# JCSS

Joint Committee
on Structural Safety

# Workshop on Assessment of Existing Structures

28th and 29th January 2021

## Semi-Probabilistic Format for the Assessment of Existing Bridges: Concepts and Challenges

André Orcesi

Cerema

# Structural assessment of existing bridges

- Various reasons
- Not restricted to deteriorated structures
- Design/assessment concepts

# Background

- Strong involvement of technical and scientific communities on this topic

**JCSS PROBABILISTIC MODEL CODE**

**Eurocodes**

**ISO (22394, 13822, 16311)**

**JCSS Probabilistic Assessment of Existing Structures**

**JRC report of EN/TC250/WG2**

**CEN/TS 17440**

***fib* Model Code 2010**
***fib* Model Code 2020**

**Ad Hoc Group Reliability of Eurocodes**

***fib* Bulletin 80 “Partial factor methods for existing concrete structures” (*fib* Task Group 3.1)**

# Aim of IABSE TG1.3

- Provide a complementary analysis, following all the theoretical developments of these last years
- Discuss assumptions
- Point of view of academics and practitioners (strong connection with JCSS and *fib)*
- Implementation on bridge case studies

# Verification formats

- **Partial factor** format

$$\underbrace{\gamma_S\, S_k}_{S_d} \le \underbrace{\left(\frac{R_k}{\gamma_R}\right)}_{R_d}$$

- **Reliability-based** format

$$\beta \ge \beta_0 \qquad \mathcal{P}_f = \mathcal{P}\left(R < S\right) \le \mathcal{P}_f^0$$

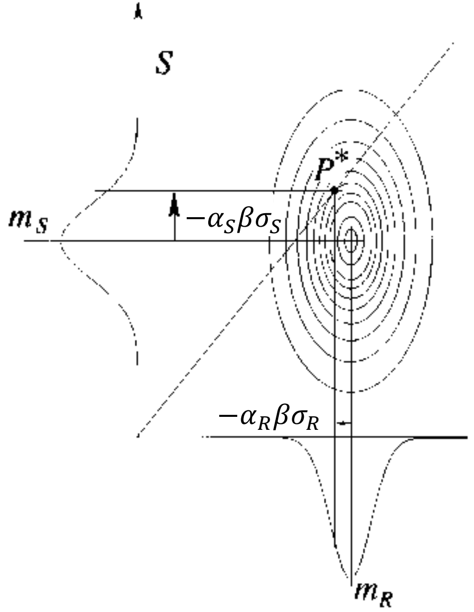
- **Risk-informed** format

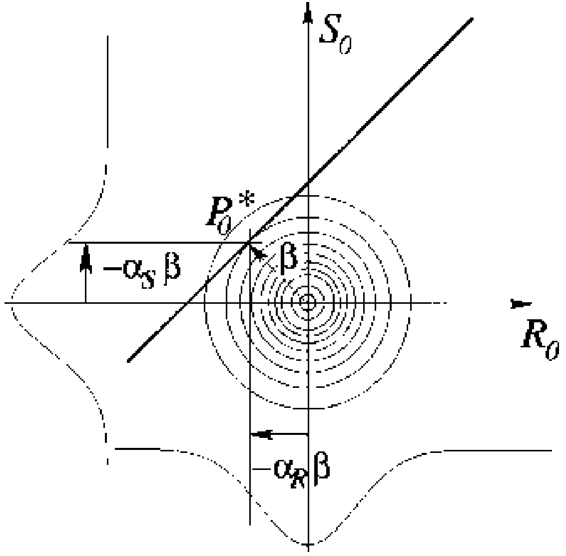
$C_f \quad P_f$

Optimization of costs

# Reliability based format

*Basic problem M = R - S*
*(with normal random variables)*



# Partial factor format

*Basic problem M = R - S*
*(with normal random variables)*

$$\frac{R_k}{\gamma_R} \geq \gamma_S \quad S_k$$

$$\gamma_R = \frac{R_k}{R_d} = \frac{\mu_R(1 - kV_R)}{\mu_R(1 - \alpha_R \beta V_R)}$$

$$\gamma_S = \frac{S_d}{S_k} = \frac{\mu_S(1 - \alpha_S \beta V_S)}{\mu_S(1 + kV_S)}$$

# Generalization

- Use of isoprobability transformation for other types of variables

- Lognormal distribution $\gamma_m = \frac{X_k}{X_d} = \frac{\mu_X exp(-1.645V_X)}{\mu_X exp(-\alpha_R \beta V_X)}$

- Gumbel distribution $\gamma_q = \frac{X_d}{X_k} = \frac{u-1/\alpha ln\left(-ln\left(\phi^{-1}(-\alpha_E \beta)\right)\right)}{X_k}$

# EN1990 & ISO2394

- Target reliability index with respect to a reference period
  - $\beta$ = 4.7 (1 yr) / 3.8 (50 yrs) – ULS (RC2)
- Use of fixed sensitivity factors $\alpha$
  - Fixed values is an assumption
  - 0.8 for a dominating resistance parameter (0,32 if non-dominating)
  - -0.70 for a dominating load parameter (-0.28 if non-dominating)

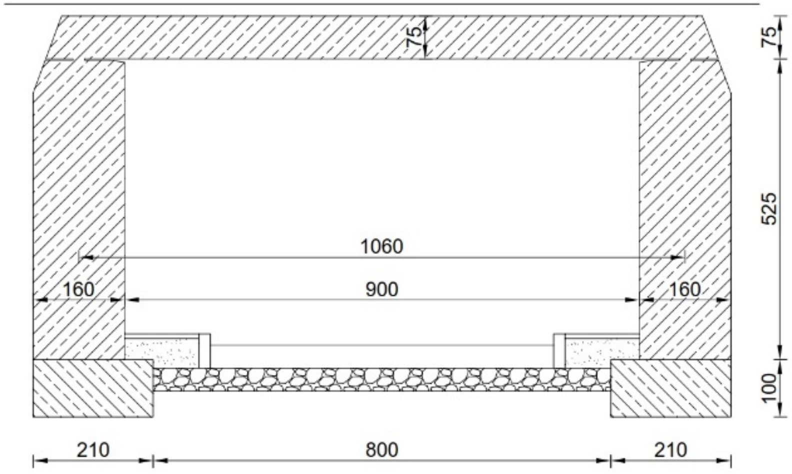
# Assignment of partial factors for existing structures

- Inconsistency if replacing initial characteristic values without changing partial safety factors
- Intuitively
  - These expressions can be used for modifying partial factors
  - Ensure the reliability level $\beta_t$

# Target reliability level

- Significant work of JCSS/ISO2394/*fib*
- Link with the consequence class and the reference period
- Economic considerations
  - Dominating costs of bridge closure
  - Less significant costs related to strengthening
- Human safety considerations
- Importance of national annexes

# Illustration with a case study considered in IABSE TG1.3




Single span reinforced concrete slab
*German case study*

# Assessment aspects (1/2)

Partial factors for new structures and within German reassessment guideline

| Partial factors | New structure | German reassessment guideline |
|---|---|---|
| Concrete compressive strength | 1.5 | 1.5 |
| Reinforcing steel | 1.15 | 1.05 |
| Prestressing steel | 1.15 | 1.1 |
| Permanent loads | 1.35 | 1.2 |
| Traffic loads | 1.35 | 1.5 |
| Other live loads | 1.5 | 1.5 |

Requires that the cross-section dimension and concrete density have been determined by measurements on the investigated structure

Based on the traffic loads of previous generations of the German standard where lower traffic loads were combined with a partial safety factor of 1.5

# Assessment aspects (2/2)

- Interesting case study
  - In situ information available

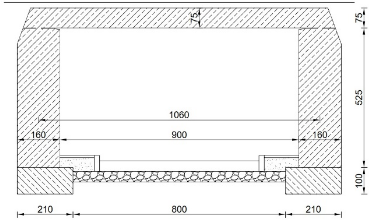
Six core samples taken from the structure
Mean value for in-situ compressive strength of 66.5 $N/mm^2$
Coefficient of variation of 0.21

  - the structure showed a just sufficient load bearing capacity both for bending and shear
  - If the currently valid traffic load model would be applied, the actions would exceed the resistances by approximately 15%

# Application of the *fib* bulletin 80

- to assign partial factors (DVM/APFM)
  - DVM evaluates partial factors based on the *simplified level II approach with fixed sensitivity factors*
  - *APFM similar approach providing adjustment factors for partial factors used for new structures*

- Consideration of CC3 with updated $\beta$ = 3.8 (50 yrs) – 1.5 =2.3




# Concrete compressive strength

## DVM

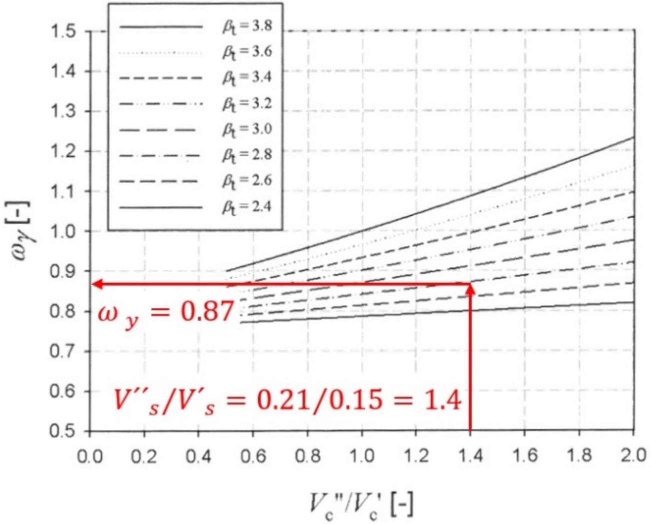
$$\gamma_C = \gamma_{Rd} \cdot \gamma_c$$

$$\gamma_C = e^{\alpha_{\theta_R} \cdot \beta \cdot V_{\theta_R}} \, e^{\alpha_R \cdot \beta \cdot V_x - 1.645 \cdot V_x}$$

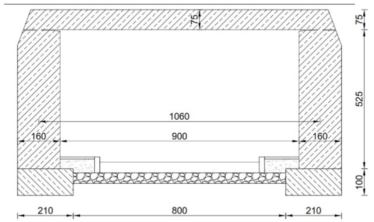
$$\gamma_C = e^{0.4\ 0.8\ 2.8\ 0.14} \cdot e^{0.8 \cdot 2.8 \cdot 0.21 - 1.645 \cdot 0.21}$$

$$\gamma_C = 1.28$$

## APFM




$$\gamma_C = 0.87 \times 1.5 = 1.30$$




# Permanent loads

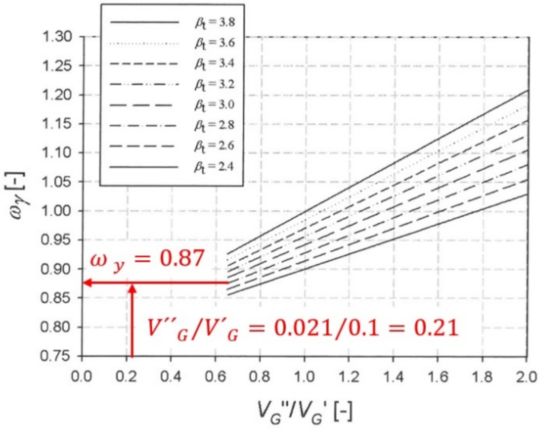
- No actual data on the density of the core samples for the selected case study
- A data set with a mean of 2362 kg/m³ and a coefficient of variation of 0.021 was considered

**DVM**

$$\gamma_G = \gamma_{Ed,G} \frac{G_d}{G_k} = e^{-\alpha_{\theta_E} \cdot \beta \cdot V_{\theta_E}} \frac{(1 - \alpha_E \cdot \beta \cdot V_G)}{(1 - k \cdot V_G)}$$

$$\gamma_G = e^{0.4\ 0.7\ 2.8\ 0.10} \frac{1 - (-0.7) \times 2.8 \times 0.021}{1 - 0 \times 0.021} = 1.13$$

**APFM**




$\gamma_G = 0.87 \times 1.35 = 1.18$

# Traffic (1/2)

- In contrast to other basic variables such as self-weight or the material parameters, there is no established approach to update the traffic load model for an existing bridge

- A sub-group was formed in IABSE TG1.3 to investigate this special topic
  - Traffic parameters to be as much as possible obtained for the specific structure
  - How to do if no data specific for the bridge is available? (use of provisions of Eurocodes - EN 1991-2 - or from literature)
  - Simplified approaches to model traffic loads ?
  - Which assumptions on traffic density and composition for traffic simulations?

# Traffic (2/2)

- Objective: use a statistical analysis to determine characteristic values or PDF for the internal forces due to traffic loads

$$\gamma_Q = \gamma_{Ed,Q}\gamma_q$$

with **(assuming a Gumbel PDF)**

$$\gamma_q = \frac{\mu_{Q,tref}\left[1 - V_{Q,tref}\left(0.45 + 0.78ln\left(-ln\left(\phi^{-1}(-\alpha_E\beta)\right)\right)\right)\right]}{q_k}$$

# Next steps

- Complete the partial factor format verification
- Comparison with a probabilistic approach

# Challenging aspects (1/2)

- Values to be considered with caution
  - Determination of target reliabilities in link with the reference period
  - Impact of distribution types, of distribution parameters
- Statistical uncertainties / additional information about the material parameters
- Fixed or adjusted (flexible) partial factors?

# Challenging aspects (2/2)

- The importance of bridge document and data
- Question of the assessment of bridges with poor documentations
- Link with national standards

# Members/invited members of IABSE TG1.3

**André Orcesi**, France - chair

**Salvatore Di Bernardo**, USA – vice chair

**Vazul Baros**, Germany

**Wouter Botte**, Belgium

**Robby Caspeele**, Belgium

**Dimitris Diamantidis**, Germany

**Ramon Hingorani**, Spain

**Amir Kedar**, Israël

**Jochen Köhler**, Norway

**Marija Kušter Maric**, Croatia

**Roman Lenner**, South Africa

**Maria Pina Limongelli**, Italy

**Heiki Lilja**, Finland

**Ana Mandić Ivanković**, Croatia

**Nisrine Makhoul**, Lebanon

**Jose Matos**, Portugal

**Alan O'Connor**, Ireland

**Niels Peter Høj**, Switzerland

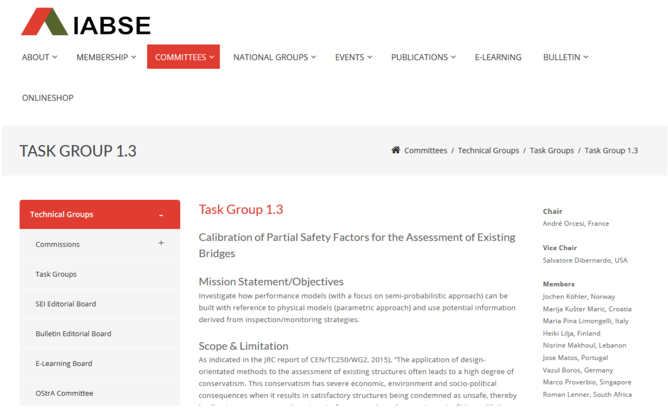
**Marco Proverbio**, Singapore

**Franziska Schmidt**, France

**Pierre Van der Spuy**, Dubai

**Miroslav Sýkora**, Czech Republic

**Peter Tanner**, Spain



# Thank you for your attention

# JCSS

Joint Committee
on Structural Safety

www.jcss-lc.org