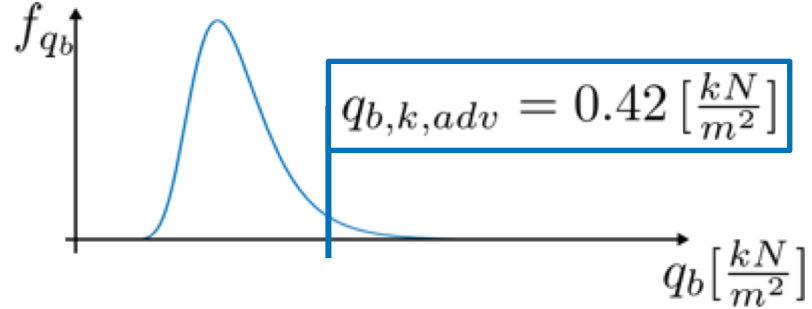
Bamberg

$$q_{b,k,EC} = 0.32\,[\tfrac{kN}{m^2}]$$



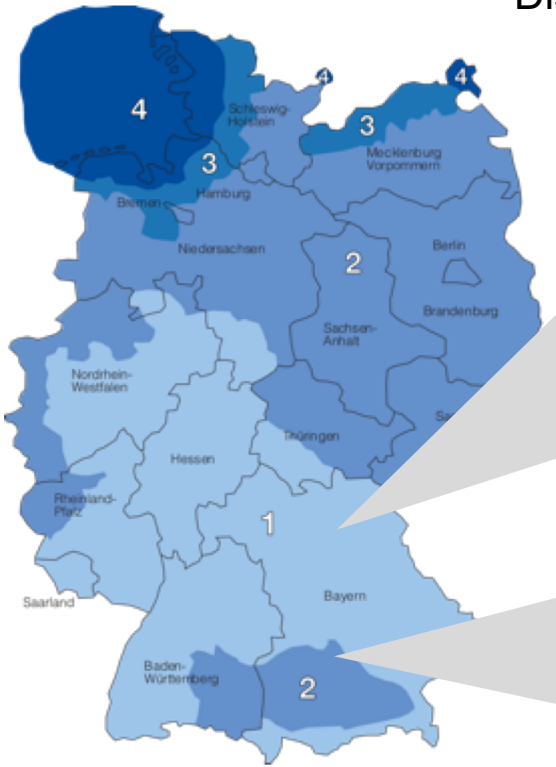
Augsburg

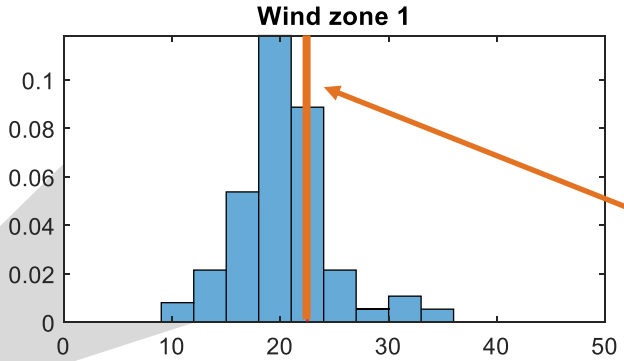
$$q_{b,k,EC} = 0.39\,[\tfrac{kN}{m^2}]$$

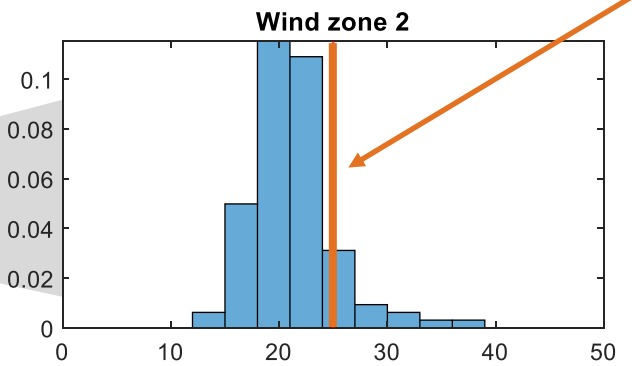


Hidden safety: Wind load model of the Eurocode

Distribution of characteristic wind speed over wind zones



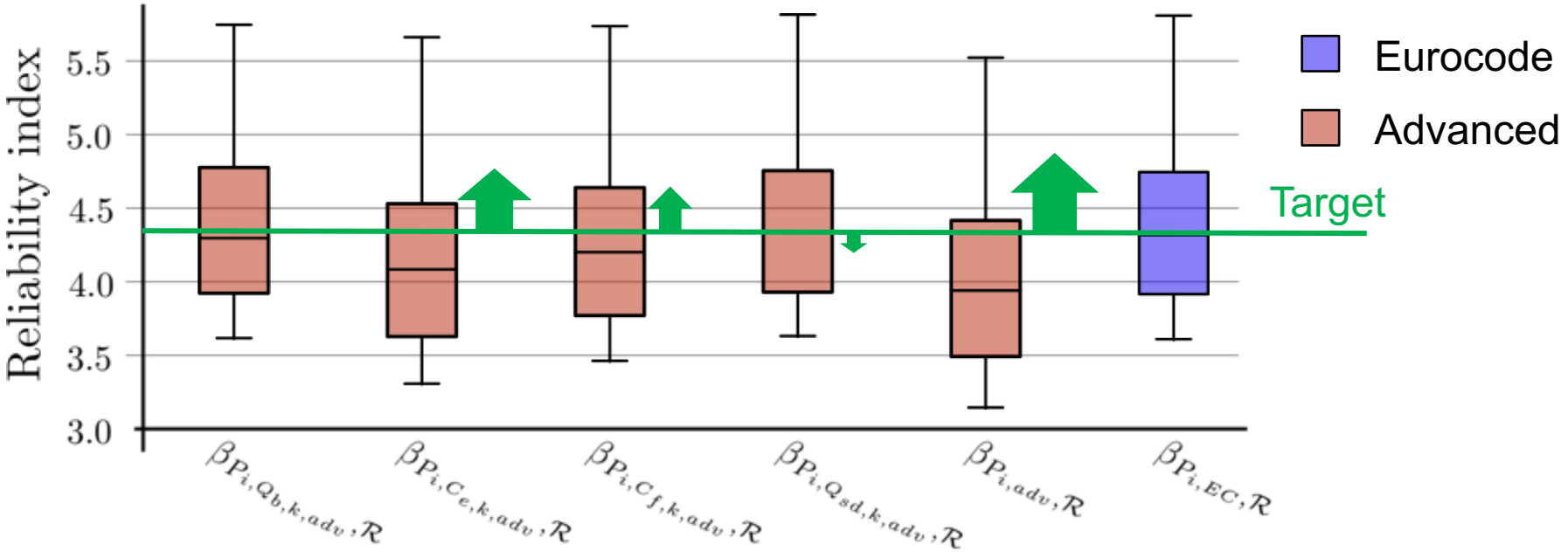




Characteristic value in code is higher than the average characteristic value

Effect of hidden safety in wind load modeling

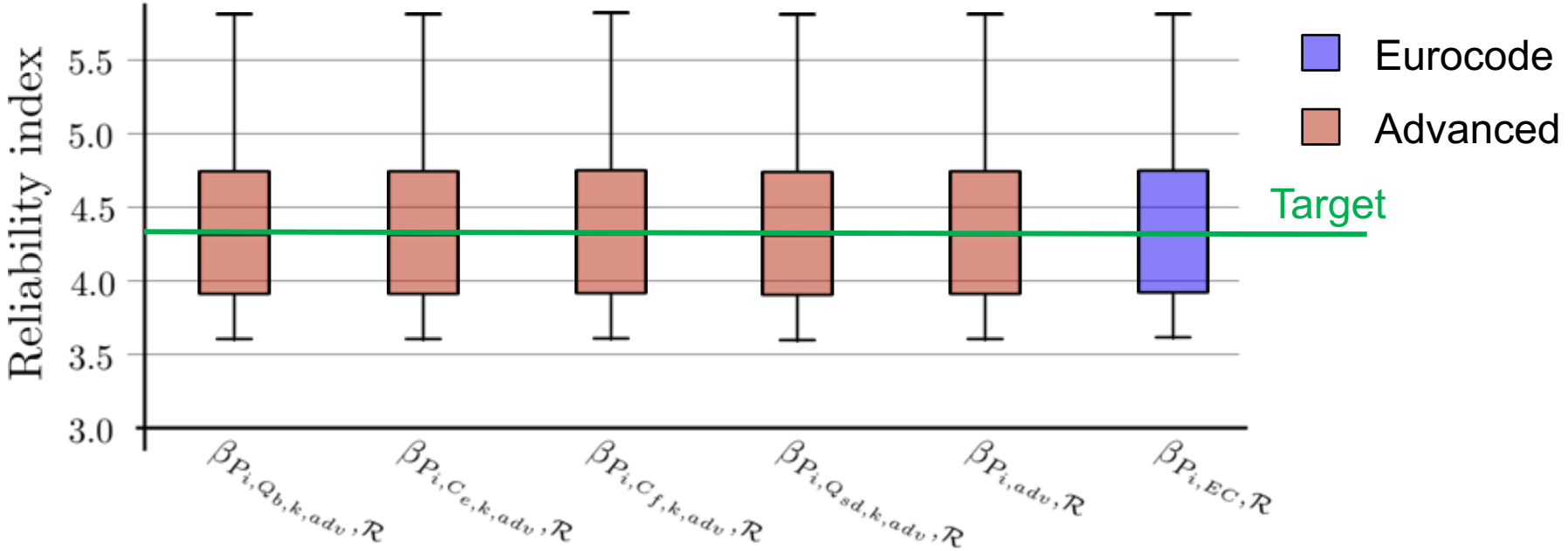
If advanced models were used for different elements of the wind load modelling chain:



Effect of hidden safety in wind load modeling

$\gamma_{Q,add}$	1.01	1.19	1.06	0.97	1.20

Additional safety factors needed to compensate for hidden safety



Assessing existing structures

Existing structures often do no longer comply with standards (changes in loads, deterioration, …)

Example Traffic load: Increases in vehicle weights lead to existing bridges no longer complying with code requirements

Traffic monitoring and simulation are increasingly utilized to obtain a more accurate load model, with the goal of demonstrating the safety of these existing bridges

Quote: „ An update following SIA 296 offers the opportunity to achieve a favorable assessment of an existing structure.“

(SIA 269: Codes for "Conservation of Structures“)

Question: What is the loss of hidden safety in the assessment of existing structures?

- Challenge:
  Answer is case specific and requires good models of model uncertainty and bias (hidden safety) in current models

- Our take here:
  Perform an idealized study to understanding the difference in advanced structural assessments between new-built structures and existing strucures

Idealized study

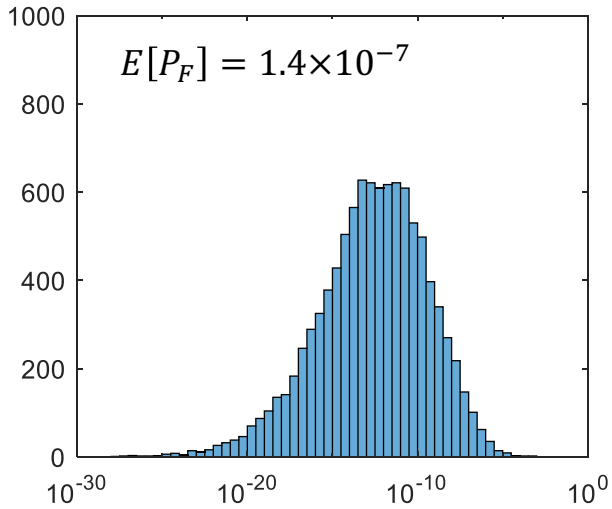
(inspired by a detailed assessment done for load traffic modelling)

- Limit state function: $g = \frac{\gamma_R \cdot \gamma_S \cdot S_{k,EC/adv}}{r_k} \cdot R - f_{inc} \cdot S$
- Probabilistic Setup: $R \sim \mathcal{LN}(1, 0.1)$
  $S \sim \mathcal{G}(1, 0.1)$
- Semiprobabilistic design: $\gamma_R = 1.1$ $\gamma_S = 1.35$
  $r_k \hat{=} 5\%$ $s_k \hat{=} 99.9\%$
- Relative error in the estimation of the characteristic load:
  - Standard model: $\Theta_{s_k,EC} \sim \mathcal{LN}(0.7, 0.15)$
  - Advanced model: $\Theta_{s_k,adv} \sim \mathcal{LN}(1, 0.1)$
- Load increase: $f_{inc} = 1.3$

Results – effect of advanced modeling in design

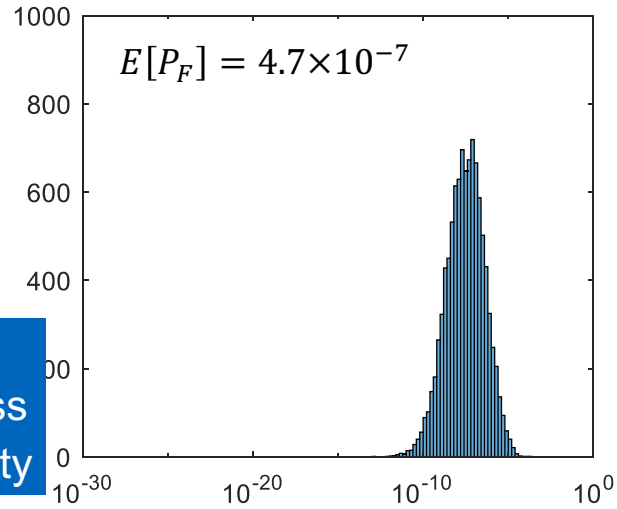
Distribution of probability of failure P_F over different structures

+ with original code-based design:



More efficient design, but loss of hidden safety

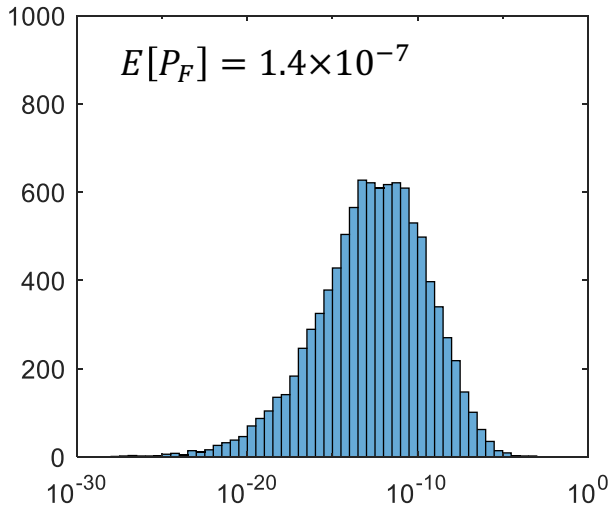
+ with advanced design:



Results – effect of increased loads

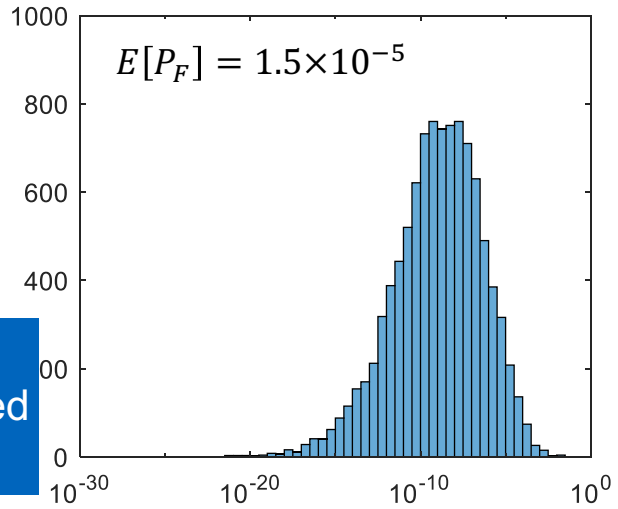
Distribution of probability of failure P_F over different structures

+ with original code-based design, original loads:



Load increase results in reduced reliability

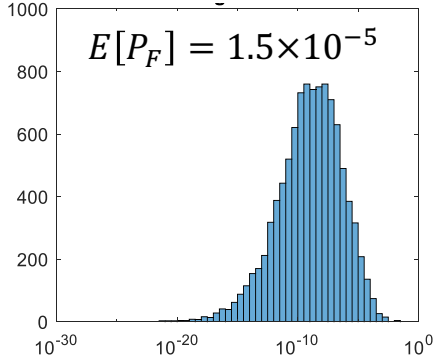
+ same structures, with increased loads



Note: with the standard assessment, none of the structures would be compliant after load increase

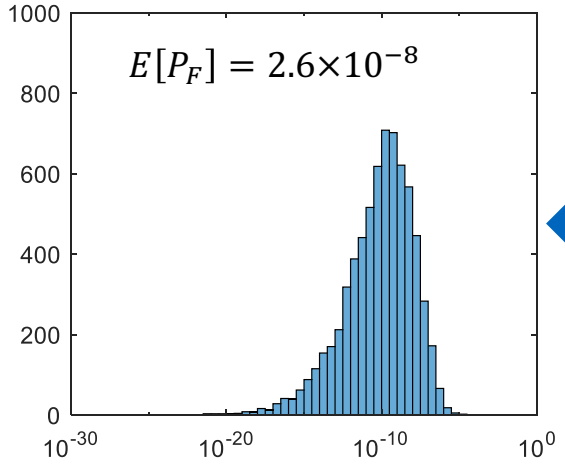
Results – existing structures after reassessment

+ original structures, with increased loads:

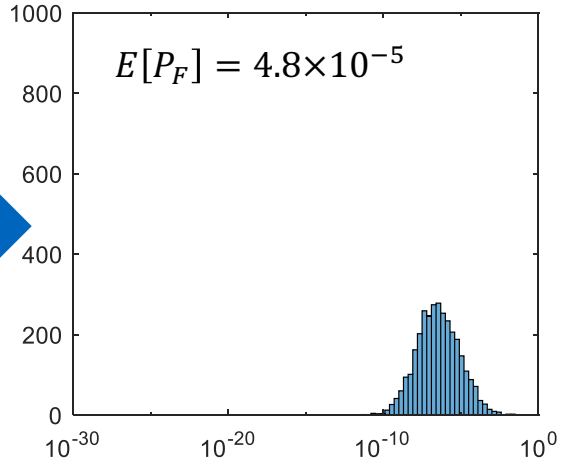


Advanced assessment

+ accepted structures (68.4%):

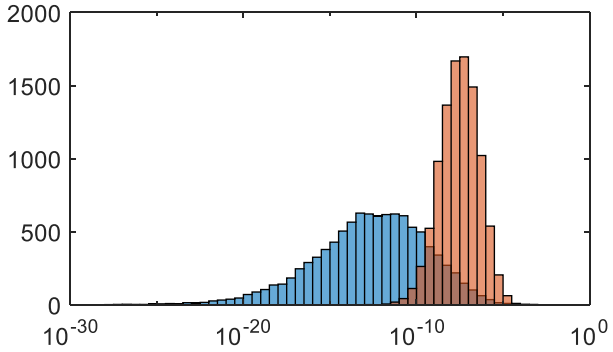


+ rejected structures (31.6%):

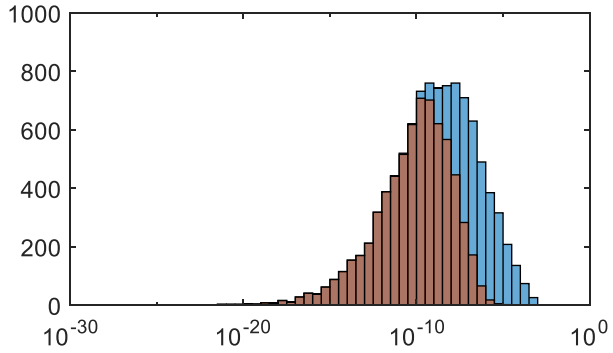


What is the difference between new designs and existing structures?

In **new structures**, advanced design leads to more optimized structures



In **existing structures**, advanced assessment enables to distinguish between safer and less safe structures



Conclusion

- Advanced design models and assessment mehodologies can lead to a more efficient design, but might reduce the reliability (unless that is compensated for)

- For existing structures with changes to loads and/or deterioration, advanced design models and assessment can be a way to separate the better-than-average from the below-average structure

- Hidden safety is also lost by this advanced assessment, but the effect on the overall average probability of failure is less pronounced than for new structures.

➢ It appears as if hidden safety is less of a concern for the assessment of existing structures than for new structures

Literature

Teichgräber M., Köhler J., Straub D.: Hidden Safety in Structural Design Codes. *Structural Safety*, under review.

Fußeder M., Teichgräber M., Bletzinger K., Straub D. (2021). *Grusibau 2.0*, Technical Report, Deutsches Institut für Bautechnik (DIBt), Berlin