

Sustainability potential of safe structures

JCSS Advanced Course on the Probabilistic
Model Code 2025

Jochen Köhler

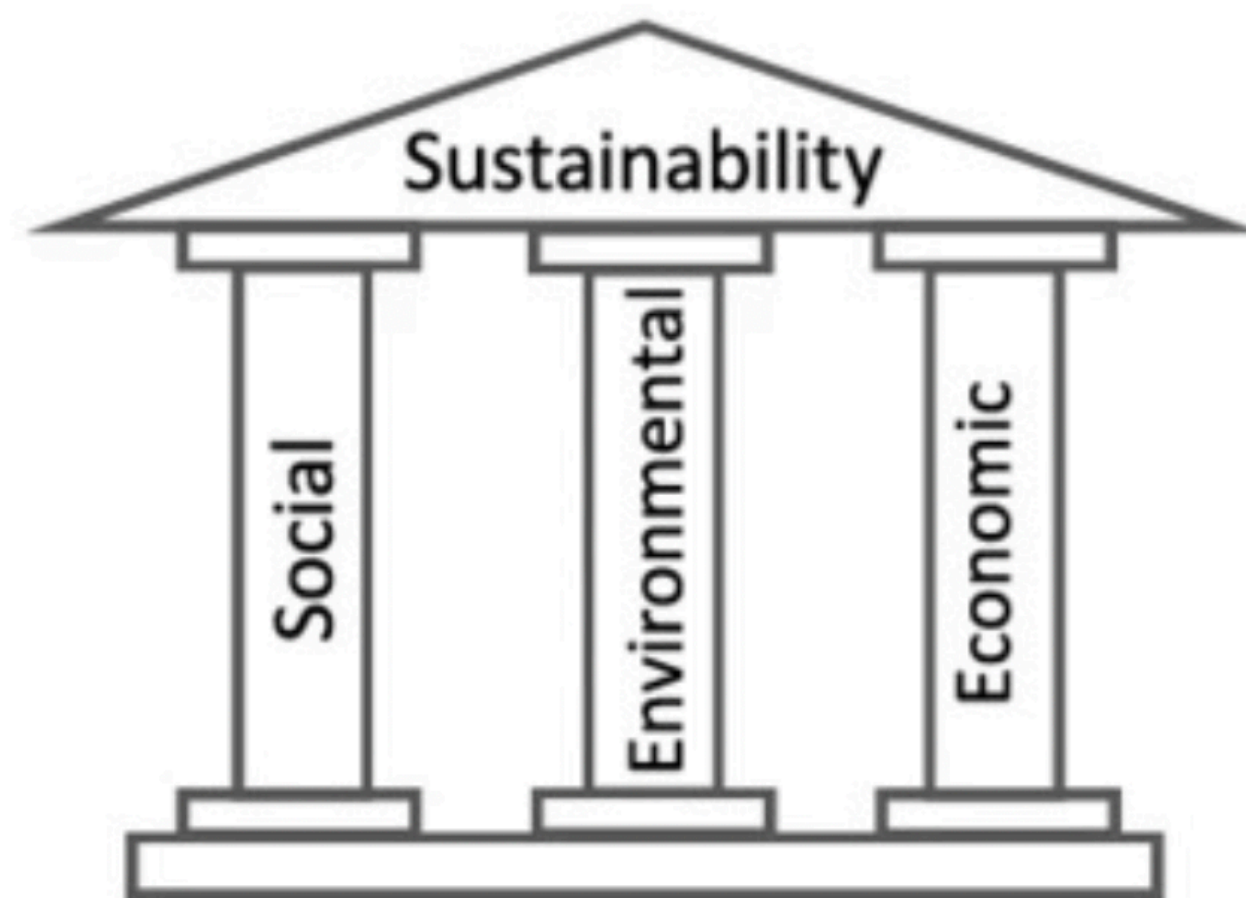
The build environment



- As the main contributor to our **societal development**,
- And, as a **major consumer** of natural resources,
- Needs proper **strategies for decision support** for further development and maintenance !!
- Objective: **sustainable development**.

Construction and sustainable development

- Construction sector causes **large environmental impacts**
- Responsible for > 20% of worldwide anthropog. GHG emissions
- “Emissions associated with development of Western standard infrastructure stocks in developing countries correspond to **about 35–60%** of the remaining carbon budget available until 2050, if the average temperature increase is to be limited to 2 °C” (Müller et al, 2013)



Structural Standards

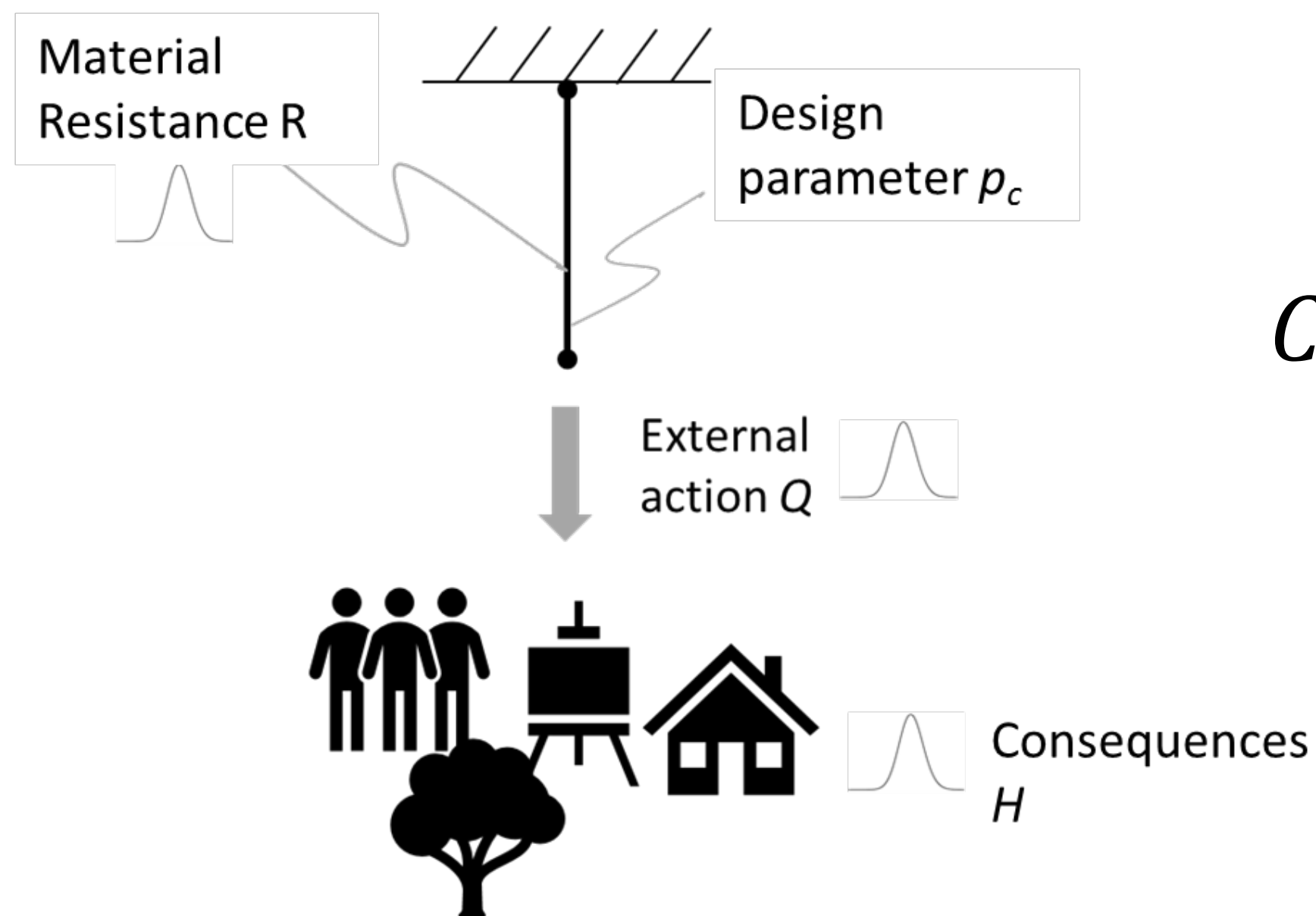
- ... are applied systematically to control material use in construction.
- ... are a main “catalysator” for the transition of (scientific) knowledge into action.
- ... must be based on best available knowledge !

Structural Standards

The **Mandate M/515 (2012): European Commissions** extend scope for developing the second generation of the **Eurocodes**.

Impact	Benefit
Use of new methods and new materials, enhanced coverage of robustness	This will enable the latest technologies and knowledge to be applied in a way that is acceptable for practitioners, promoting cost effectiveness and sustainability in design, and innovation. Given the huge size of the construction market across Europe even the most modest efficiency saving arising from new and innovative technologies will yield €multi-million annual savings.
Relevant sustainability consideration incorporated within design requirements	This supports European Community objectives, including those for energy saving and waste accrual.
Climate change consideration embraced within Eurocodes	This will provide increased resilience of long-life infrastructure assets to potential climatic changes. It is very cost effective to address such risks at the design stage rather than through later retrofitting. Such an approach also reduces user disruption and environmental impacts.
Incorporation of initial requirements for assessment and retrofit of existing structures	This supports the effective and sustainable management of existing infrastructure, providing a consistent technical framework across member states as a platform for future R&D and appropriate harmonization, enabling the sustainable life extension of existing assets.

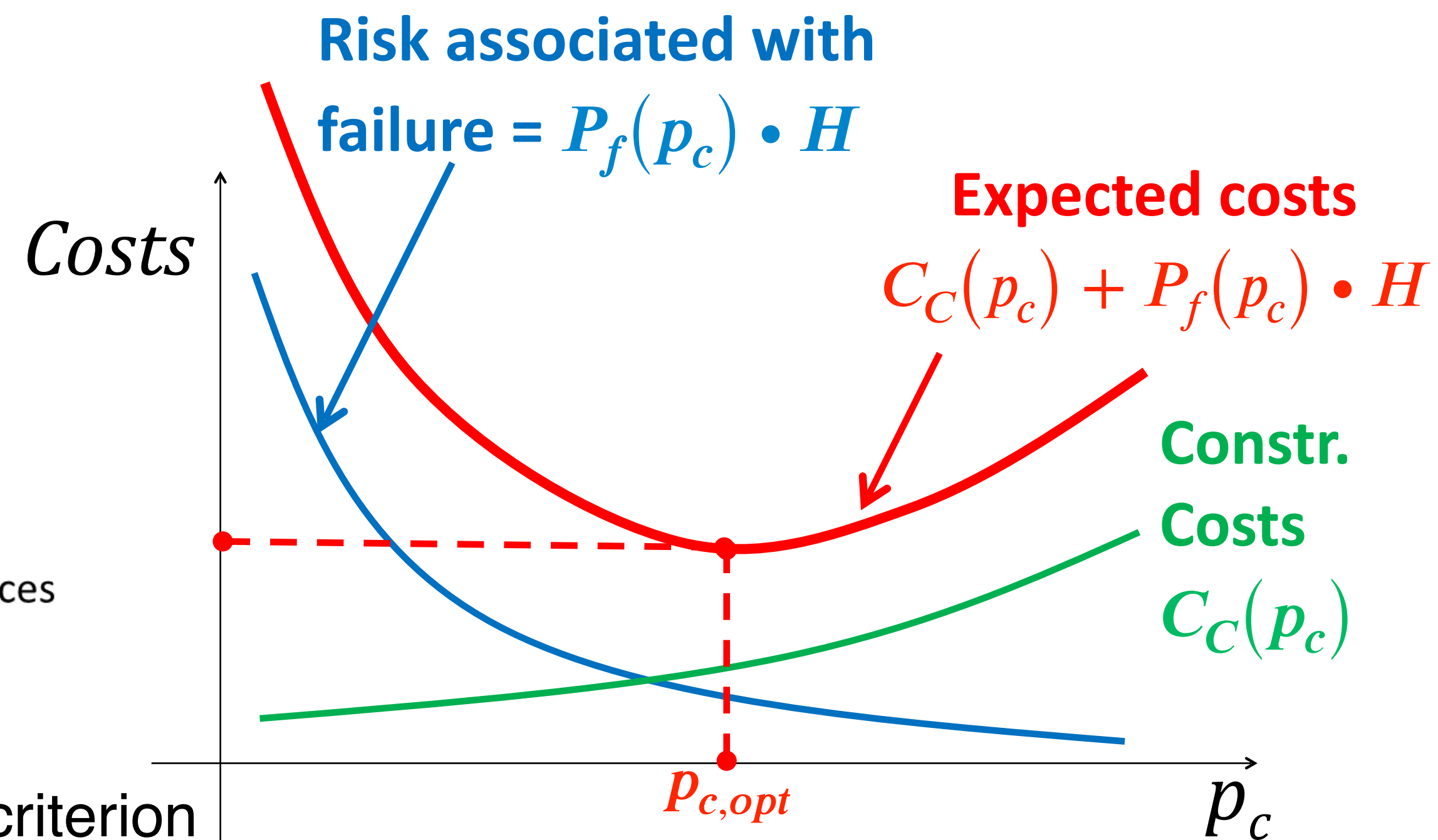
Structural Standards - rational basis



Risk based criterion

Reliability based criterion

Semi-prob. criterion



$$P_f(p_{c,opt}) = P_{f,opt}$$

$$\gamma_M, \gamma_Q: P_f\left(p_c = \frac{\gamma_M}{f_k} \cdot \gamma_Q \cdot q_k\right) \equiv P_{f,opt}$$

Reliability Benchmark of the Eurocodes

➤ Design Equations with one variable load

$$\Sigma F_d = \sum_i \gamma_{G,i} G_{k,i} + \gamma_{Q,1} Q_{k,1} + \sum_{j>1} \gamma_{Q,j} \psi_{0,j} Q_{k,j} + (\gamma_P P_k) \quad (8.12)$$

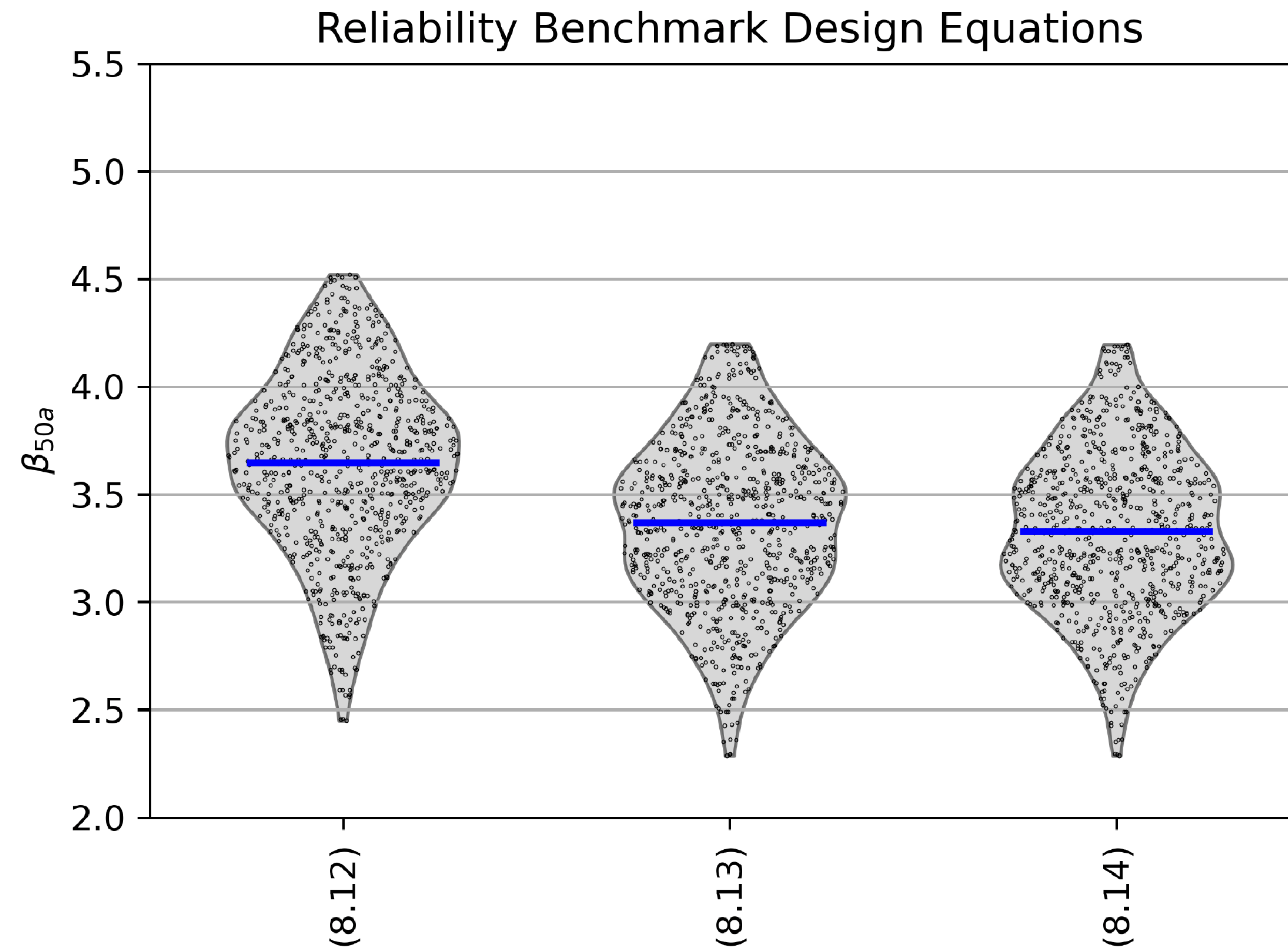
or

$$\Sigma F_d = \begin{cases} \sum_i \gamma_{G,i} G_{k,i} + \gamma_{Q,1} \psi_{0,1} Q_{k,1} + \sum_{j>1} \gamma_{Q,j} \psi_{0,j} Q_{k,j} + (\gamma_P P_k) \\ \sum_i \xi_i \gamma_{G,i} G_{k,i} + \gamma_{Q,1} Q_{k,1} + \sum_{j>1} \gamma_{Q,j} \psi_{0,j} Q_{k,j} + (\gamma_P P_k) \end{cases} \quad (8.13)$$

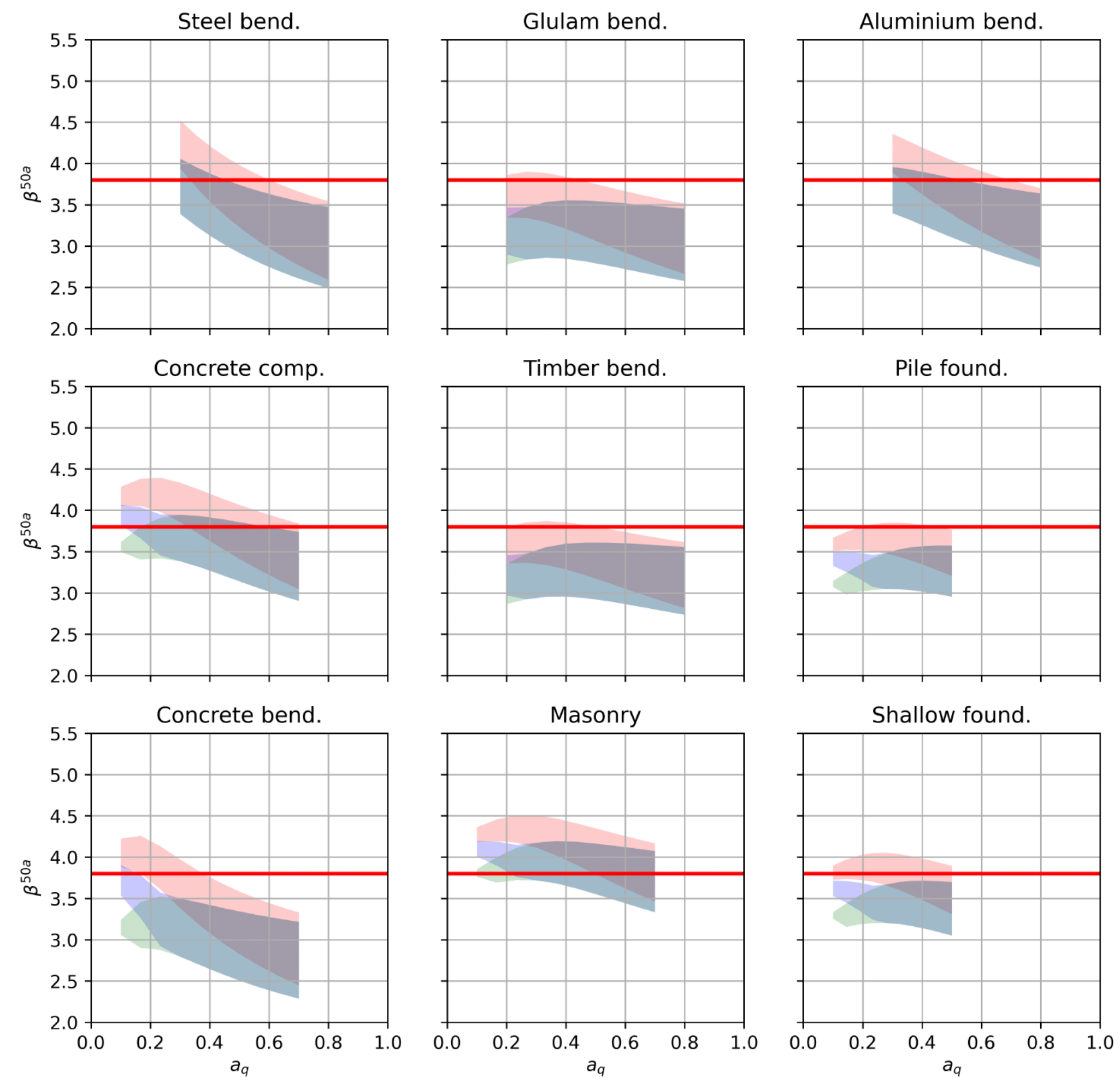
or

$$\Sigma F_d = \begin{cases} \sum_i \gamma_{G,i} G_{k,i} + (\gamma_P P_k) \\ \sum_i \xi_i \gamma_{G,i} G_{k,i} + \gamma_{Q,1} Q_{k,1} + \sum_{j>1} \gamma_{Q,j} \psi_{0,j} Q_{k,j} + (\gamma_P P_k) \end{cases} \quad (8.14)$$

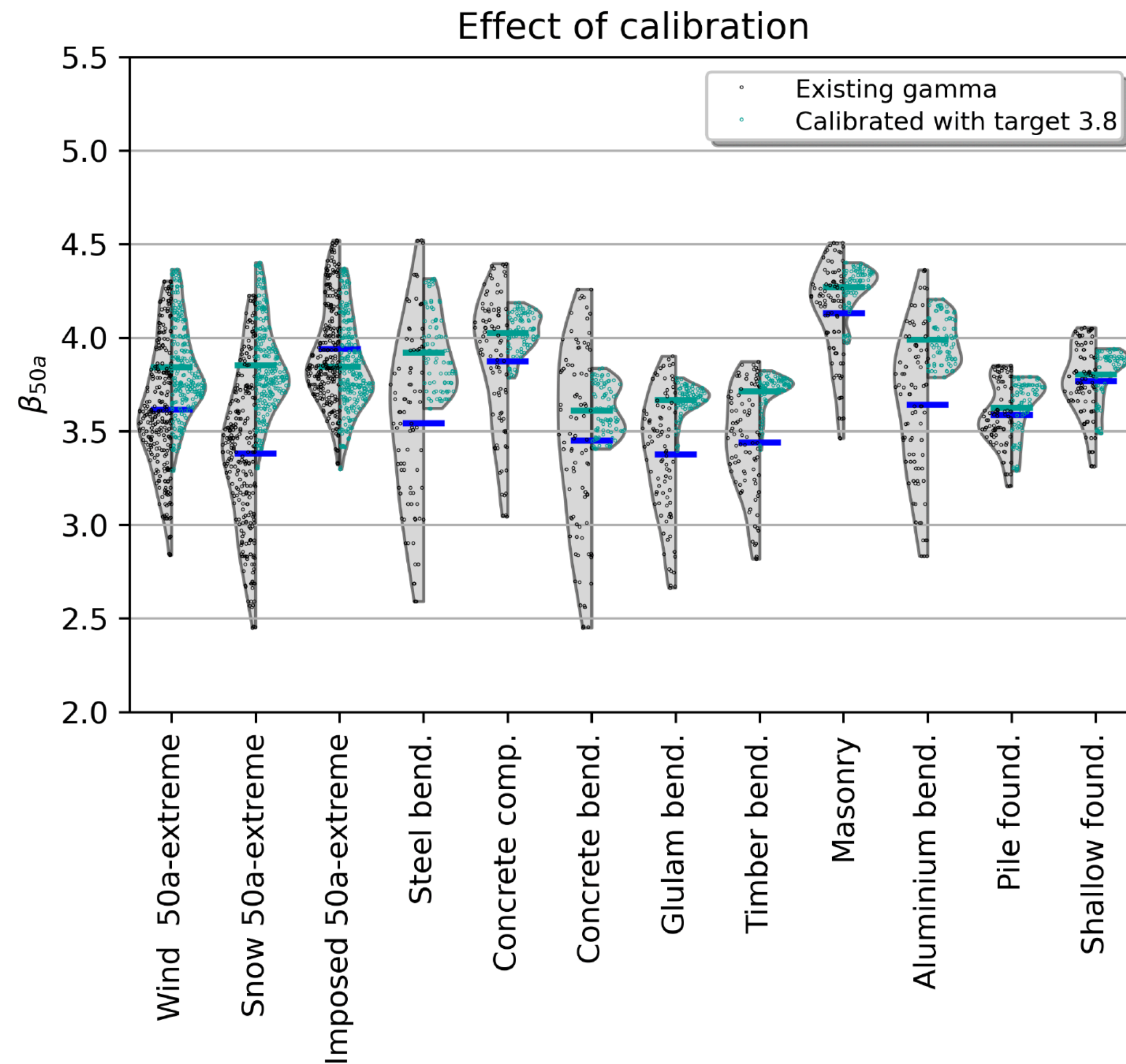
Reliability Benchmark of the Eurocodes



Reliability Benchmark of the Eurocodes



Reliability Based calibration of the Eurocodes



$$M(\gamma_S) = \sum_{k \in D} w_k \left(\beta_k(\gamma_S) - \beta_{target} \right)^2$$

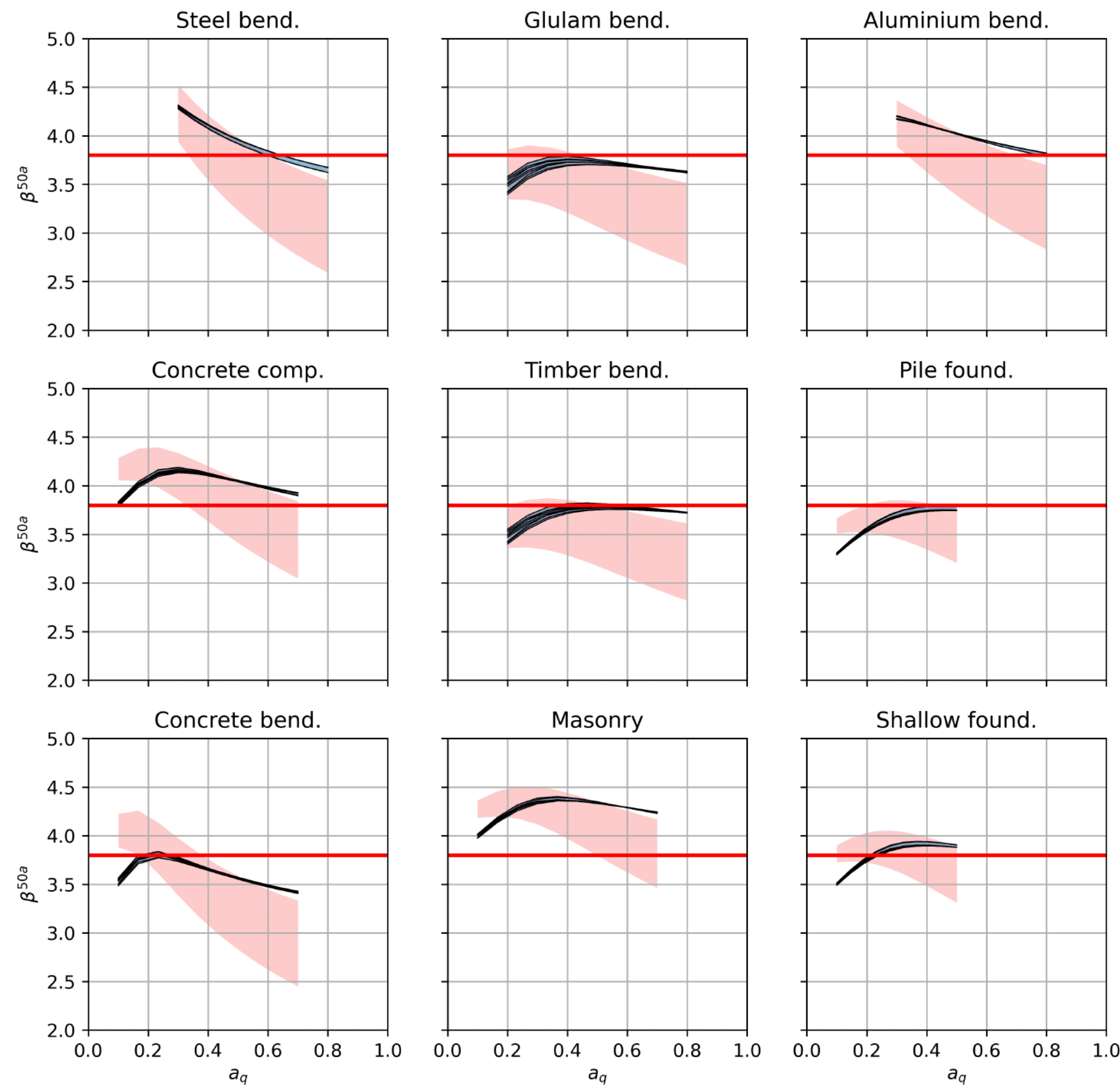
$$\gamma_G = 1.19$$

$$\gamma_{Q,wind} = 1.94$$

$$\gamma_{Q,snow} = 2.35$$

$$\gamma_{Q,imposed} = 1.60$$

Reliability Based calibration of the Eurocodes



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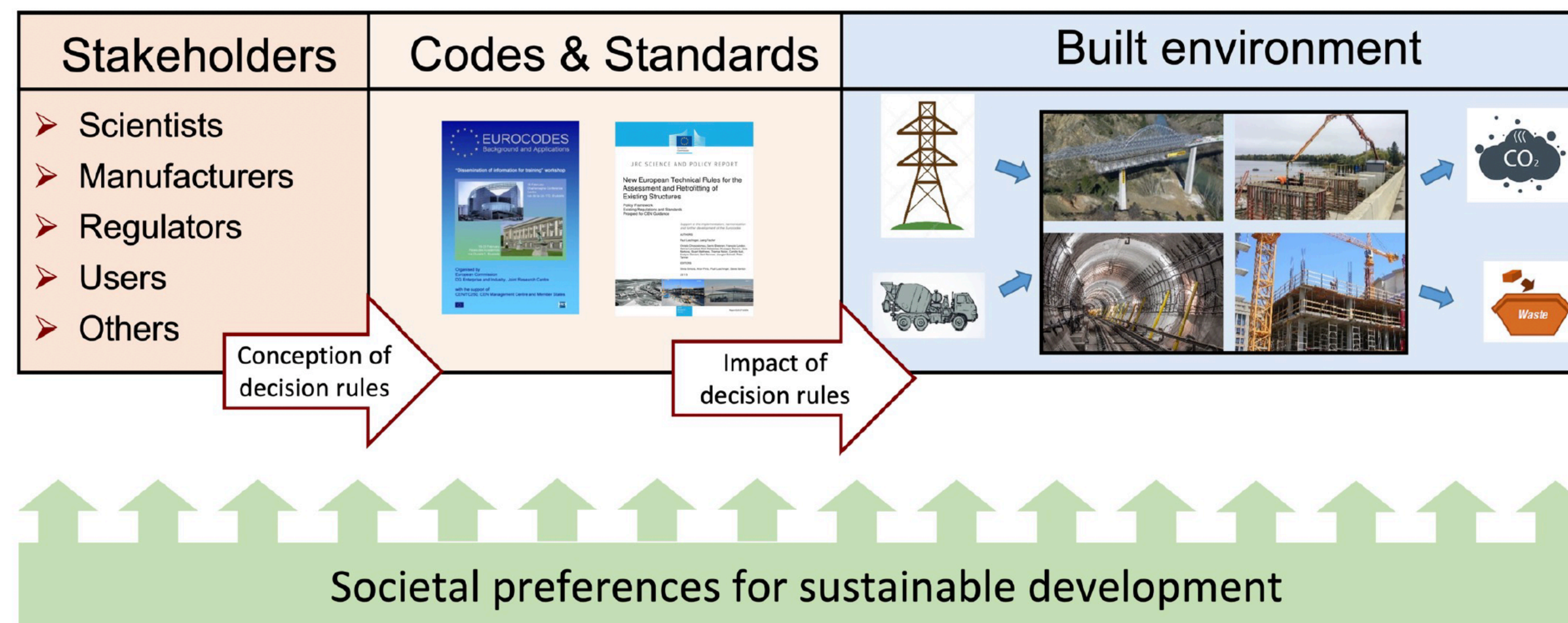
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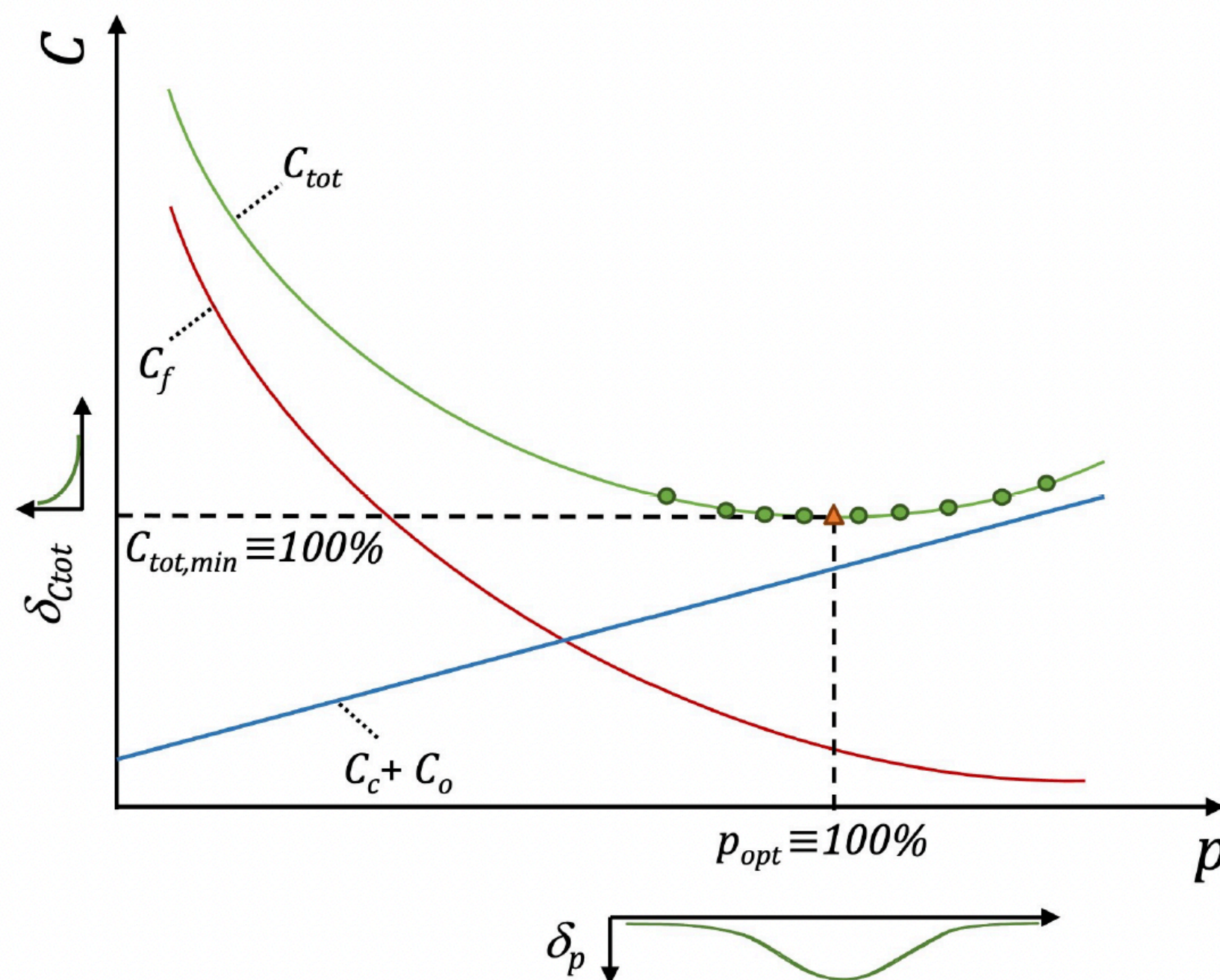
Required paradigm shift in standardisation

- Environmental (and economical) objectives not efficiently addressed or even entirely disregarded
- **Need for systematic approach** at the level of codes and standards
- Compulsory decision rules applied in **daily structural design**
- Any modification has a **large impact**

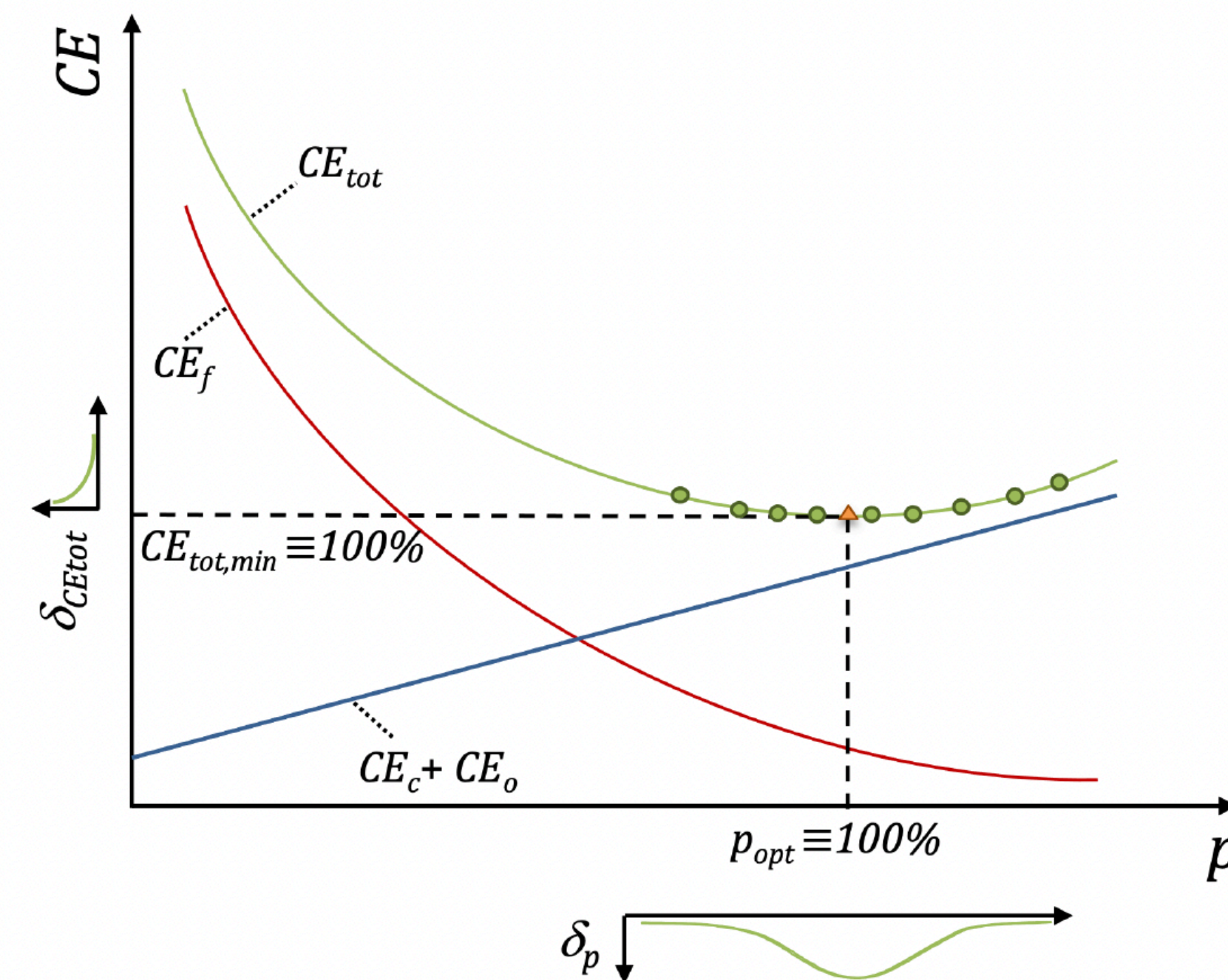


Cost of sub-optimality of simplified standards

- How large are the % deviations (d) from an optimum decision, when designing according to the suboptimal PFM?

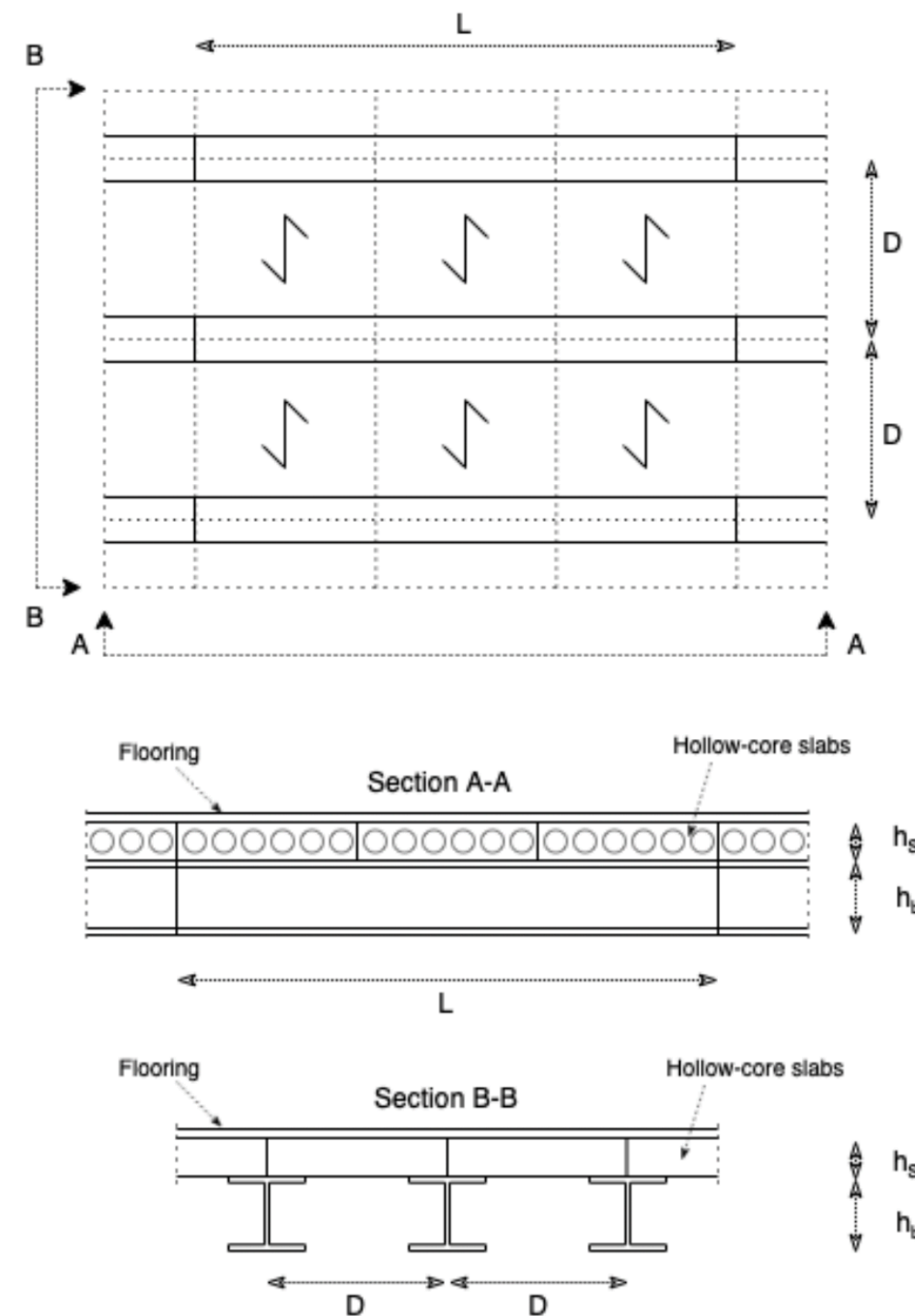


➤ A) Cost (C) –based optimisation

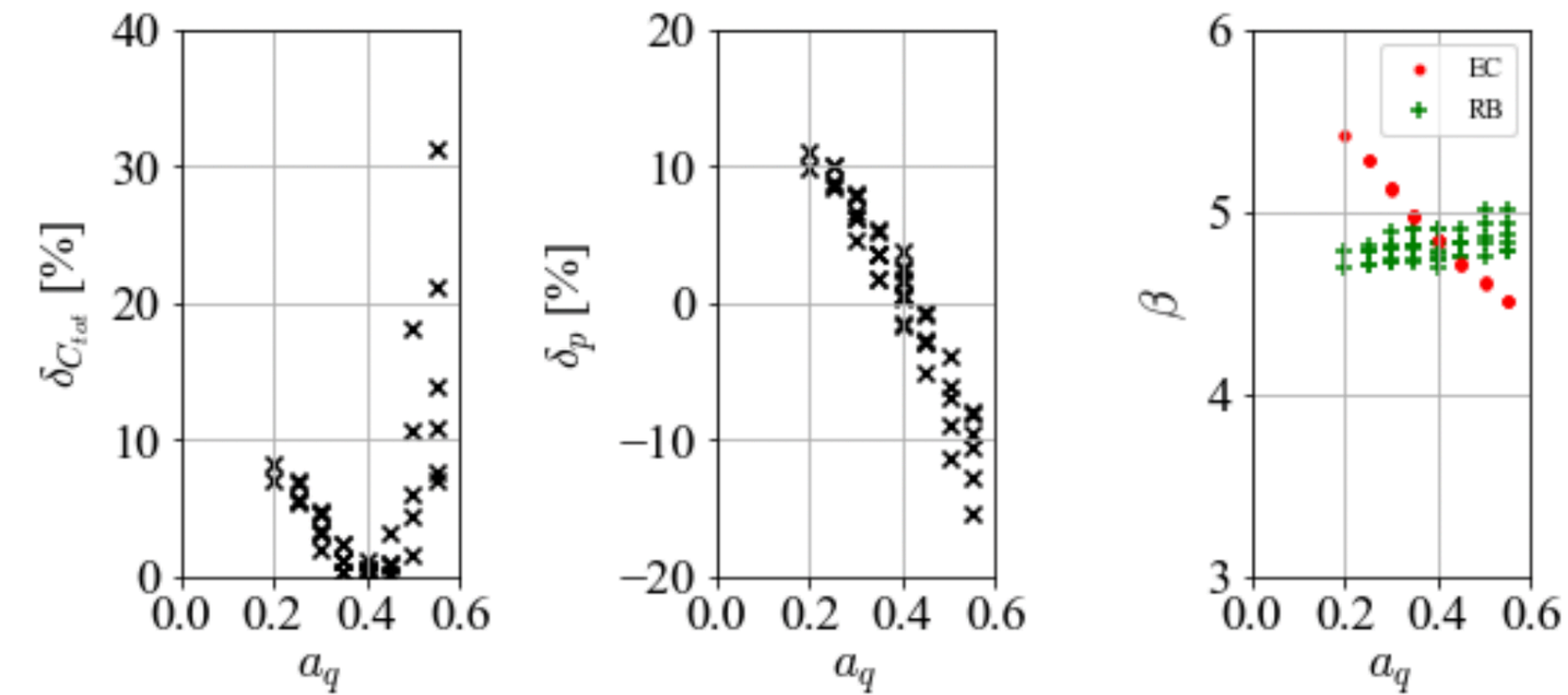


➤ B) Carbon emission (CE)-based opt.

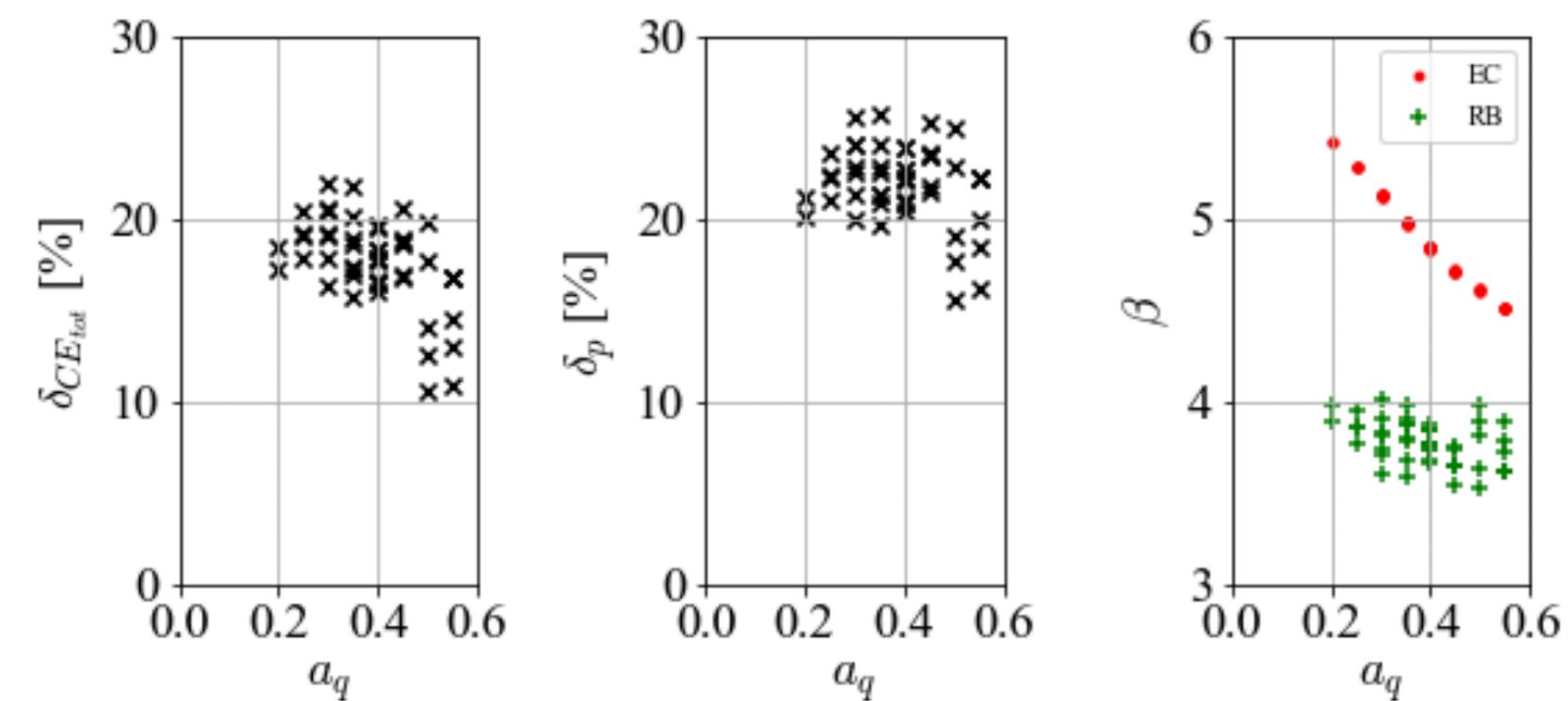
Example saving potential Steel frame-floor / live load



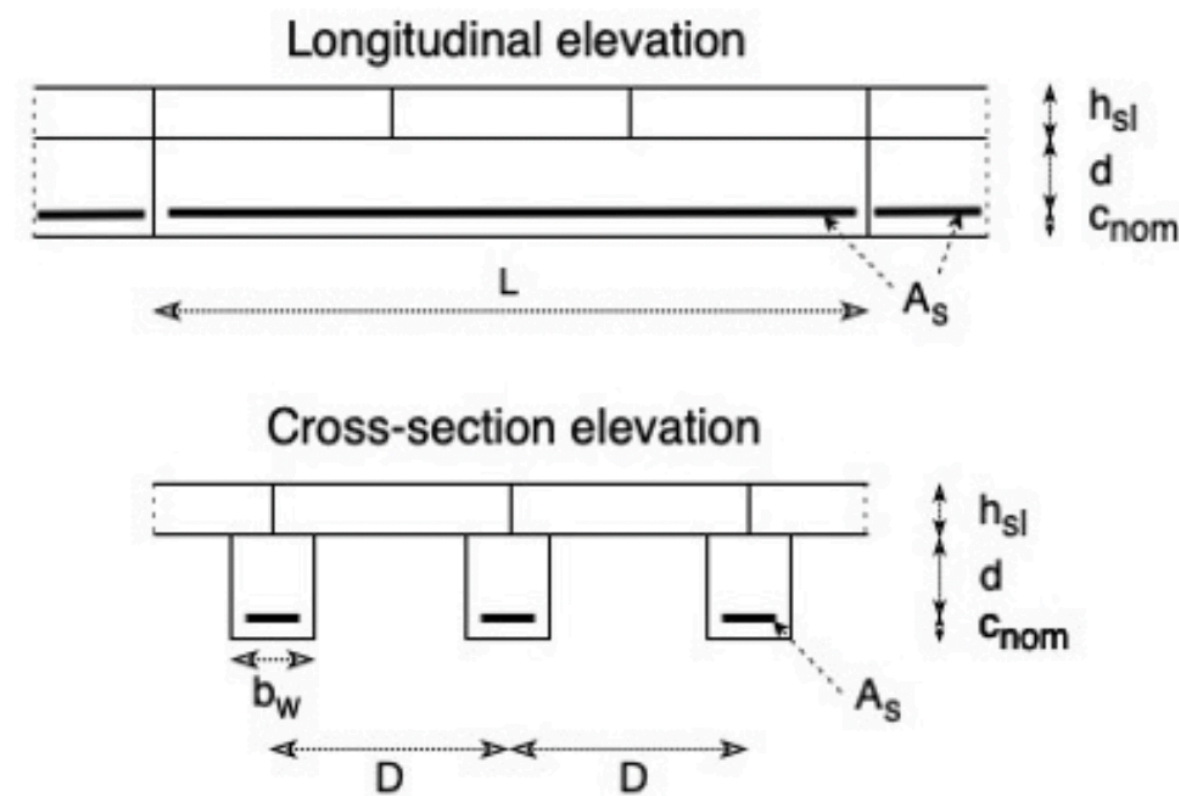
Cost criterion:



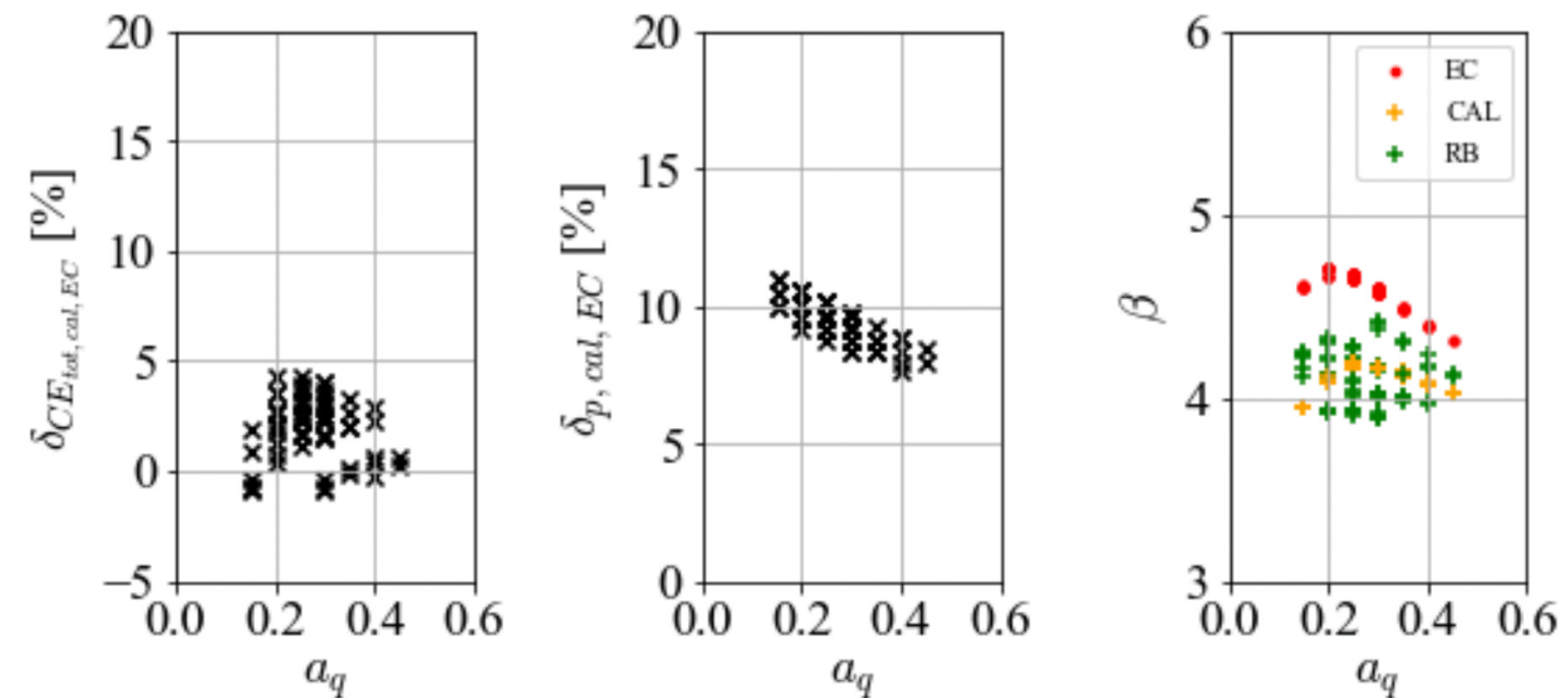
CO2 - criterion:



Example saving potential concrete floor / live load



$$\gamma_G = 1.21; \gamma_Q = 1.45$$



Nationally Determined Parameters NDP



NEW MINISTERIAL DECLARATION

Nordic Ministerial Declaration on Commitment to Low Carbon Con- struction

21-11-2023

<https://www.nordicsustainableconstruction.com>

Nationally Determined Parameters NDP

06 February 2024

Nordic priority paper to harmonise the national annexes for eurocodes

"The Nordic authorities propose the following focal points.... :

For eurocode 0 - Basis of structural design:

- a) Level of reliability
- b) National partial safety factors for actions and resistances
- c) Combination of actions
- d) Allow relaxation of regulations followed by ongoing monitoring of the construction

For eurocode EC 2-7, EC9 and EC10 (concrete, steel, composite steel and concrete, timber, masonry, Geotechnical, aluminium, glass):

- e) Methods of Design model structural analysis for each material
- f) Constructive rules for each material
- g) Possibility of reuse and recycling of building components and building materials
- h) Requirements for strength and development of strength (maturity)
- i) Use of more advanced methods or calculation for material

Conclusion

- Large potential for increasing efficiency in structural design not utilised so far.
- National “degrees of freedom” are a way to follow political advice.
- Collaboration and coordination across countries important.
- JCSS can be an important platform for these important developments!

Sustainability potential of safe structures

Workshop dedicated to the 50th anniversary of the JCSS

Klokner Institute, Prague

23.5.2024

Jochen Köhler