From **data** to **decision-making** under conditions of uncertainty

August 26th to 28th, 2025

RISK Summer School 2025

Assessing infrastructures and buildings from an engineering perspective

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Université Grenoble Alpes

GS @UGA Université Grenoble Alpes

FRANCE 2030

GRENOBLE INP UGA

POLYTECH GRENOBLE

GRENOBLE INP UGA Ense3

Risk Institute Université Grenoble Alpes

DECODE Project

Decode stands for : DEvelop COmptences DEvoted to the management of uncertainty with creativity and drama tools

BRITISH COUNCIL

Swansea University Prifysgol Abertawe

Introduction / context

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Civil Engineer

Master & PhD in reliability & mechanics

Researcher

Lab: Soils, Solids, Structures, risks (3SR)

UGA Université Grenoble Alpes

Team: Risks and vulnerability of materials and structures

Teacher

Co-leader of the RISK's Cluster
« Engineered assets at risk »
Infrastructures, structures, systèmes et risques

Institute of technology (UGA)
Civil Engrg &
sustainable construction

3SR Lab

Theoritical & numerical & experimental mechanics

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- Civil engrg, environment, energy, transport, defense, health
- 120 people, with 40 researchers

Experimental research

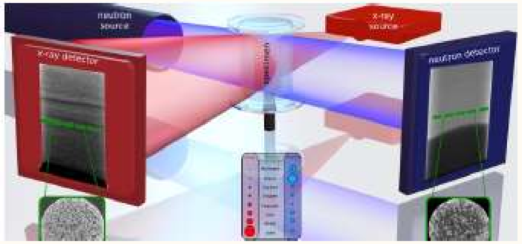
Data

Models

Numerical research

Shaking table

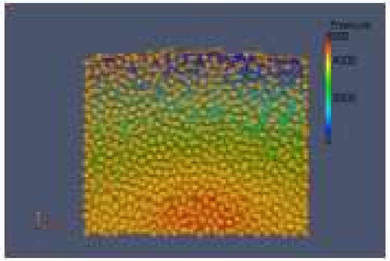
gaz gun (1000m/s)



Tomography (neutrons-rayons X)

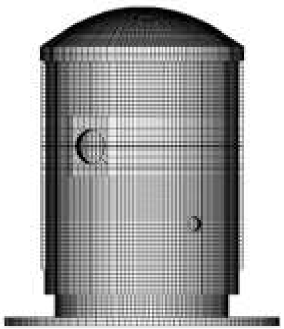
Probabilistic coupling for reliability and sensitivity analysis

Exemple Yade-DEM



Fluid-grain coupling

Discrete and finite element modeling



Thermo-hydro-mechanical of Reinforced concrete modelling

Introduction / context

- 🔧 Role of engineers: data used to ensure structural safety and performance
- 🏗️ Why/how assessing new designs and existing infrastructures
- Ageing infrastructures, evolving hazards: climate change…

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1. What is structural assessment?

process aiming to check the "integrity" of a structure

- "integrity" : **safety**: does not collapse, causing death, injury or economic loss **0 or 1**

  reliability: probability that the structure can perform as required **[0,1]**

  under specified service conditions during a given period of time

  durability: ability of the structure to remain functional in time Δt

- (Infra)structures: buildings, bridges, industrial plants, roads, slopes…

1. What is structural assessment?

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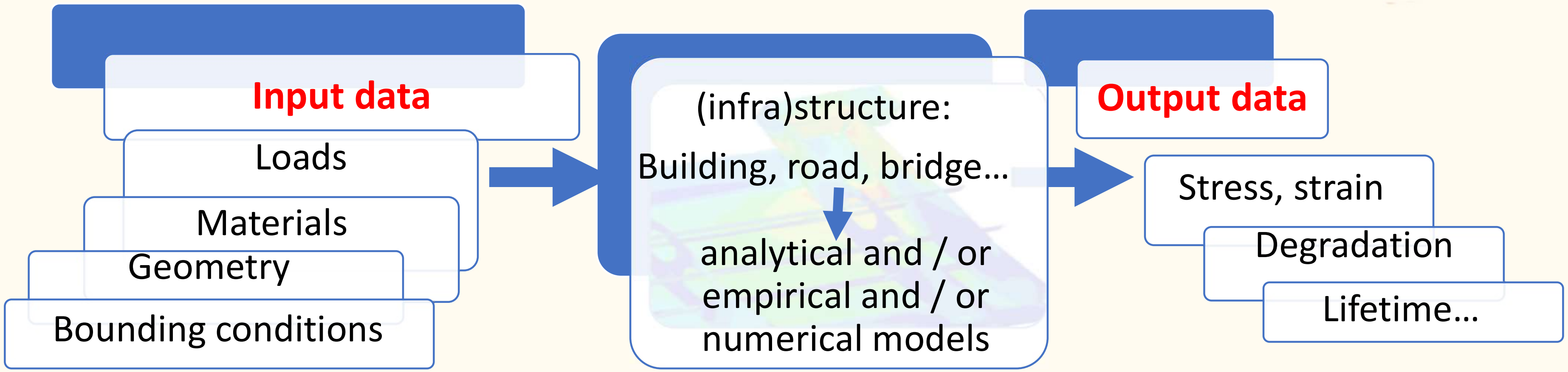
The engineer builds model(s) to check the safety and the performance of a structure, e.g.

Resistance > loads

Settlement > Allowable settlement

…

according to a building code…



1. What is structural assessment?

Deterministic assessment

The engineer checks e.g.

Resistance R > solicitation S ⬄ R/S > Factor of safety (FOS)

Numerical application:

R = 450 MPa ; S = 360 MPa => R/S = FOS = 1.25

Is + 25 % enough ? Uncertainties related to input data ?

1. What is structural assessment?

Uncertainties related to input data? More of less difficult to measure/predict…

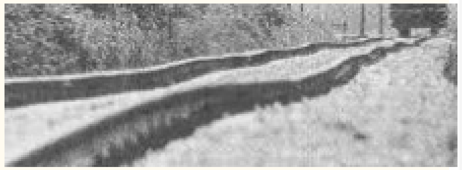
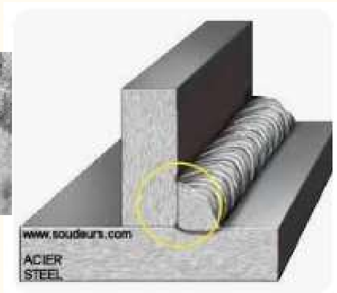
Input data



Loads



Materials

Geometry

(infra)structure assessment estimation

Output data

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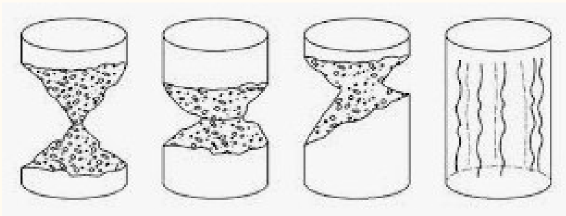
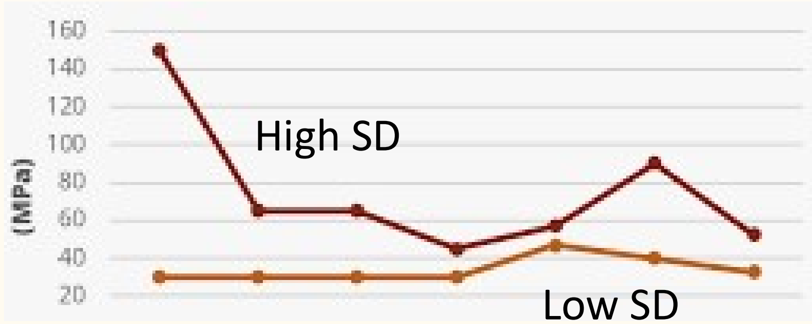
1. What is structural assessment?

Uncertainties related to input data: example of the material strength

Example of concrete specimen under uniaxial compressive load: one test is not enough!



Different ruptures
Different values of
compressive strength
(even for one rupture mode)



Series of tests with more of less

“variability”/ “dispersion”…

standard deviation (SD)

1. What is structural assessment?

Concept of probability of failure Pf

More data: mean and standard deviation of 2 materials

Resistance R m(R1) = 450 MPa ; SD(R1) = 40 MPa < 10% coef of variation
m(R2) = 450 MPa ; SD(R2) = 100 MPa > 20% coef of variation

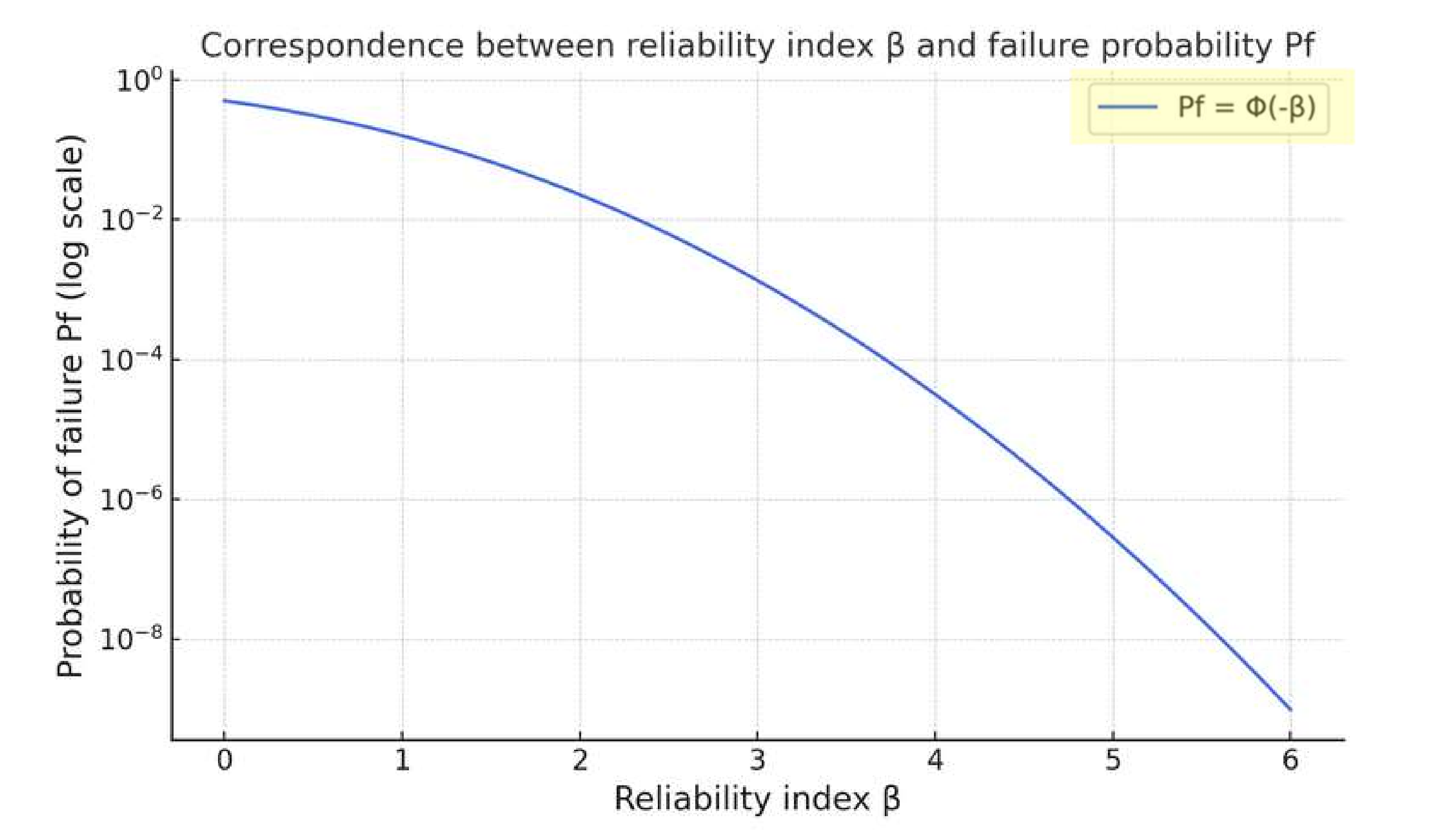
Solicitation S m(S) = 360 MPa ; SD(S) = 30 MPa

One prefers material 1 compared to material 2

Probability of failure Pf1 < Pf2

1. What is structural assessment?

Concepts of probability of failure Pf, reliability : 1 – Pf, reliability index :



$$\beta = \frac{m_R - m_S}{\sqrt{sd_R^2 + sd_S^2}}$$

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} \exp\left(-\frac{t^2}{2}\right) dt,$$

1. What is structural assessment?

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Probabilistic structural assessment

The engineer checks that Prob(G<0) = Pf remains under a limit

G is the performance function, e.g. G = Resistance R - solicitation S

1. What is structural assessment?

Probabilistic structural assessment

The engineer checks that Prob(G<0) = Pf remains under a limit

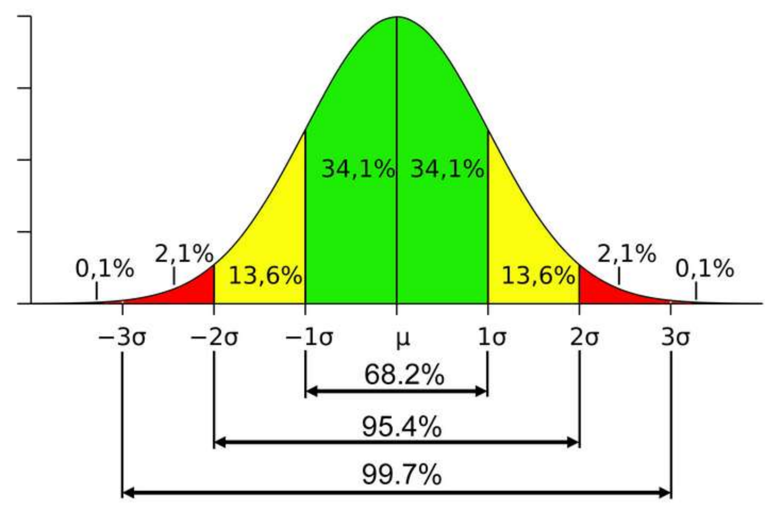
G: performance function, e.g. G = Resistance R - solicitation S

Numerical application: R and S follow a Gaussian distribution

mR = 450 MPa ; mS = 360 MPa

sdR = 40 Mpa ; sdS = 30 MPa => Beta = 1.8 => Pf= ?

sdR = 100 Mpa ; sdS = 30 MPa => Beta = 0.86 => Pf= ?



1. What is structural assessment?

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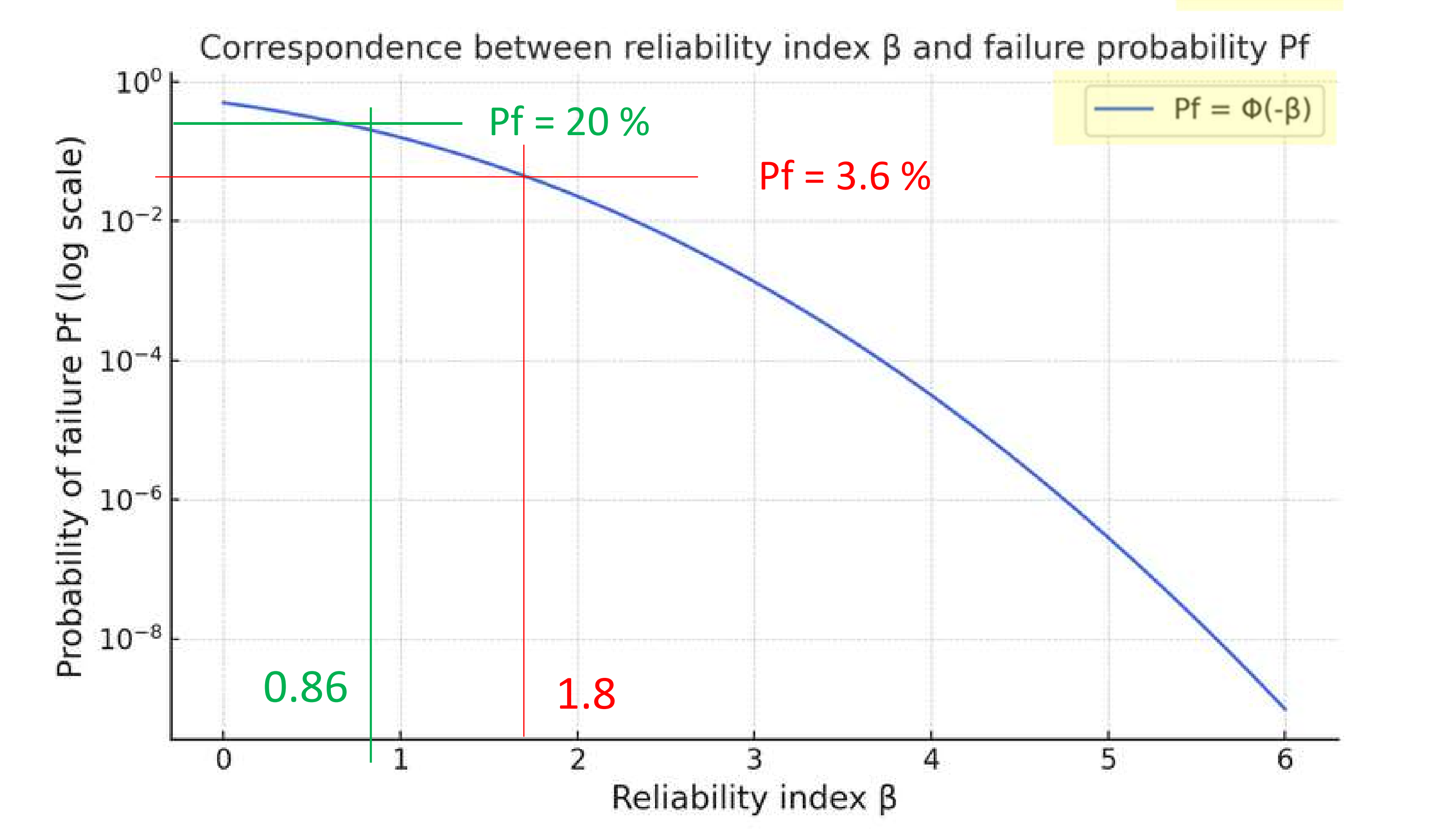
Concepts of probability of failure Pf, reliability : 1 – Pf,



1. What is structural assessment?

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process aiming to check the "integrity" of a structure

- "integrity" : **safety** vs failure 0 or 1

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Reliability Class	Minium 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

Recommended minimum values for reliability index β for ultimate limit states (EN 1990 - Annex B)

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2. The Eurocodes

European standards for the design of buildings and civil engineering structures providing rules for structural safety, reliability, durability (materials and actions)

Eurocode 0: Basis of Structural Design
Eurocode 1: Actions on Structures
2: Design of Concrete Structures
3: Steel Structures
4: Composite Steel and Concrete Structures
5: Timber Structures
6: Masonry Structures
7: Geotechnical Design
8: Structures for Earthquake Resistance
9: Aluminium Structures

2. The Eurocodes based on limit states

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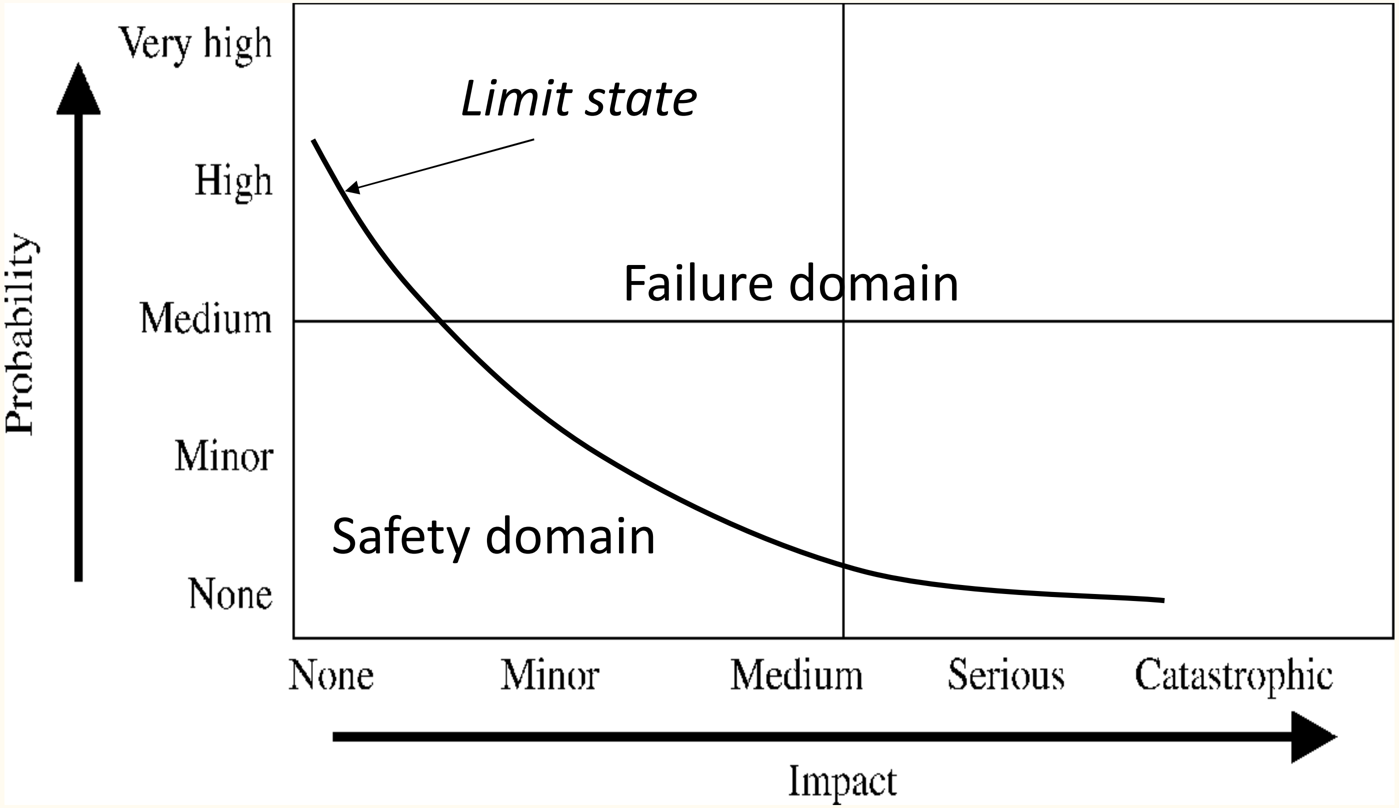
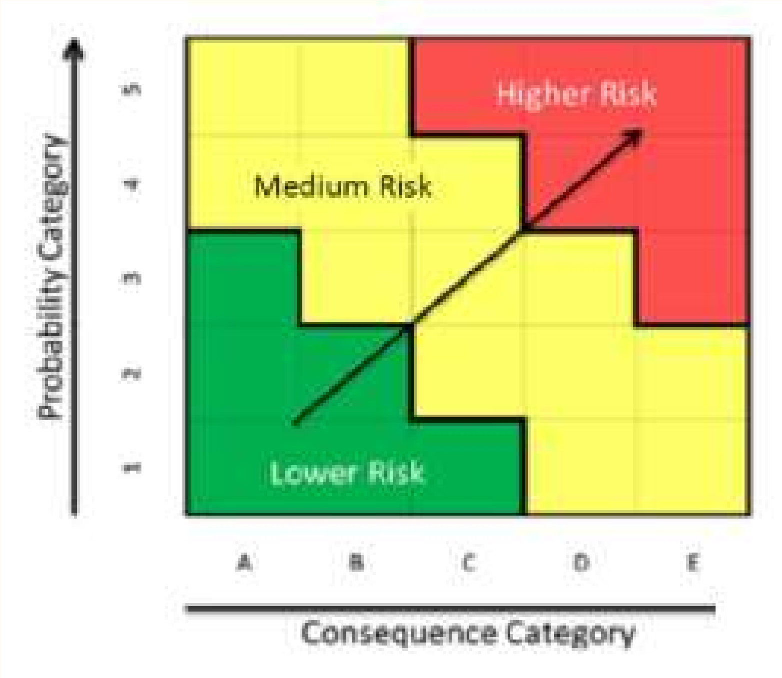


Farmer diagram (from Lemaire, 2011)



Risk matrix

2. The Eurocodes

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limit states

- Ultimate limit states (ULS)
- Serviceability limit states (SLS)

Impact

Falling rocks

Vibration

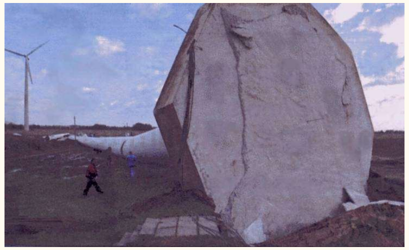
Wind

Bearing capacity of soil (Liquefaction during an earthquake)

Fire

Avalanche

Soil failure



Stability

Deflexion

2. The Eurocodes: a « Semi-Probabilistic » Framework

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Based on

- target reliability index ($\beta \approx 3.8$ for 50 years)
- **characteristic values & partial safety factors**

$Prob(R<Rk) = 5\%$

$Prob(S>Sk) = 95\%$

$Rk / \gamma_R > Sk \times \gamma_S$?

2. The Eurocodes: double precaution against uncertainty

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Example:

Resistance R m(R1) = 450 MPa ; sd(R1) = 40 MPa

Load S m(S) = 360 MPa ; sd(S) = 30 MPa

Characteristic values: Rk = 450 – 1,65 x 40 = 384 MPa < 450 MPa

Sk = 360 + 1,65 x 30 = 410 MPa > 360 MPa

Sk > Rk ⚠

Partial safety factors ⚠ Rk **/ 1.5** > Sk **x 1.35** ⚠

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From data to decision making under conditions of uncertainty

Assessing infrastructures and buildings from an engineering perspective : tools for Structural Evaluation

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Experimental research

- Visual inspections (corrosion, cracks…)
- Environemental data (meteo…)
- Sensor data (strain, displacement, temperature, water level…)
- …

Data

Models

Numerical research

- Finite/discrete element modelling
- Damage mechanics, fatigue modelling
- Model updating
- Probabilistic modelling

From data to decision making under conditions of uncertainty

Assessing infrastructures and buildings from an engineering perspective : tools for Structural Evaluation

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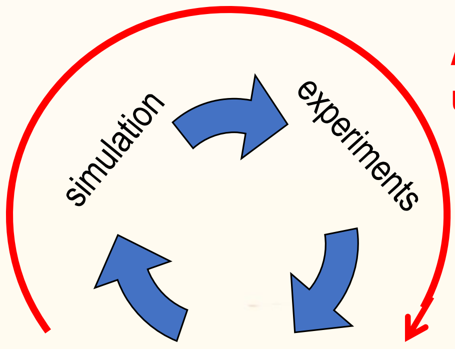

Accounting for uncertainties

Probabilistic modelling of (infras)structures

From data to decision making under conditions of uncertainty

Assessing infrastructures and buildings from an engineering perspective : tools for Structural Evaluation

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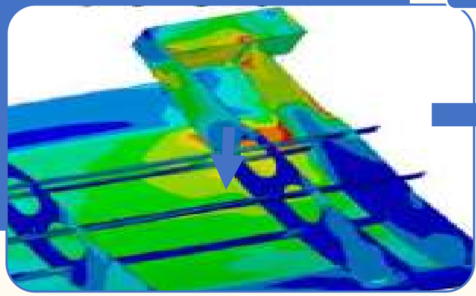
Input data

- Loads
- Materials
- Geometry
- Bounding conditions

(infra)structure model



Output data

- Stress, strain
- Degradation
- Lifetime…

Database, expert judgement, probabilistic hypotheses

Random vector

- Means, standard deviations
- Confidence Intervals
- Probabilites of failure
- Fragility curves, reliability indices

Assessing infrastructures and buildings from an engineering perspective : tools for Structural Evaluation

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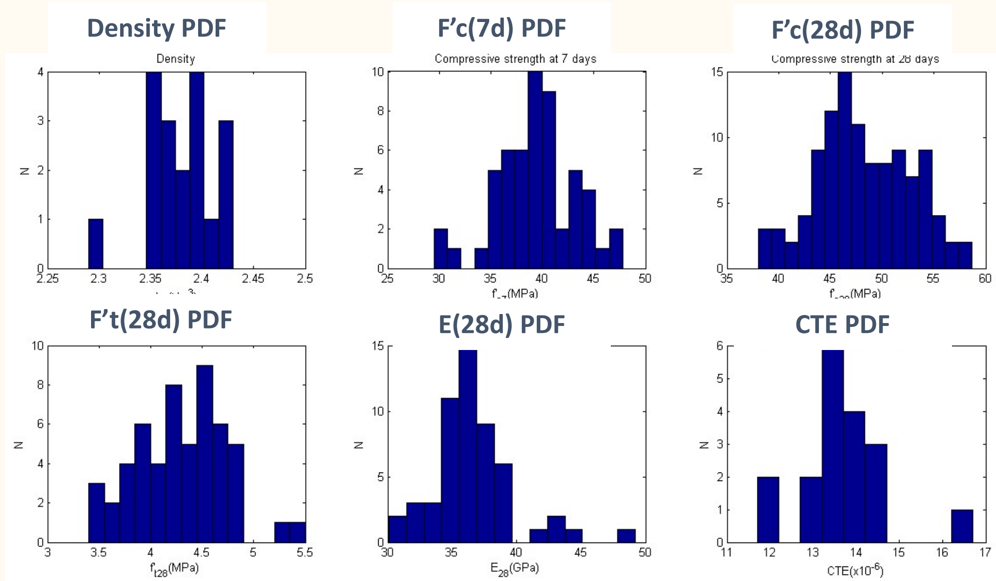
Variability of inputs (VeRCoRs concrete)

a)

b)

c)



Experimental 1:3 scaled double-walled nuclear containment building (NCB) – VeRCoRS mock-up: overview – photo by eDF (a), view of concrete specimens (b) histograms of material properties of VeRCoRs concrete (c).

E.M. BOUHJITI, J. BAROTH, F. DUFOUR, B. MASSON – Int. Conf. MMR 2017, Grenoble

Design phase

Structural plans

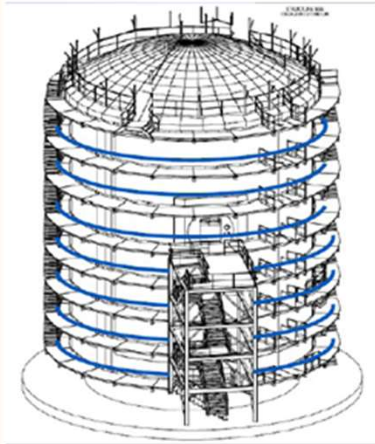
Concrete mix

Operational phase

On site structure

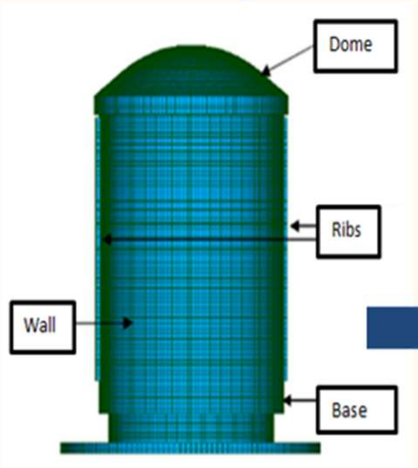
1

Experimental tests (Specimen scale)



Predictive calculations

2



Numerical analysis (Structural scale)

Adjustment of model's input

3

Assessment of model's accuracy

Monitoring of the structural response

Steps of interest

Not covered

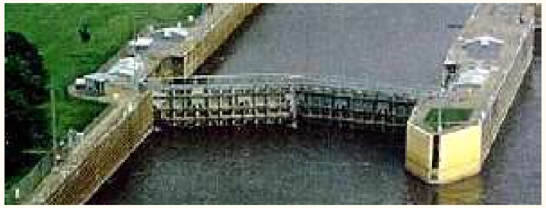
E.M. BOUHJITI, J. BAROTH, F. DUFOUR, B. MASSON – Int. Conf. MMR 2017, Grenoble

Assessing infrastructures and buildings from an engineering perspective : tools for Structural Evaluation

Medelia
BY FONDATION GRENOBLE INP

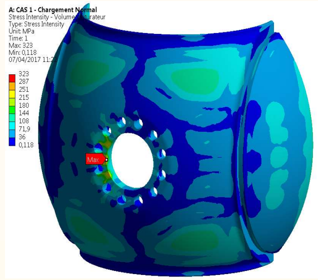
Industrial chair

SPRETEC designs or checks structures



Lock gates (USACE, 2002)

Turbine (EdF & GE, 2018, in Savin et al. 2021)



Ball valve (SPRETEC)

To care for ageing hydromechanical structures

- Artelia / SPRETEC company
  + EdF / CIH + CNR
- 2 co-holders, 6 years

From data to decision making under conditions of uncertainty

Assessing infrastructures and buildings from an engineering perspective : tools for Structural Evaluation

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Medelia BY FONDATION GRENOBLE INP

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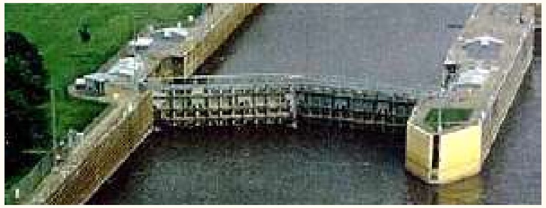
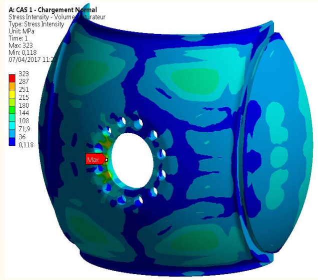
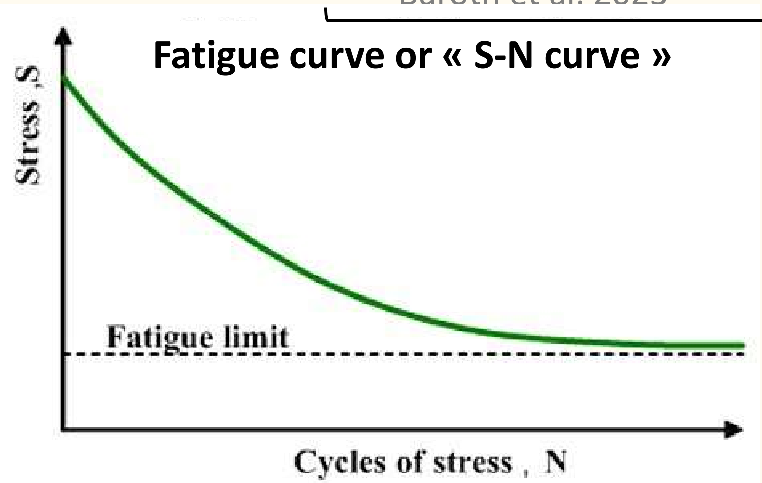


Lock gates (USACE, 2002), in Baroth et al. 2023

Turbine (EdF & GE, 2018, in Savin et al. 2021)



Ball valve (SPRETEC)



subjected to fatigue

= decrease of material resistance under repeated load cycles

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Discussion: from Data to Decision in Structural Assessment

- Input: inspections, sensors, documentation, environment…
- Model: simulation, model updating, reliability computation
- Output: decision to accept, repair, monitor, or replace
- Engineers bridge data and critical decisions under uncertainty…

From data to decision making under conditions of uncertainty

Assessing infrastructures and buildings from an engineering perspective

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Discussion: from Data to Decision in Structural Assessment

Example

Bryla et al. 2024:

Penstock Diagnoses At EdF

- EDF operates more than 450 hydropower plants
- Penstock convey water from the reservoir to the turbines
- Cumulated length > 250 km
- Average age ~ 70 years
- Complete diagnoses with penstock assessment are performed periodically
  - Visual inspections (internal & external) with thickness measurements
  - Evaluation of the residual Margin Factor (MF)

$$MF = \frac{f}{\sigma_C^*} \quad \begin{array}{l} \longleftarrow \text{Allowable stress} \\ \longleftarrow \text{Maximal in-service stress} \end{array}$$

EDF

| 2

DTG

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Discussion: from Data to Decision in Structural Assessment

- Assessment requires data… but also engineering judgement/expertise
- Advanced modelling supports decision-making…

  but many engineers do not decide, they check mechanical rules, if possible providing reliability indicators (Bryla et al. 2024)

- Eurocodes provide consistent reliability framework…

  but needs to be completed for existing structures

- Need for collaboration across disciplines and stakeholders:

  e.g. Chaires Medelia (2023-28) or MIAI/PRISM (2025-29)

PRISM : Predictive Risk-Informed asset Strategic Management

Context : Management of ageing assets in a hazardous environment

Debris flow © P. Zufferey

Key challenges :

- Lack of information
- Heterogeneous data
- Evolution of assets in time
- Maintenance strategies

Multi-disciplinary team: L. Doyen, R. Drouilhet, O. Gaudoin, S. Capdevielle, J. Baroth, C. Bérenguer, JM. Tacnet

Statistics and probability methods, reliability, physical numerical modelling, decision sciences, risk management

Research program:

Axis 1: From data and information to a knowledge model for asset condition prediction

Axis 2: Predictive decision-making for asset management

Innovation and external partne

Education

- New multi-disciplinary course for the doctoral schools:
- AI subjects in Risk thematic program of the Graduate School@UGA
- Numerical resources for online training

From data to decision making under conditions of uncertainty

Assessing infrastructures and buildings from an engineering Perspective: references

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