JCSS

Joint Committee
on Structural Safety

Workshop on Assessment of Existing Structures

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fib TG 3.1 Developments Concerning Semi-Probabilistic Format

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KI 100th ANNIVERSARY OF THE KLOKNER INSTITUTE CTU IN PRAGUE

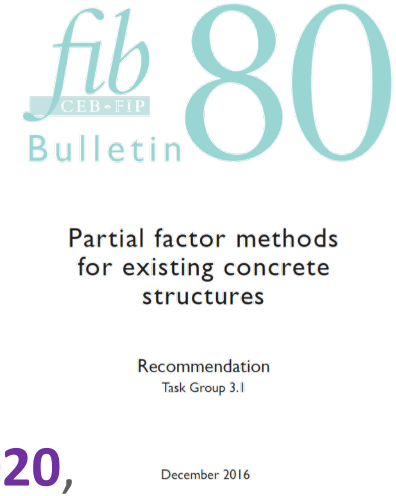
OTH OSTBAYERISCHE TECHNISCHE HOCHSCHULE REGENSBURG

1. INFORMATION ON TG3.1

Full-probabilistic and semi-probabilistic methods for existing structures

Chairs and technical secretary: Miroslav Sykora, Raphaël Steenbergen (TNO Delft), Wouter Botte (Ghent University), 22 active out of 31 members

- ***Reliability*** and (risk) ***assessment*** of existing structures
- ***Target levels*** for assessment and retrofitting
- ***Fully probabilistic*** reliability analysis
- ***Semi-probabilistic*** assessment of existing structures


fib CEB-FIP Bulletin 80

Partial factor methods for existing concrete structures

Recommendation
Task Group 3.1

December 2016

but also revision of ***basis for design*** in Model Code **MC 2020**, including **partial factors**

2. VERIFICATION FORMATS/ METHODS

- **Partial factor method**
- Reliability based method
- Risk informed method

hierarchy compatible to **prEN1990** (version 22-09-2020, Annex C)

C.3.1 Overview of reliability verification approaches

Method: *the greek word* ***methodos*** *means* ‘pursuit of knowledge’, from *meta-* (expressing development) + *odos* (way)

3. TARGET RELIABILITY IN MC2020

Table 5.2-2: Annual target β-values for Ultimate Limit States based on economic optimisation (examples), adopted from (JCSS, 2001) and ISO 2394

Relative cost of safety measure	**Consequence Class** CC1	CC2	CC3	
Large (A)	3.1	3.3	3.7	assessment
Normal (B)	3.7	**4.2**	4.4	design
Small (C)	4.2	4.4	4.7	

Table 5.2-3: Informative target reliability indices β for structures to be designed, related to a 50-year reference period

Consequence Class CC1	CC2	CC3
3.3	**3.8**	4.3

REASONS FOR INTRODUCING ANNUAL TARGET LEVELS

- Complies with concept of ***systematic repairs***.
- Changing reference period from 50 years to 1 y. ***decreases scatter of β-levels*** for different load ratios and fixed α-factors.

  Meinen & Steenbergen - Reliability levels obtained by Eurocode partial factor design…, Heron
- Target levels need not be recalculated for existing structures with ***different service lives***.
- ***More consistent with regulations/ acceptance criteria*** related to life safety
  - no need for averaging of human risks over longer periods
- More suitable for ***rapid degradation*** (fatigue) – no averaging over 50 years when failure is likely in last few years

  Steenbergen, Rozsas, Vrouwenvelder - Target reliability of new and existing structures…, Heron
- ***Updating*** considering new information (proof loading, tests, measurements, satisfactory past performance) is more illustrative.

4. PARTIAL FACTOR FORMAT

Inequality for verification with assessment values:

$$E_a \leq R_a$$

Assessment value of action effects is determined in the same way as design value, but substituting values of all design parameters by corresponding values for assessment.

Partial factors can be set **fixed** or can be **adjusted**

a) **Fixed partial factors**

cluster of cases: e.g. consequence classes

b) **Adjusted (flexible) partial factors**

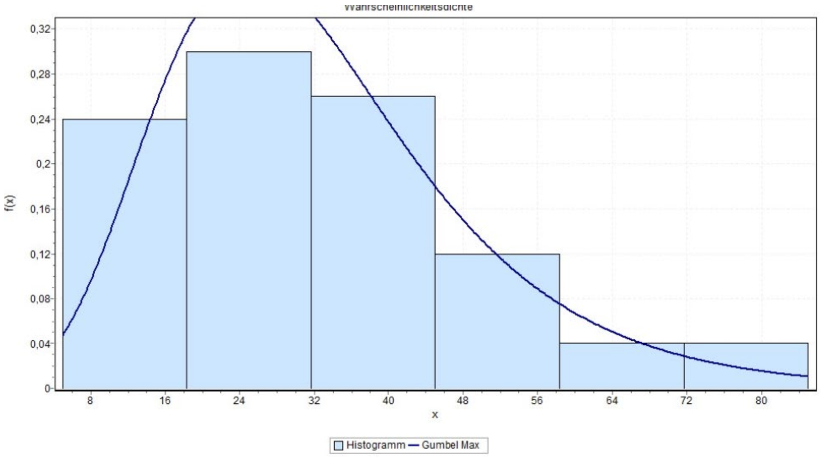
individual case

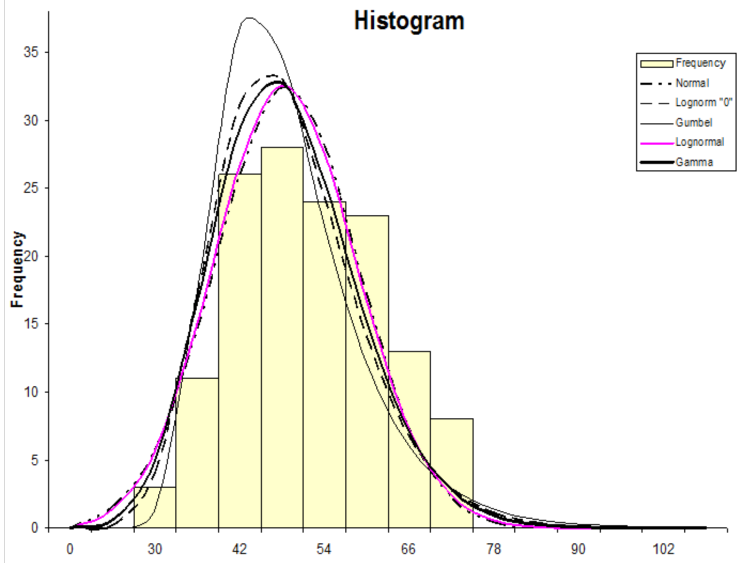
Partial factors γ depend on:

- Target reliability index β_t: reduced values
- Sensitivity factor α: rule for the values (s. EN 1990-1 C.4.4.2)
- Distribution type and parameters (updated)

The updating methods can be applied in accordance with the principles given in JCSS Probabilistic Assessment of Existing Structures and fib Bul. 80.

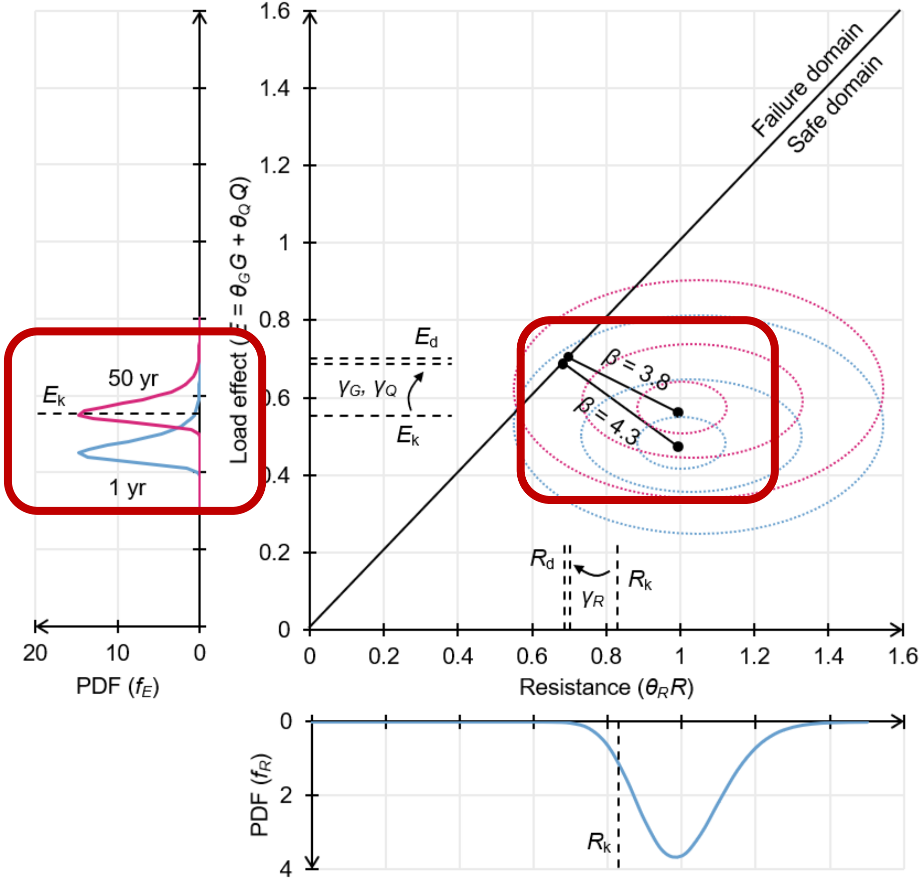
Snow height on ground 40 years





MC2020, 6.4.3 Partial factor format

- Change $\beta_{50} \rightarrow \beta_1$ should be accompanied by ***changes of sensitivity factors***!



Parameter type	Influence	Coefficient
Resistance	Leading	0.8
	Accompanying	0.4 · 0.8 = 0.[illegible]2
Load effect	Leading	-0.7
	Accompanying	-0.4 · 0.7 = -0.28

Parameter type	Influence	Coefficient
Resistance	Leading	0.7
	Accompanying	0.4 · 0.7 = 0.28
Load effect	Leading	-0.8
	Accompanying	-0.4 · 0.8 = -0.32

MC2020, 6.4.3 Partial factor format

Table 6.4.3-y2: Recommended values of the partial factors γ_M for materials (design)

CC γ_M

Always *update* for existing structures!

Table 6.4.3-5: Recommended values of the partial factors γ_M for materials for assessment to verify the need of safety measure(s)

CC	γ_M			
	γ_C		γ_S	
$V_{fc,is}$ = 0.08		0.15	finished str.	normal unc. in geo.
CC1	1.10	1.10	0.975	1.075
CC2	**1.125**	1.15	**1.0**	1.075
CC3	1.15	1.20	1.0	1.1

5. DISCUSSION

- Probabilistic model of *I*

$E_Q \approx$ model unc. x t

shape, gus

Time-invariant coefficie

Variable load	Proba (P$_{C0}$) [
Imposed (C_{0Qimp})	Gumbel
Wind (C_{0W})	0.95
Road traffic (C_{0T})	-
Snow (C_{0S})	0.9

Time-variant components

Variable load, load parameter	Ref. period	Probab. P_{Qk} [-]	CoV (V_Q) [-]	Bias (μ_Q / Q_k) [-]
Imposed (Q_{imp})	5 years	0.995	1.1	0.20
	50 years	0.95	0.37	0.59
Basic wind speed (v_b)	1 year	0.98	0.15	0.72
	5 years	0.904	0.13	0.86
	50 years	0.364	0.10	1.05
Basic wind pressure ($W = v_b^2$)	1 year	0.960	0.32	0.60
	5 years	0.817	0.23	0.85
	50 years	0.132	0.16	1.19
Road traffic (T)	1 year	0.999	0.075	0.73
	5 years	0.995	0.069	0.80
	50 years	0.95	0.061	0.90
Ground snow load (S)	1 year	0.98	0.65	0.37
	5 years	0.904	0.36	0.68
	50 years	0.364	0.22	1.11

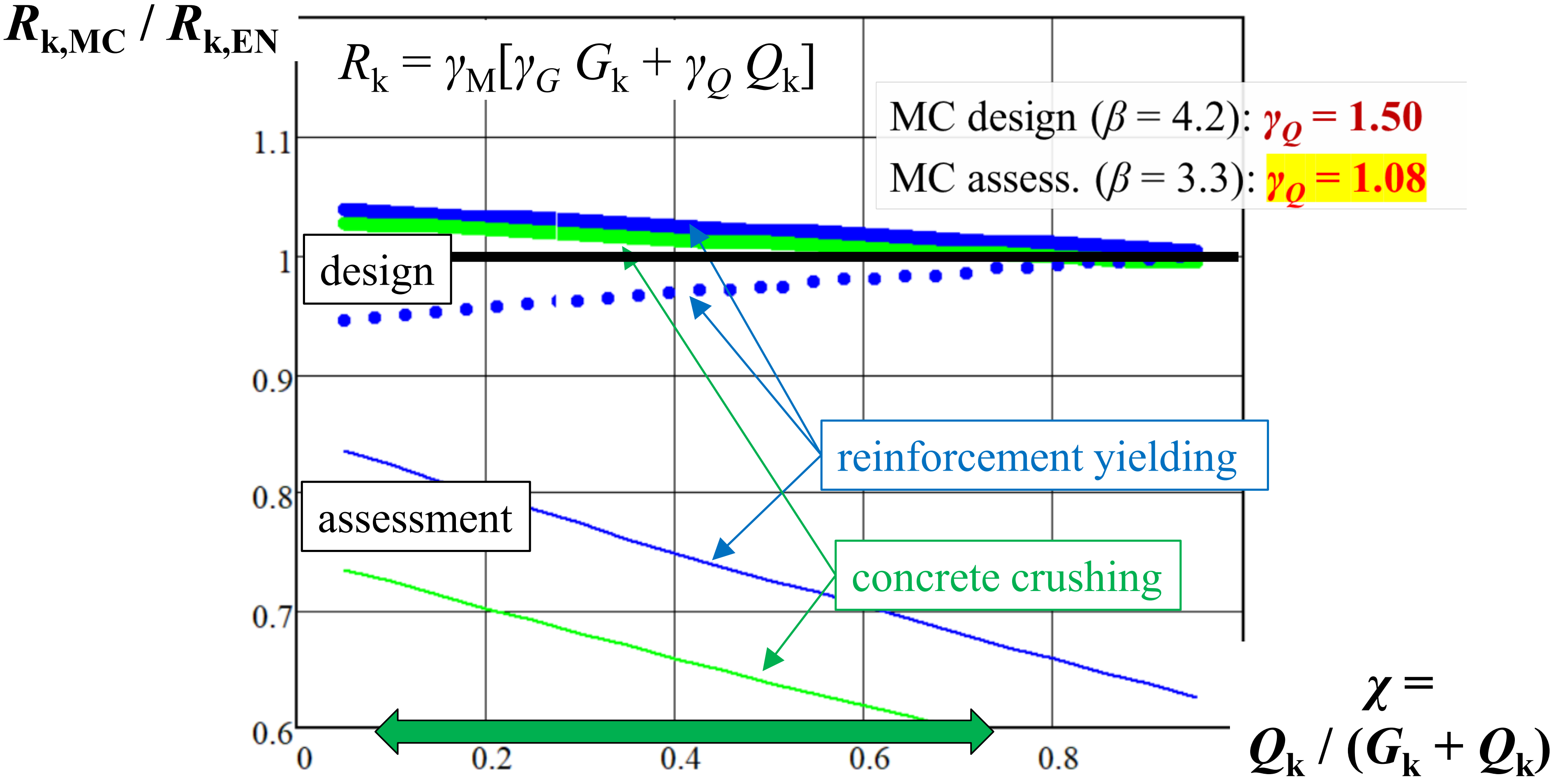
Why does $\gamma_{S,design}$ = 1,15 reduce to $\gamma_{S,assess}$ = 1,0?

- ‚**Global‘ partial** factor:

  $\gamma_M \approx [\exp(-1.645 V_f)] / [\mu_{\theta R}\, \mu_a \exp(-\alpha_R\, \beta \sqrt{(V_{\theta R}^2 + V_a^2 + V_f^2)})]$

- MC design - $\gamma_{S,design}$ = 1,15:
  - V_f = 0,045; $\mu_{\theta R}$ = 1,09 and $V_{\theta R}$ = 0,045
  - normal uncertainty in geometry: μ_a = 0,95 and V_a = 0,05
  - for t_{ref} = 50 y.: α_R = 0,8 and β = 3,8
- Changing t_{ref} = 1 y.: α_R = 0,7 and β = 3,3 gives $\gamma_{S,assess}$ = 1,08
- Assuming further effective depth is based on measurements on existing structure, μ_a = 1 and V_a = 0,01 apply, yielding $\gamma_{S,assess}$ = 0,99

Comparison of resistances (CC2, imposed load)



6. CONCLUSIONS

- **Fixed partial factors** recommended for **conventional cases**
  MC assessment (β_t = 3.3)

- **Adjusted partial factors** for **individual cases** where:
  - overcoming degree of approximation with fixed values
  - for key members, improved production or execution quality etc.

- **Ongoing numerical checks**

- **Further development** of reliability-based and risk-informed assessment (beyond the scope of MC 2020)

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Thank you for your attention!

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