



NTNU

Faculty of Engineering
Department of
Structural Engineering

Structural Safety Criteria

A brief introduction to principles and challenges of reliability based design and assessment

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Structural Safety

- a principle demand



Structural Safety for New Structures

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- **Quality Control**
 - Assuring that planning, design, execution and use is according to specifications and no errors are present.

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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;

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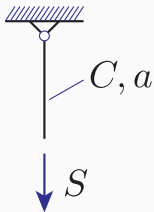
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- the possible cause and /or **mode** of attaining a limit state;
- the possible **consequences** of failure in terms of risk to life, injury, potential economical losses;
- public **aversion** to failure;
- the **expense** and procedures necessary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

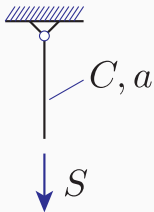


	μ	σ
Capacity C [kN/mm^2]	1	0.10
Load S [kN]	1	0.34

C, S Normal distributed.

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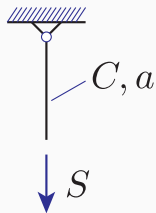
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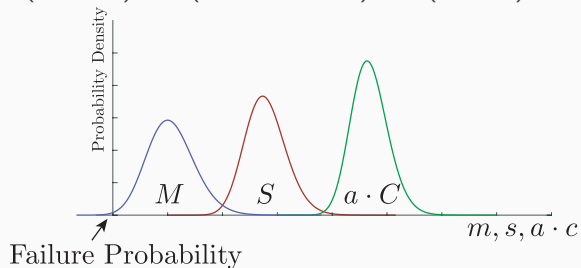
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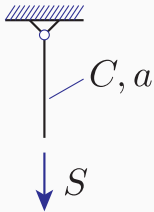
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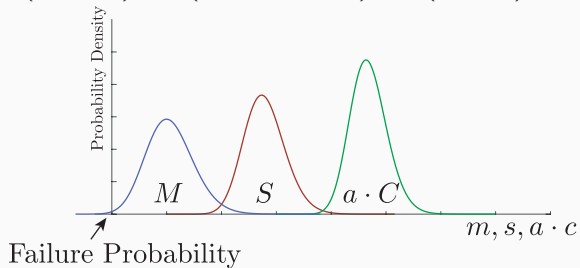
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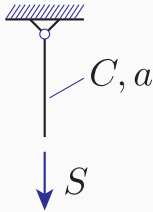
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$$P(M < 0) = \Phi\left(\frac{0 - \mu_M}{\sigma_M}\right) = \Phi\left(\frac{-a \cdot \mu_C + \mu_S}{\sqrt{a^2 \sigma_C^2 + \sigma_S^2}}\right) = \Phi(-\beta)$$

Reliability based design - a simple example



Reliability based design with target reliability $\beta_t = 3.8$:

$$a \text{ such that } \beta_{req} = 3.8 \leq \beta = \frac{a \cdot \mu_C - \mu_S}{\sqrt{a^2 \sigma_C^2 + \sigma_S^2}}$$

In this example equality is obtained for $a = 2.615 \text{ mm}^2$.

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Reliability based design - discussion

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- The achieved reliability is **conditional on utilised knowledge** - the reliability based design solution is also conditional on knowledge!
- Reliability is always dependent on specified **reference time**.

Practical Design

Recapturing the Example from above, Safety/Reliability is evaluated based on a limit state function:

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In practical design, Safety/Reliability is evaluated based on *Design Equations* that are related to the limit state:

$$a \cdot \frac{c_k}{\gamma_C} - \gamma_S \cdot s_k < 0$$

Here, the random variables are replaced by a combination of so-called characteristic values (c_k, s_k) and safety factors (γ_C, γ_S). No reliability analysis is necessary.

According to the Eurocode Design Equations are generally used. Corresponding information is provided by the standard, i.e.:

- safety factors for different structural materials and loads,
- characteristic values for material strength, load intensity,
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- safety factors for different structural materials and loads,
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The information is generalised and valid for the design of new structures!

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- safety evaluated at single cross sections individually.

Intermediate Conclusion

- practical design based on generalized information and subject to simplifications,

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- practical design based on generalized information and subject to simplifications,
- reliability requirement not to be seen as absolute but relative to the generalized and simplified representation.
- **However**, the approach works: Structures are perceived safe and (sufficiently) efficient.

Structural Safety of Existing Structures



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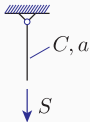
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- **Change in use**
 - Change in use implies different loading than projected and requires reassessment.

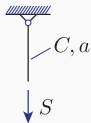
Reliability reassessment - a simple example (cont.)



	Type	μ	σ
Capacity C [kN/mm^2]	Logn	1	0.10
Load S [kN]	Gumbel	1	0.34
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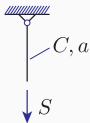


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- The reliability becomes time dependent (and the decay of reliability can be predicted based on the model assumptions).

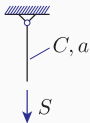
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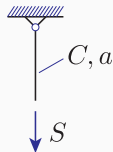
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- The consideration of information has a direct effect on the computed reliability!

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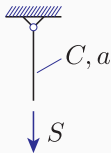
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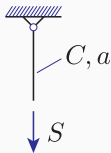
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- Measurements/observations provide often only indirect information, updating requires likelihoods and these are difficult to specify.

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- Mitigation measures are costly and often hard to implement.



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- Safety requirements from the codes are used in practice for both, design and assessment situations.
- What problems does this imply?

Questions?