


Calibration of partial factor design formats

Best practice and challenge

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Keynote

[Prof. Jochen Köhler](#)

[Download Jochen Köhler's course material](#)

- Design and assessment criteria for safety and cost efficiency
- Background document for further reading and reflection

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Monitoring and auscultation

Course material

by Jochen Köhler, 23./24.10.2020 / online

[View the Project on GitHub](#)
jochenkohler/INFRA_course_material_JK



Calibration - best practice and challenge

- [About the course](#)
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Course Material

- [Lecture Slides](#)
- [Lecture Notes](#)
- [Jupyter Notebook](#)

Keynote lecture

Abstract:

A rational basis for the specification of reliability requirements for design and assessment of structures is introduced and discussed in this lecture. It is thereby focused on the challenges related to the practical application of reliability requirements and aspects of standardization.

- [Keynote Slides](#)
- [Background document](#) for further reading and reflection

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Motivation for Calibration

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- Sustainable development of the build environment requires optimal balance between **safety** and **resource efficiency**.
- For **structural** design this balance can be identified using a **high** level design strategy - e.g. risk informed decision making.
- Daily life practical decisions require a simple and easy to use **low** level design strategy - e.g. partial factor design.

Levels of Structural Engineering Decision Making

	Commonly applied when:	Objective:
Risk-informed decision making: - decisions are taken with due consideration of the decision makers preferences.	Exceptional design situations in regard to uncertainties and consequences.	Maximize the expected utility of the decision maker.
Reliability-based design and assessment: - estimation of the probability of adverse events.	Unusual design situations in regard to uncertainties.	Satisfy reliability requirements.
Semi-probabilistic: - safety format prescribing design criteria in terms of the design equations and the analysis procedures to be used.	Usual design situations in regard to consequences and uncertainties. Default method of most design codes.	Satisfy deterministic design criteria.

Questions?

Reliability based design

How safe is safe enough?

Reliability requirement

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- the possible cause and /or **mode** of attaining a limit state;
- the possible **consequences** of failure in terms of risk to life, injury, potential economical losses;
- public **aversion** to failure;

How safe is safe enough?

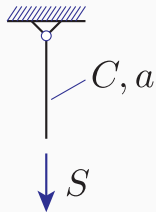
In the Eurocodes *appropriate* level of reliability is dependent on:

- the possible cause and /or **mode** of attaining a limit state;
- the possible **consequences** of failure in terms of risk to life, injury, potential economical losses;
- public **aversion** to failure;
- the **expense** and procedures necessary to **reduce** the risk of failure.

Reliability Class	Minimum values for β	
	1 year reference period	50 years reference period
RC3	5,2	4,3
RC2	4,7	3,8
RC1	4,2	3,3

Figure 1: Reliability requirements as stated in EN 1990:2002

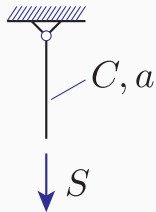
Reliability based design - a simple example



	μ	V
Capacity C [kN/mm^2]	1	0.10
Load S [kN]	1	0.34

C, S Normal distributed.

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- Reliability is always dependent on specified **reference time**.

Questions?

Design Value Format

Derivation of design values

Based on the simple reliability problem:

$$\beta = \frac{\mu_R - \mu_S}{\sqrt{\sigma_R^2 + \sigma_S^2}} \quad (1)$$

And

$$\beta \stackrel{!}{=} \beta_{req}$$

Design values and characteristic values

The **design value** of a basic variable Y is defined as the multiplication or division of a corresponding **partial safety factor** γ_Y and the characteristic value y_k :

$$\frac{r_k}{\gamma_R} = r_d \geq e_d = \gamma_E e_k \quad (2)$$

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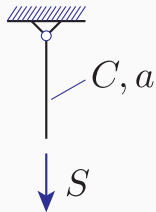
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Note: Typical values for p are:

- resistance related variables: $p = 0.05$;
- permanent actions: $p = 0.5$;
- time-variable actions (yearly reference period): $p = 0.98$.

Design value format - a simple example



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Design value format - generalisation to other distributions

Normal:	$y_d = \mu_Y (1 + \alpha_Y \beta_t V_Y)$ $y_k = \mu_Y (1 + \Phi^{-1}(p) V_Y)$
Log-Normal:	$y_d = \mu_Y \exp \left(-\frac{1}{2} \ln (1 + V_Y^2) + \alpha_Y \beta_t \sqrt{\ln (1 + V_Y^2)} \right)$ $y_k = \mu_Y \exp \left(-\frac{1}{2} \ln (1 + V_Y^2) + \Phi^{-1}(p) \sqrt{\ln (1 + V_Y^2)} \right)$
Gumbel:	$y_d = \mu_Y \left(1 - V_Y \frac{\sqrt{6}}{\pi} (0.5772 + \ln (-\ln (\Phi(\alpha_Y \beta_t)))) \right)$ $y_k = \mu_Y \left(1 - V_Y \frac{\sqrt{6}}{\pi} (0.5772 + \ln (-\ln (p))) \right)$

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- ... but only for **specific design cases**.
- The α values are case specific and their determination may be cumbersome.
- Both, α and the extreme value distribution representing the variable load have to relate to the same **time reference period** than the reliability target.

Questions?

Generalising α

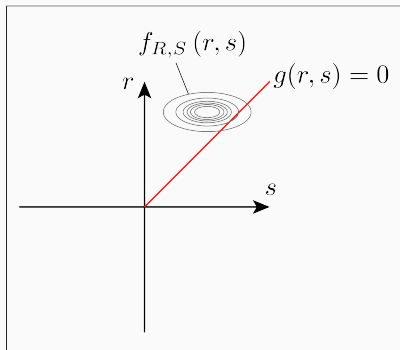
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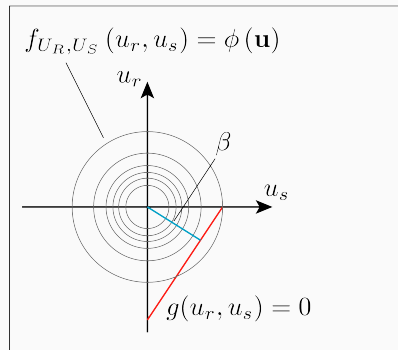
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- **Alternative representation** of the reliability problem for an informed choice.

Hasofer-Lind representation of reliability problem

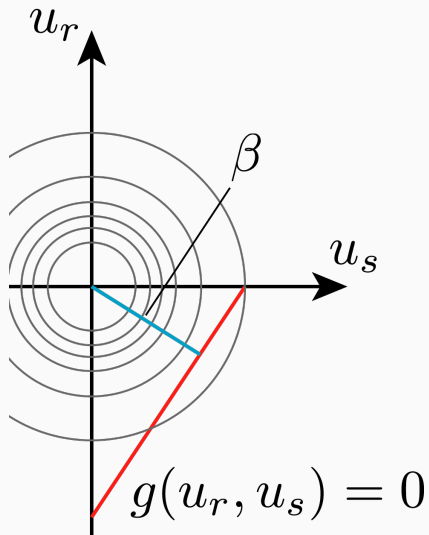
real space



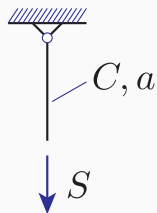
u -space



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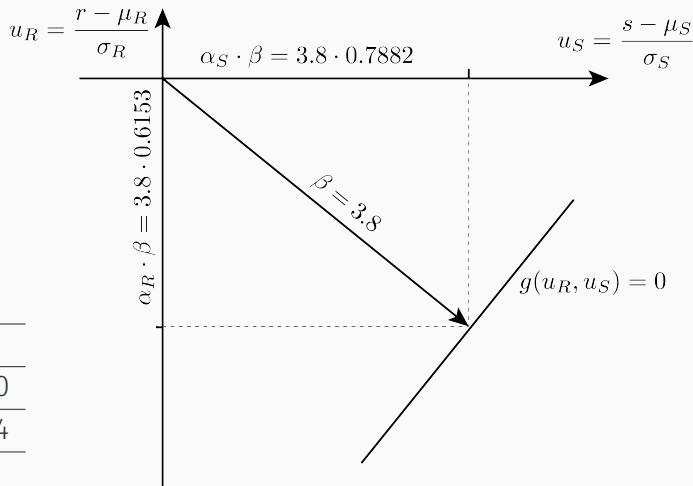


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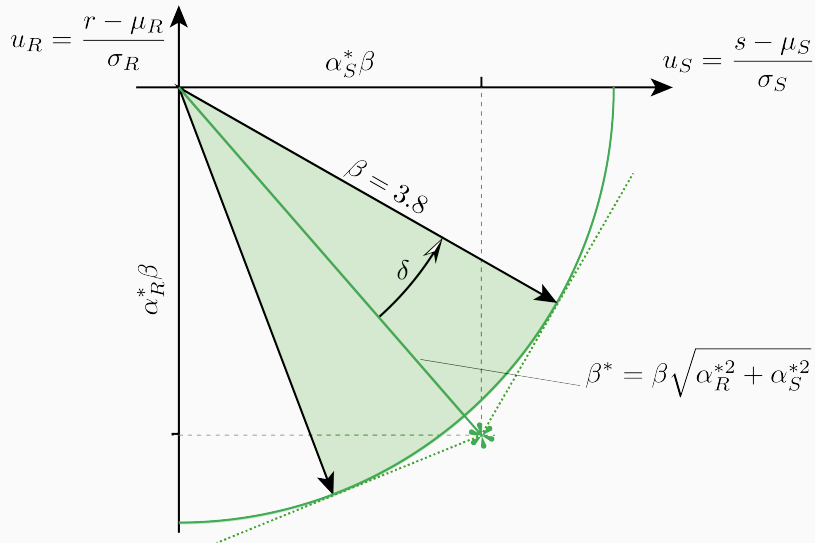


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Generalisation



Generalisation chosen in the Eurocode

The following Eurocode standardized values can be used for a 50 years reference period:

- If Y represents a strength related variable: $\alpha_Y = -0.8$
- If Y represents a load related variable: $\alpha_Y = 0.7$
- If Y is dominating the reliability problem: $\alpha_Y = (-)1$
- If Y represents a secondary strength or load related variable: $\alpha_Y = -0.8 \cdot 0.4$ or $\alpha_Y = 0.7 \cdot 0.4$ correspondingly.

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 - safe by large margin, that corresponds to unnecessary use of material.
- Especially the application of the generalised α -value on single variables in isolation is not effective and, as demonstrated in this note, the obtained safety levels are partly not acceptable.
- It is recommended to reconsider the recommendation of the design value approach with its generalised α -values in the revision of the Eurocodes.

Questions?