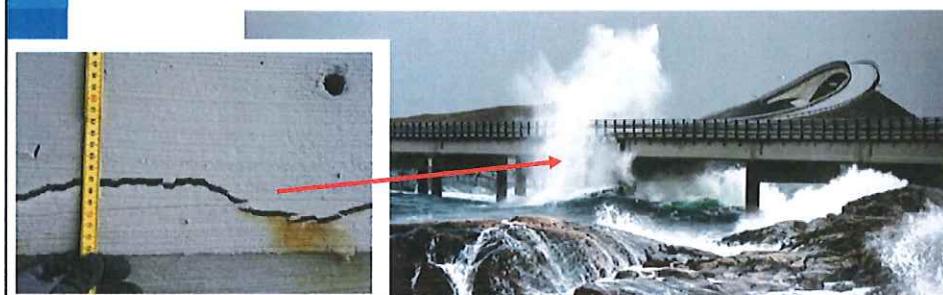


Belfast-meeting may 15-16th, Workgroup 3: Development of recommendations and products to improve concrete structures serviceability

GP3a Product development for testing and monitoring by Neil J. Campbell &
Willem S. Kroese

GP3b Product development for software and design methods by Jesus Miguel
Bairán Garcia

GP3c&d Development of Recommendations and pre-standard methods by
Terje Kanstad & Marcus Vill



More corrosion under severe conditions ...



Points from meeting in Paris October 20-21st 2017

The level of ambitions should be realistic
Standardization

- Our results will migrate into future revised standards
- Background documents may be written
- New standards may be drafted (proposed)
- Information on to get involved in standardization-work is requested

Concerns regarding devices ...

- Hard to bridge scientific aspects and practical applications
- Difficult to conclude from Paris-meeting
- We have to initiate well-defined activities

How to influence standardization?

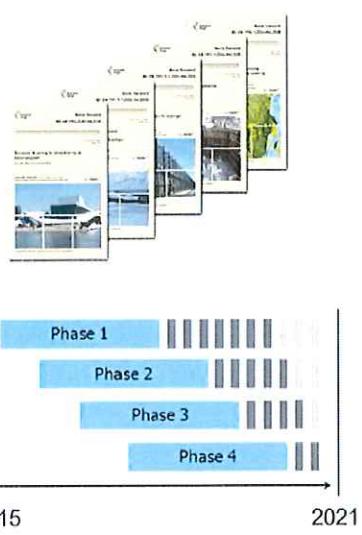
- Published standards within the concrete area:
 - Norwegian standards (NS): 12
 - Europeisk origin (NS-EN): 256
 - Global origin (ISO): 69
- Three main possibilities:
 - European global expert (influence the entire process)
 - (Even possibly project team member (those who are paid for writing ..))
 - National mirror committee (follow the work)
 - Comments to hearing versions of the standard (comments)
- Others?
 - Propose standards

International participation from Norway:

- Norske delegater til komitemøter
- Norsk ledelse og sekretariat:
 - CEN/TC 104/SC 2 (utførelse)
 - CEN/TC 104/WG 9 (silikastøv)
 - ISO/TC 71/SC 3 (betong og utførelse)
 - ISO/TC 71/WG 7 (tilsetningsstoffer)
 - ISO/TC 71/WG 8 (tilslag)
- Norske eksperter i arbeidsgrupper o.l.:
 - CEN/TC 104 (betong og utførelse): 14
 - CEN/TC 250/SC 2 (Eurokode 2): 11
 - CEN/TC 229 (betongelementer): 4
 - CEN/TC 51 (sement): 3
 - CEN/TC 177 (porebetong): 0
 - ISO/TC 71 (betong): 6
- a

Revision av Eurokodene

- Alle eksisterende 58 deler revideres
- Nye deler:
 - Bærende konstruksjoner av glass
 - Duk-konstruksjoner*
 - Fiberamrørte kompositter*
 - Eksisterende konstruksjoner*
- Ferdig ca. 2021 – 2022 (???)



Revision of Eurocode 2 for concrete structures

- Development areas:
 - Strengthening and reinforcement by fibre reinforced polymers
 - Fibre reinforced concrete
 - Existing structures
 - Skjær, torsjon
 - Fire
 - Structural analysis
 - Timedependent effects
 - Fatigue
 - Bridges
-

7

GP3c&d Development of Recommendations and pre-standard methods

- Eurocode 2, Annex D Early age concrete
 - Background document on Annex D, incl crackwidth calc.
- Pr EN 12390-xx Shrinkage (insufficient at early ages)
- Pr EN 12390-xy Creep (as above)
- New standard proposal for determination of thermal dilation
- New standard proposal for the starting point of stress calculations
(final setting + something)
- New standard proposal for activation energy

8

Follow up from WG 1 and WG 2 reporting
here in Belfast today and yesterday

-



TU1404 WG3 approach

Belfast meeting May 16 2017

GP3.a: Product development for testing and monitoring methods

Objective: Qualify experimental devices associated to control of early age properties in relation to serviceability (limit bias and scatter, ensure consistency with interpretation and modeling): e.g. for conductivity, ultra-sonic strength measurement, shrinkage and thermal dilation, restraint-induced stresses and cracking.

Leaders: Neil John Campbell (IE) & Willem Stenfert Kroese (NL)

GP3.b: Product development for software and design methods

Objective: Qualify software/associated design and computational methods related to prevention and control of early age cracking.

Leader: Jesus Miguel Bairan Garcia (ES)

GP3.d: Recommendations, pre-standard documents and associated coordination

Objective: Prepare standard definition of relevant specifications: which parameters? Which threshold values? Classes (benchmarks/calibration)?
Contribute to improvement of the material and execution standards.

Ensure coordination with relevant RILEM and CEN committees.

Leader: Markus Vill (AT)

GP3 Approach (1)

- I) Develop information template for each subject:
 - 1. testing and monitoring methods
 - 2. software and design methods
 - 3. Recommendations, pre-standards

GP3 Approach (2)

- II) Send template to all participants, asking them to fill it in for their methods relating to GP3a,b,c
- III) Review the received information, ask for clarification and edit where needed
- IV) Publish on TU1404 website
- V) Disseminate!



WG3b: Product development for software and design methods

Task 3: Development of guidelines for validation and documentation of a software or parts of FE code associated to the SLS advanced verifications

J.
Polytechnic University of
Barcelona

Background

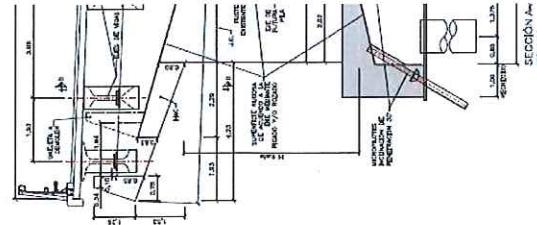
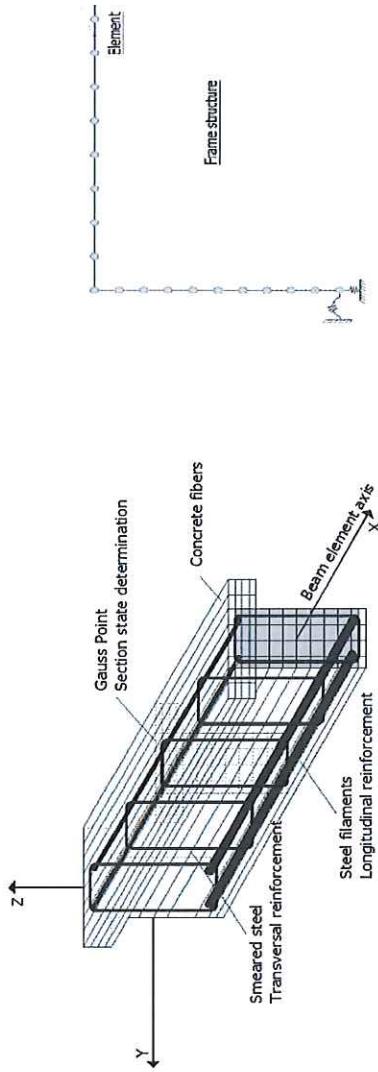
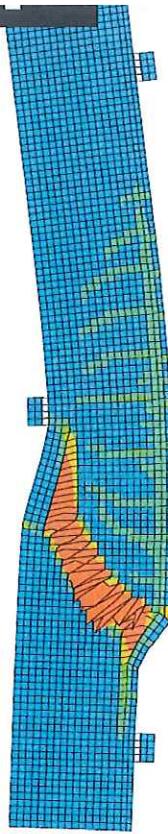
- Focus: early age cracking / induced damage
- Number of parameters vary in different models.
 - Adequacy of models may vary for different problem applications. Objective assessment is needed.
 - Existing commercial software.
 - Models developed/tested in WG 2.
 - WG3: Product development \Rightarrow Engineering applications and design.
Product: Model as engineering design tool of structural elements
 - WG3b: not development of new models but to provide means to use models to verify design in a reliable manner.

Property		Unit	
Volumetric mass	r	kg/m ³	
Thermal capacity	c	J/°C/kg	
Linear dilation	a _T	1/°C	
Cement phases			
C ₃ S	%		
C ₂ S	%		
C ₃ A	%		
C ₄ AF	%		
Maximum heat release	Q _{máx}	kJ/kg	
Activation energy	E _a	kJ/mol	
Degree of hydration	α_u	-	
Thermal conductivity	k	J/(m·seg·°C)	
Compression strength			
Elastic modulus			
Tension strength			
Creep			
Autogenous shrinkage			

Design in the context of service life

Product development \Rightarrow Engineering applications and design.

- Models:
 - Local 0: Material models
 - Local 1: Sections / elements
 - Local 1: Local regions (3D FEM)
 - Large scale: Frames / slabs / shells
- Types of problems:
 - crack control/prevention
 - existing structures deterioration processes
 - re-adaptation, strengthening
 - safety assessment
 - staged construction



Focus of at this stage was set in models for early age problems
(Paris meeting)

Design in the context of service life

Relevant issues for a model to be used as design tool:

- Ease of use / availability of parameters
- Robustness
- Accuracy (what level of accuracy is enough?)
- Computational time: suitability for reliability analysis implementation



Design in the context of service life

Possible outputs of WG3b

- Guidelines and recommendations for modelling early age problems.
 - Catalogue of types of models: Describe basis, variables needed, procedures to measure (link WG3a/c).
 - Methodology for qualification models for different problem applications.
-
- Safety factor framework for early age crack verification of designs based on numerical model
 - Recommendations for probabilistic analysis / Performance-based design: variables statistical models and target reliability indexes.

Design in the context of service life

- Approach for design guidelines

- Guidelines and recommendation of use.
 - Model construction recommendations.
 - Recommendation exist on advance modelling.
 - Complementary to existing recommendations.
- Catalogue of existing model types for different problems.
 - Recommendation for model selection / qualification.
- Benchmark database tests
 - Experimental tests / Cases in WG2.
 - Validation / Qualification
 - Asses model error (bias).
- How to use in design?
 - Limit State Design: model safety factor formats
 - Recommendations for reliability analysis



fib
bulletin 45
practitioners' guide to
finite element modelling
of reinforced concrete
structures

fib
bulletin 34
model code
Model Code for
Service Life Design



CEO.S.fr CONCRAC

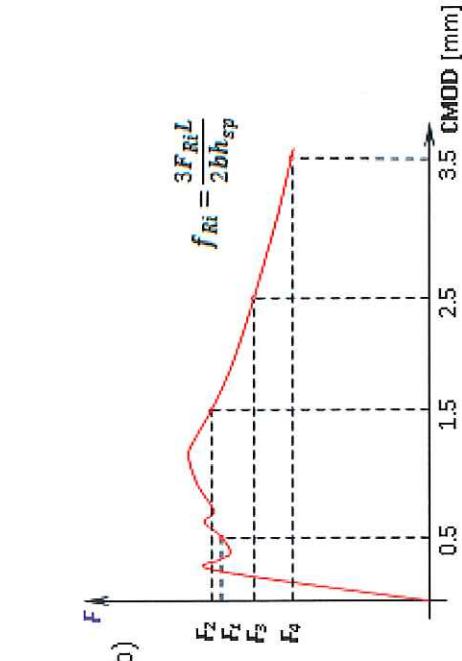
Design in the context of service life

- Approach for design guidelines

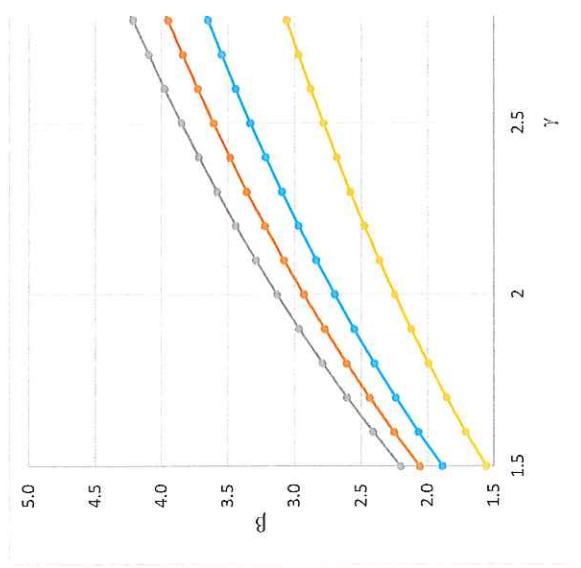
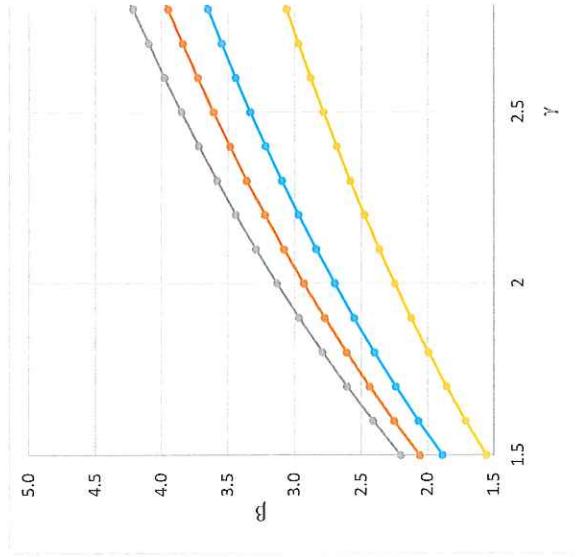
- How to use for design?
 - 2 possibilities to design justification through advanced models (non-linear).
 - Direct reliability analysis.
 - Limit State Design: partial safety factors, including model factor.

$$E\left(\gamma_G G + \gamma_Q Q\right) \leq R \left(\frac{q_{ud}}{\gamma_{Rd} \cdot \gamma_O} \right)$$
$$\text{EN1992-2} \quad E_d \leq R_d = \frac{R_d}{Y_R}$$

Safety factors: a) calibration through reliability optimization
(time expensive with complex numerical models)

$$G = \delta R - E \quad (\delta: \text{model factor})$$


Cracking of FRC



Design in the context of service life

- Approach for design guidelines

- How to use for design?
 - 2 possibilities to design justification through advanced models (non-linear).
 - Direct reliability analysis.
 - Limit State Design: partial safety factors, including model factor.

$$E(\gamma_G G + \gamma_Q Q) \leq R \left(\frac{q_{ud}}{\gamma_{Rd} \cdot \gamma_0} \right) \quad \text{EN1992-2}$$
$$E_d \leq R_d = \frac{R_d}{Y_R}$$

Safety factors: b) estimated

$$Y_R = e^{\alpha_R \beta V_R} \quad \text{Assumption of model distribution function!}$$

$$V_R = \frac{1}{1.65} \ln \left(\frac{R_m}{R_k} \right)$$

Cervený

$$V_R = \sqrt{V_{Geometria}^2 + V_{marstials}^2 + V_{models}^2}$$

Schlund

V: coefficient of variation

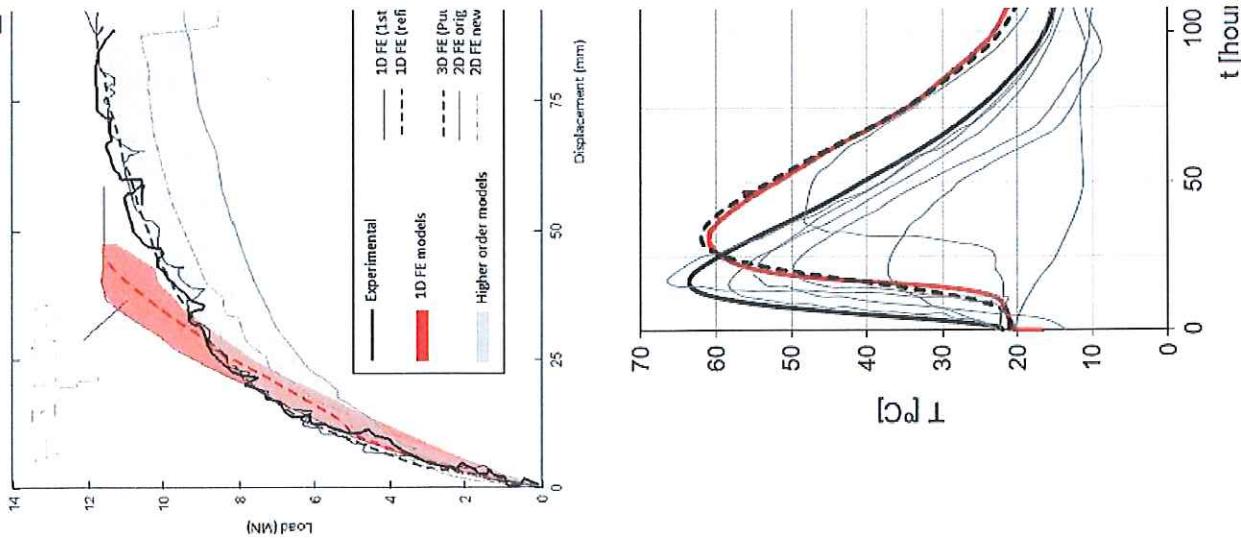
- Recommendations for reliability analysis
 - Recommend variables distribution based on output of WG1/WG2?

Methodology for model selection / qualification

Based on objective indicators.

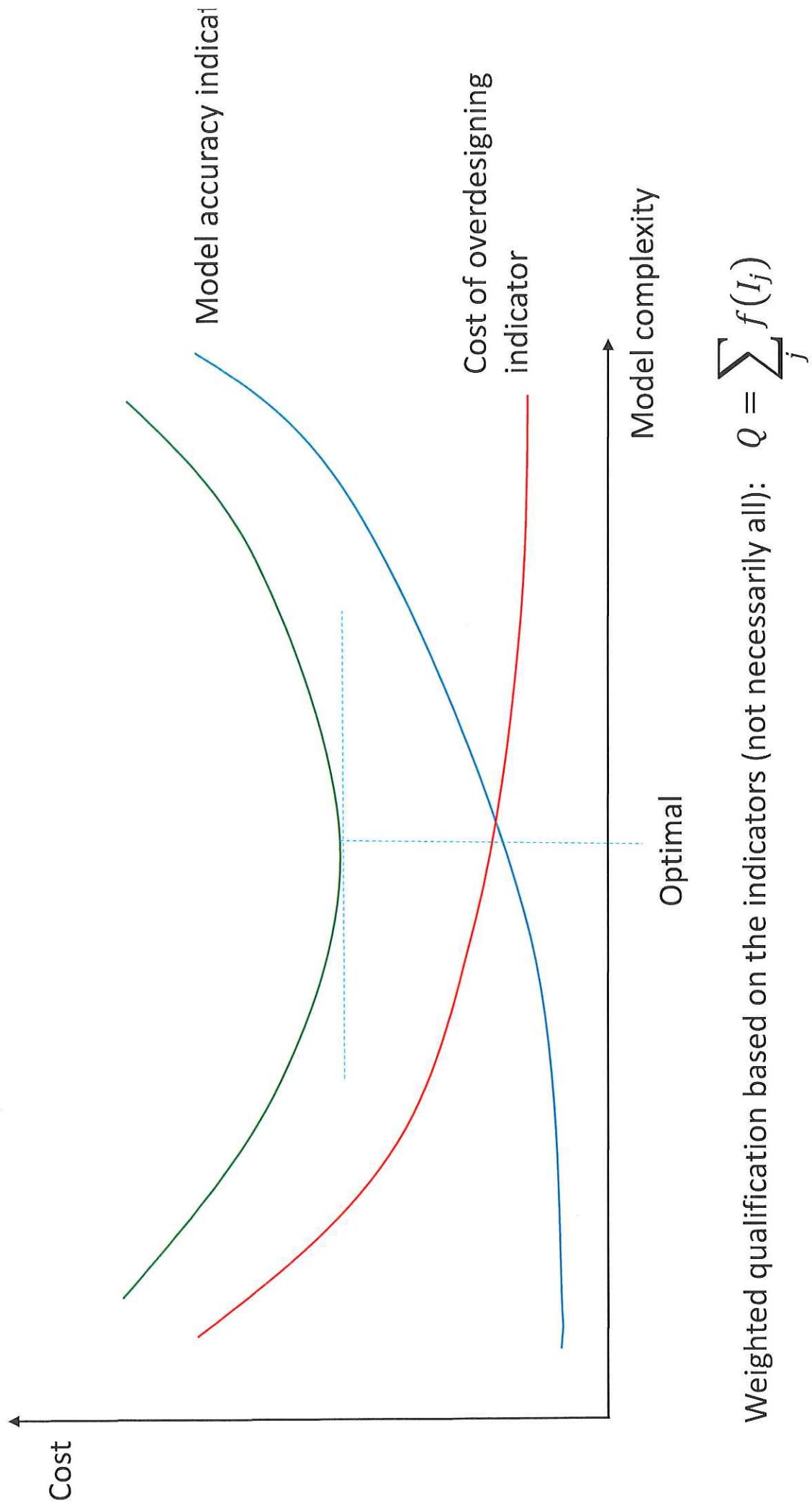
(To be assessed through WG1 and WG2 results)

1. Model bias (δ) with respect to problem type.
2. Number of input parameters needed.
3. How reliable can **input parameters** be measured?
4. Model sensitivity: sensitivity vector α
$$\alpha_i = \frac{\partial R}{\partial a_i} \frac{\bar{a}_i}{\bar{R}}$$
5. Capability to reproduce trends of parametric analysis (based on experimental benchmarks).
6. Model reproducibility: variations in results based on blind predictions of different users on the same type of model.



Methodology for model selection / qualification

Based on objective indicators.



Methodology for model selection / qualification

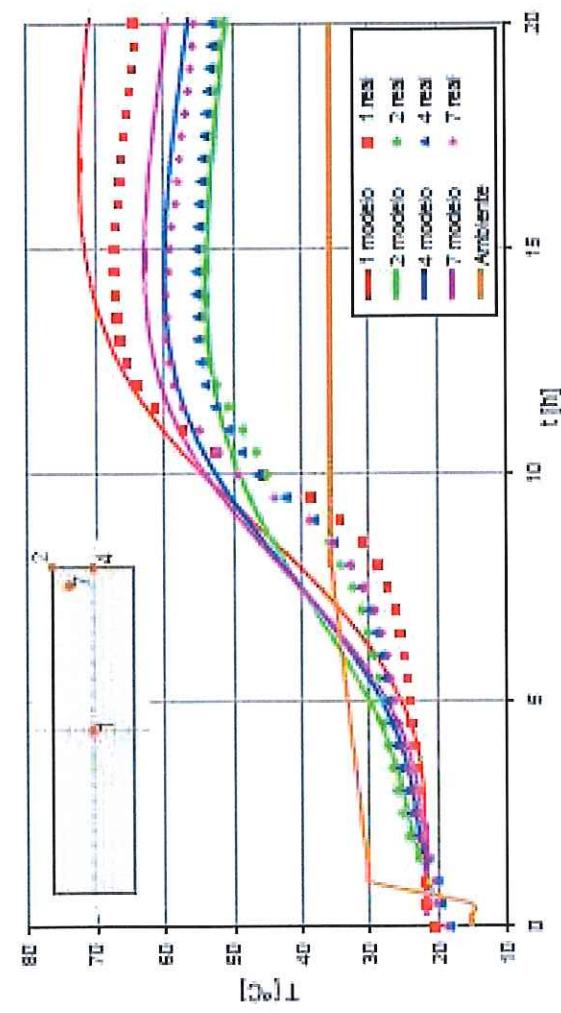
Based on objective indicators.

Indicators:

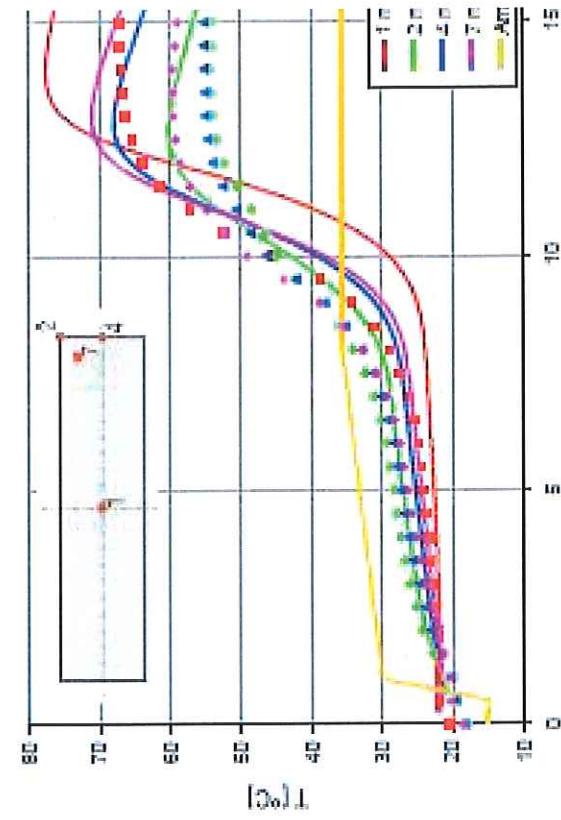
1. Model bias (based on experimental deterministic tests).



Pajares Tunnel line



Jonansson Model for heat generation



Freisleben Model for heat generation

Methodology for model selection / qualification



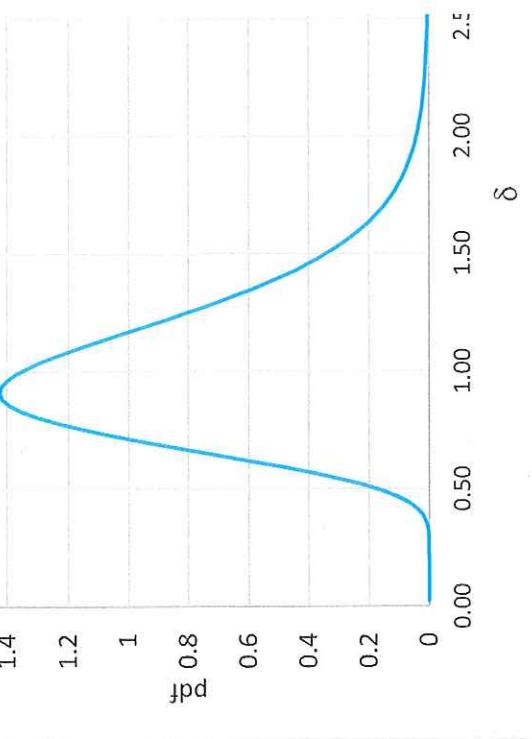
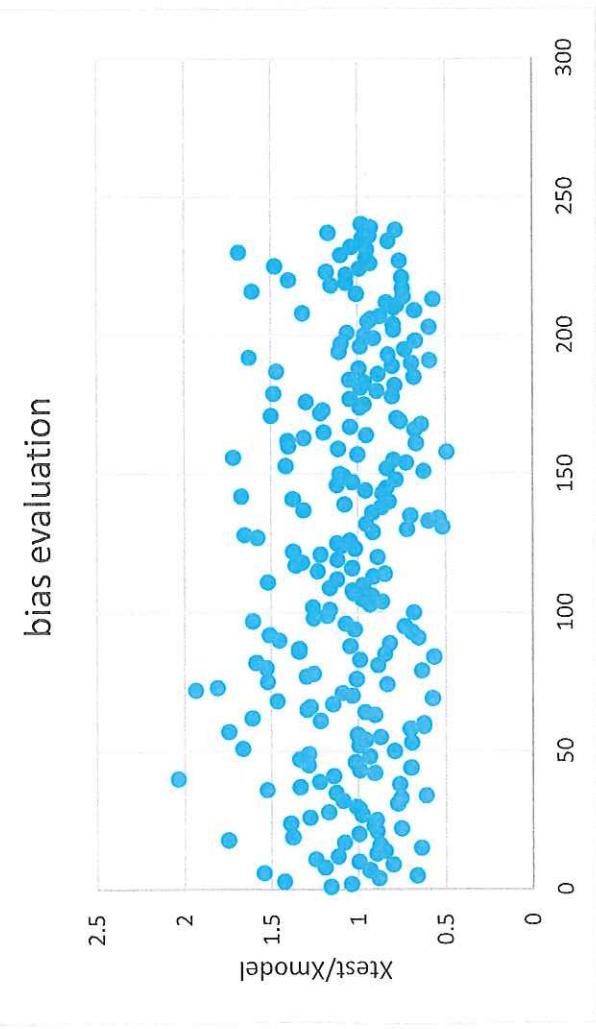
Based on objective indicators.

Indicators:

1. Model bias (based on experimental benchmark tests).

$$\delta = \frac{X_{test}}{X_{model}}$$

Mean and coefficient of variation estimation.

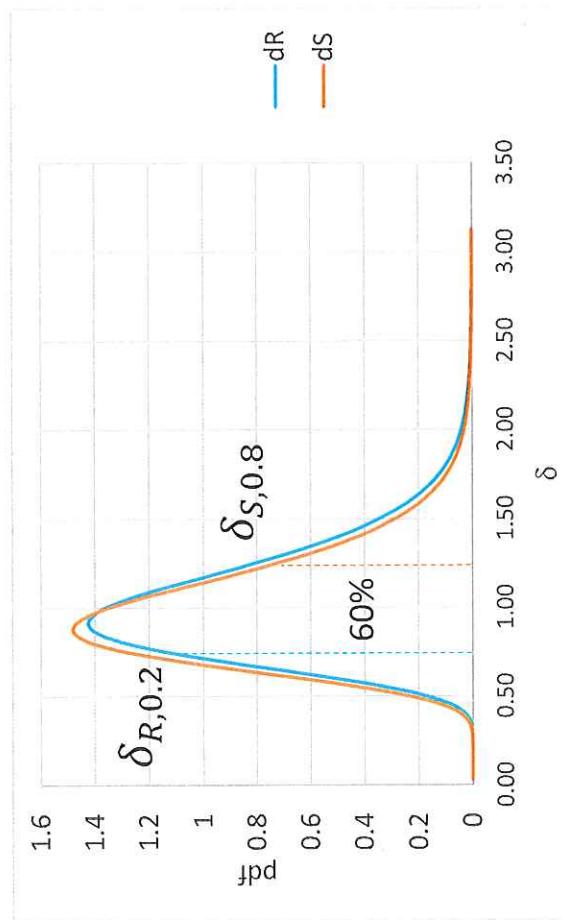


If DB is not available,
recommend values for
different types of models?

Methodology for model selection / qualification

Example: Proposal for model bias based ranking

Problem type	Type of Limit State to verify by model
Crack occurrence	$f_{ct}(t) \geq \sigma_{c,t}(t) / \Delta T_{max} \geq \Delta T(t)$
Crack control	$\omega_{max} \geq \omega(t)$
Long-term damage	$T_{max} \geq T(t)$



Related to the estimated mean reduction in reliability index due to model error.

Indicator	Range	Model safety factor
$I_\delta \geq a_1^*$	Minimum acceptable	Good
$I_\delta \geq a_2^*$		Very good
$I_\delta \geq a_2^*$		Very good

Model safety factors may be based on
 δ_R : Resistance model bias.
 δ_S : Demand model bias.

W3b Sub-tasks

Stage 1

1. Compile information on models used in WG2: characteristic hypotheses, variables needed, sensitivity analysis, reference links.
2. Modelling recommendation (complementary to existing documentation specific early age).
3. Select set of benchmark experimental tests for model qualification for different problem type (focus on early age), e.g.:

Problem type	Type of Limit State to verify by model	Variables
Crack occurrence	$f_{ct}(t) \geq \sigma_{c,t}(t)$ $\Delta T_{max} \geq \Delta T(t)$	Strength, imposed strains, maximum gradient
Crack width control	$\omega_{max} \geq \omega(t)$	Crack width for imposed strains
Long-term damage	$T_{max} \geq T(t)$	Maximum temperature

Database benchmark experimental tests

W3b Sub-tasks

Stage 2

4. Model bias assessment/estimation:

- Model bias against experimental benchmarks (interaction with WG2)
 - Response trends against different parameter effects.
5. Determine indicators for model qualification and assess indicators performance.
6. Recommended statistical models for parameters / safety factors?



WG3b: Product development for software and design methods

Task 3: Development of guidelines for validation and documentation of a software or parts of FE code associated to the SLs advanced verifications

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