Lifetime Oriented Design Concepts under Aspects of Degradation

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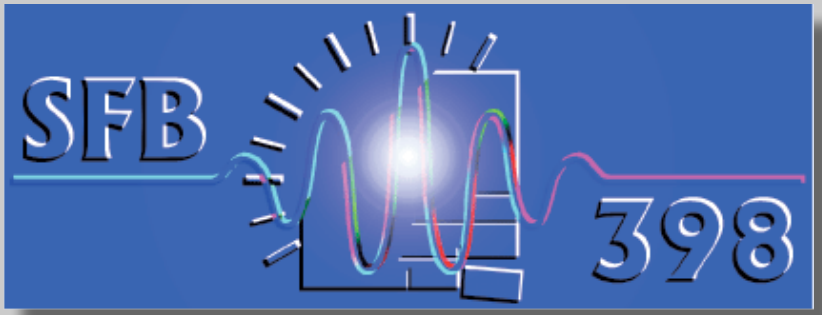

Deutsche
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Sonderforschungsbereich 398:
Lebensdauerorientierte Entwurfskonzepte unter Schädigungs- und Deteriorationsaspekten

Cooperative Research Center 398:
Lifetime Oriented Design Concepts

Ruhr-Universität Bochum

Basic Qualities of Buildings and their Construction

- technical safety (for all the expected lifetime),
- sustainability (for us and for following generations),
- harmony with nature, also with human nature, now and in future.

→ qualities not only for now, but reaching into the future

→ **Prognostical methodology needed**

Survey

in the focus of SFB 398:

Concrete (reinforced, in case: prestressed) structures,
steel and composite structures, as well as their foundations
→ load carrying components of a building

not focussed:

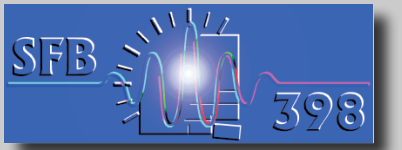
Interior and facade components, technical equipment etc.;
in general with shorter life cycles
→ in principle, same methodology can be used,
but life cycle differences must be accounted for

The following synopsis refers to structural concrete, only.

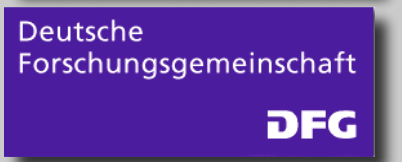
Lifetime Related Aspects of Structural Concrete

Appropriate Quality Assurance (QA) for structural design, detailing and execution

Lifetime oriented design concepts



Cooperative Research Center, Bochum



Sponsored by German Science Foundation

Own basic SFB 398 research

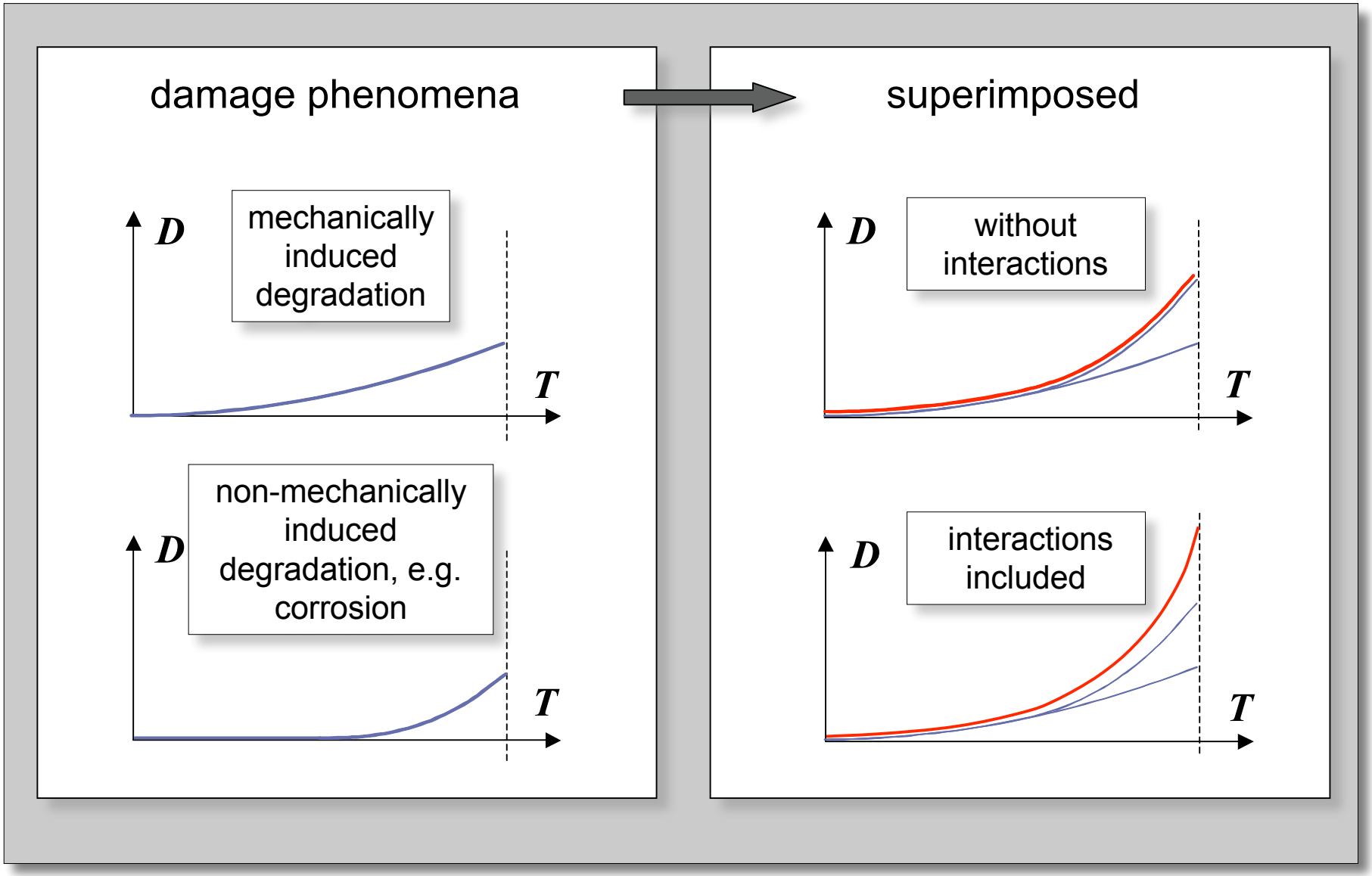
- Resistance against fatigue (cyclic loading)
- Resistance against frost (-thaw cycles)
- Simulations for combined mechanical and chemical processes and propagations
- Integrated design concepts

Durability

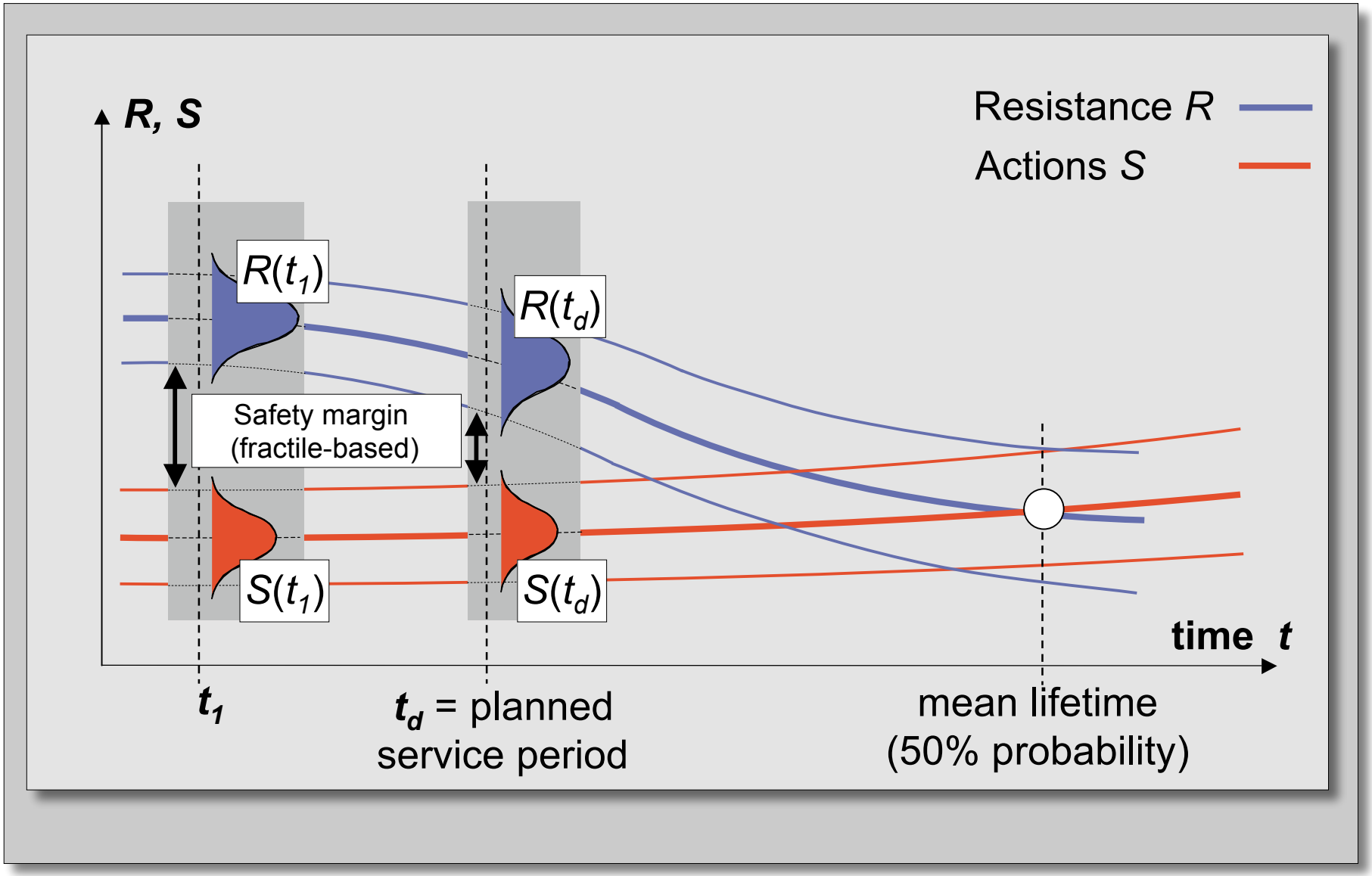
Integrated from outside into SFB 398 models and concepts

- Resistance against abrasion
- Chemical durability against substances penetraiting from outside
- Corrosion protection of reinforcing steel in concrete:
  - carbonation
  - penetration of chlorides
  - further deteriorations

Evolution of Degradation



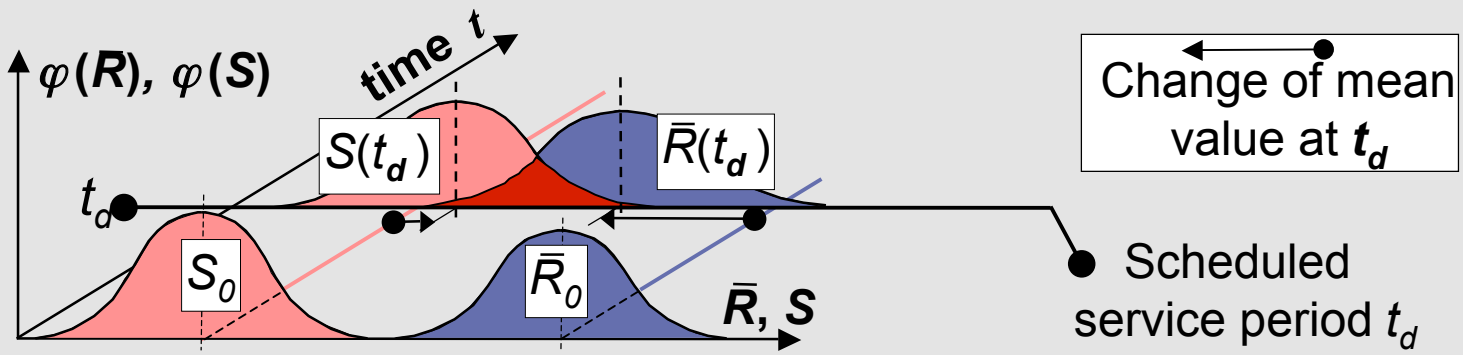
Time-dependent Reliability of Structures



Time-dependent Reliability of Structures

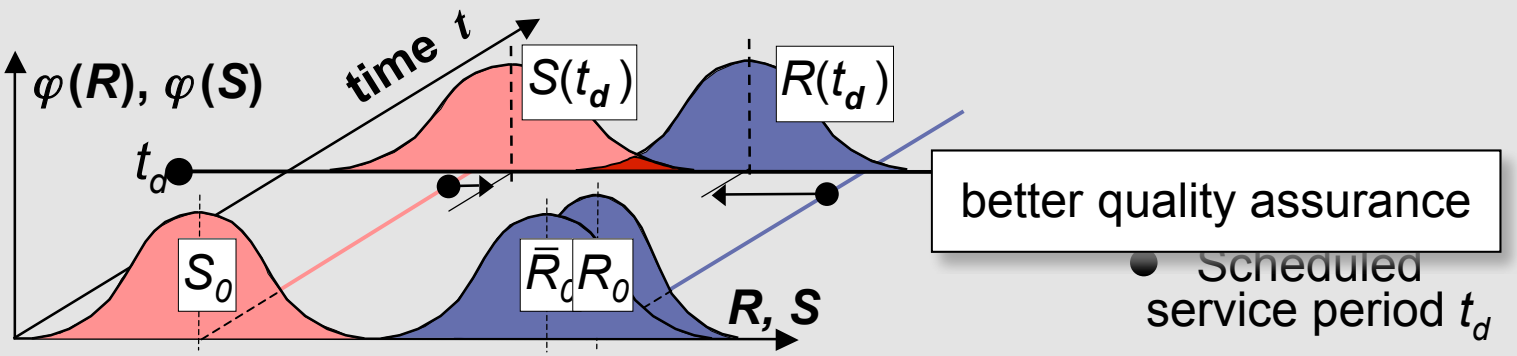
At time t_d inacceptable design

Safety margin : $\boldsymbol{Z(t_d) = \bar{R}(t_d) - S(t_d)} \leq$ scheduled value

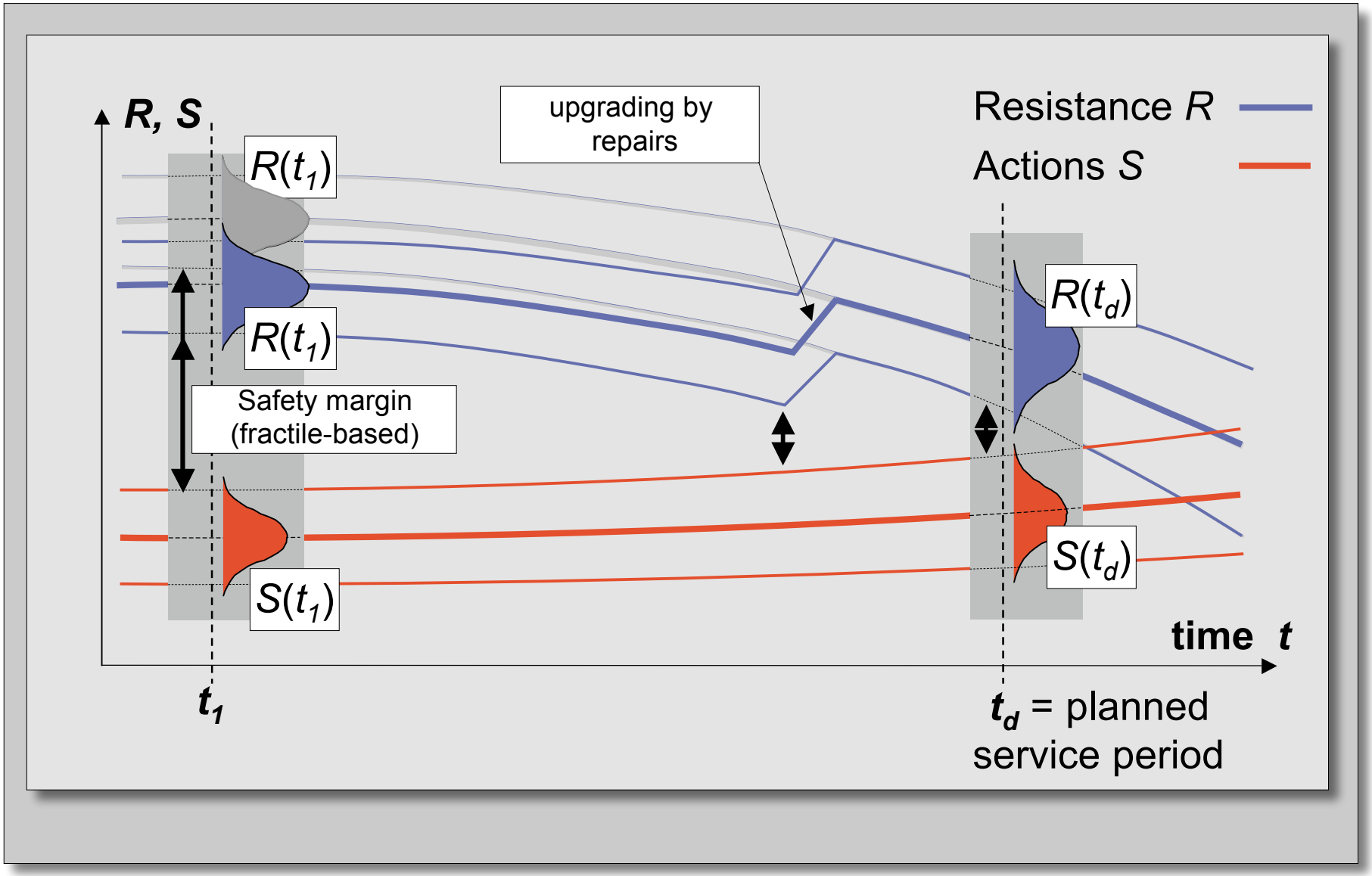


Improved design, at time t_d acceptable

Safety margin: $\boldsymbol{Z(t_d) = R(t_d) - S(t_d)} \geq$ scheduled value



Time-dependent Reliability of Structures



Building Classes

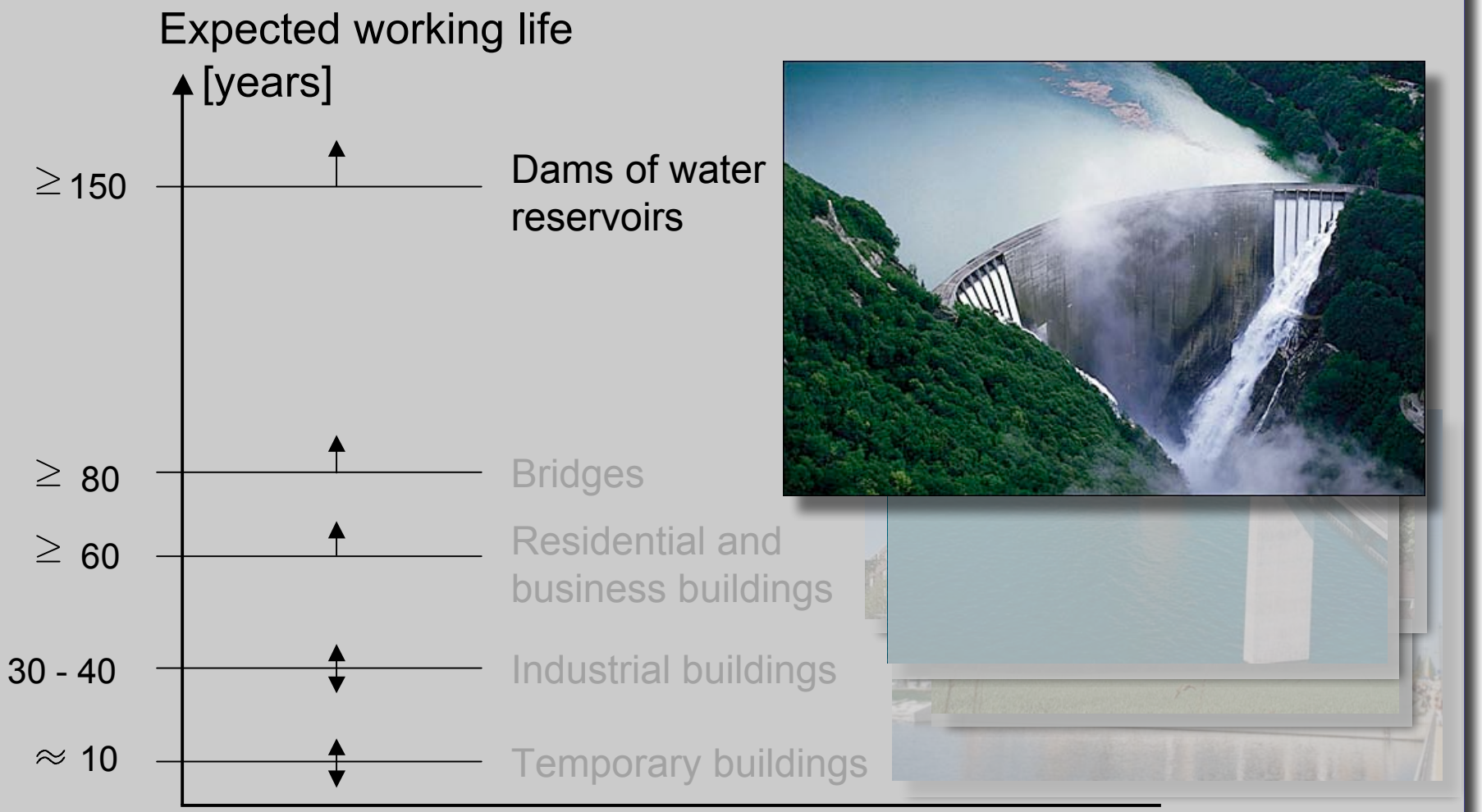
Problems

- Standard design without account for different service lives; almost no differentiation.
- The service life often is not long enough, without unplanned repairs.

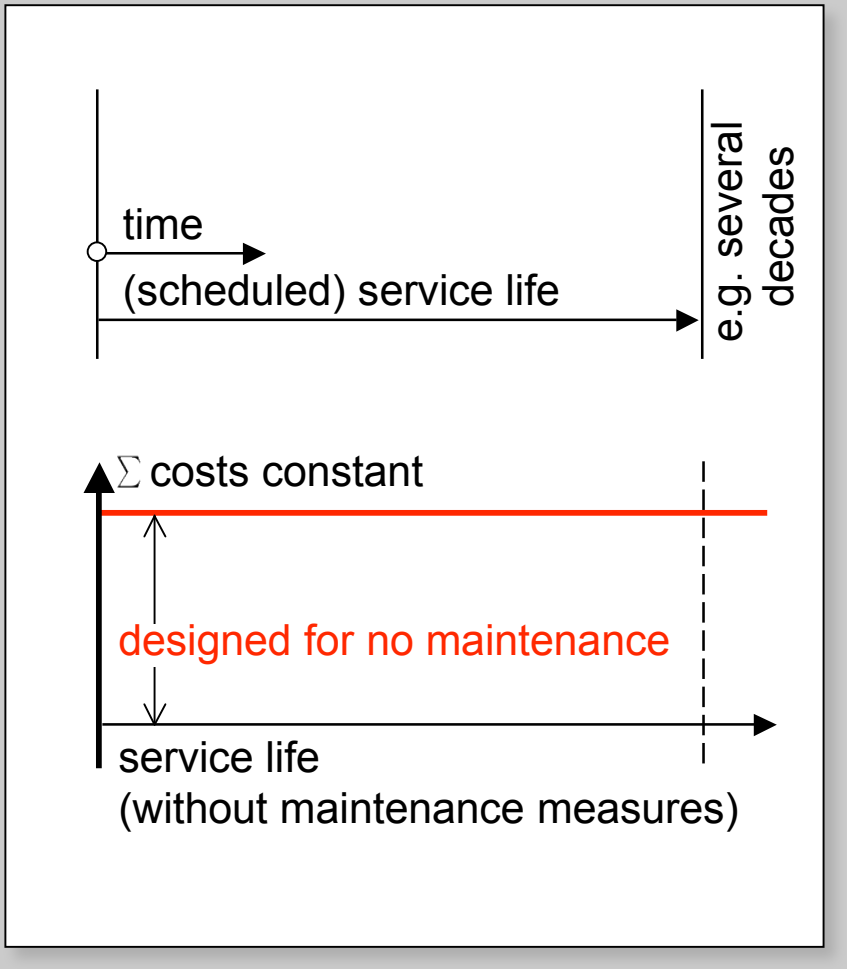
Demand

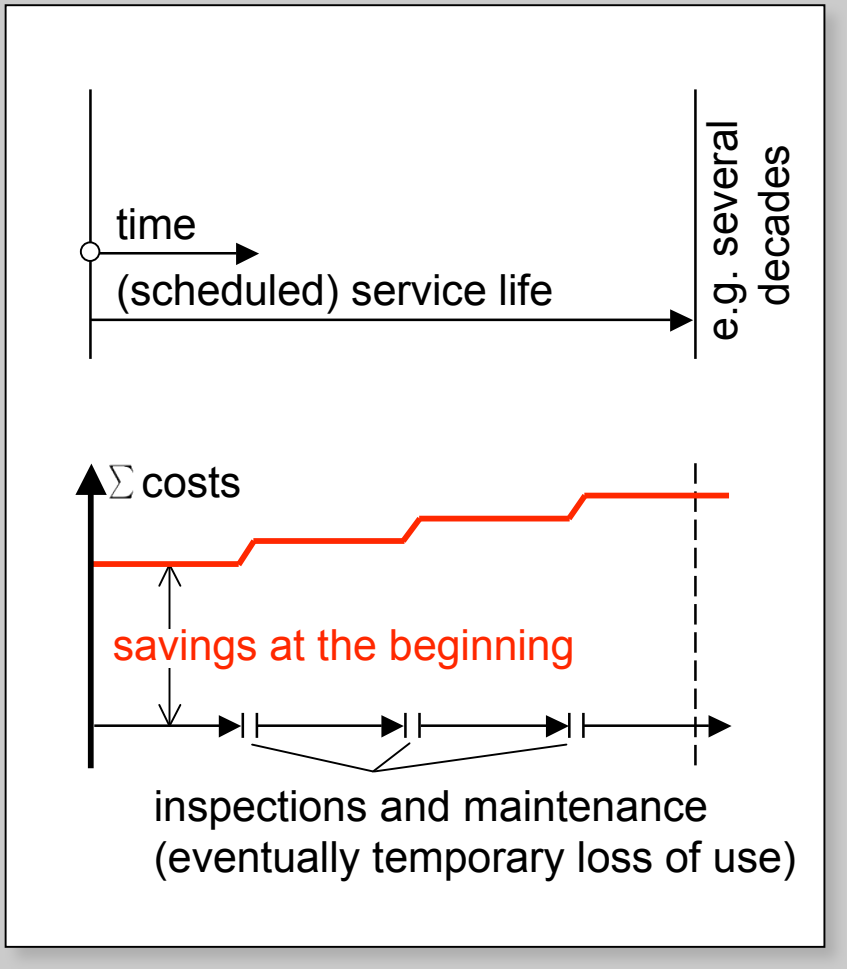
Differentiation according to building classes of different service life

Expected Working Life



Service Life Control and Economic Aspects





Service Life and Investment Costs

Goal: Optimization of building investments

- construction,
- the (if necessary) periodic inspection, maintenance and strengthening
- temporary loss or restriction of use (e.g. due to maintenance interruptions) and consequent effects,
- financing etc.

→ Establishing of interfaces*) in the SFB-concept for later assessment of costs

and preparation of optimization methods

*) cooperation with University of Munich, construction operation, Prof. Remmer and with University of Colorado, Boulder, Prof. Frangopol

Service Life Control and Sustainability

Savings of natural ressources,
e.g. economizing raw materials, energy etc.

- minimizing costs of structural repair
- lifetime oriented strategies for successful investment economy

Law Aspects

Duration time of warranty of structural quality is different in different countries (5 or 10 years or other)

→ Duration time of warranty should be conform with the planned service life and be harmonized internationally

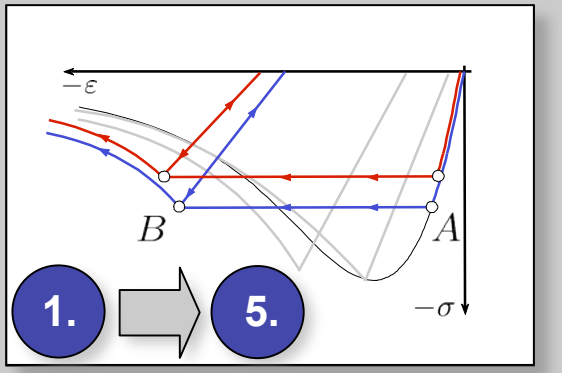
Planned for the Final Phase of SFB 398

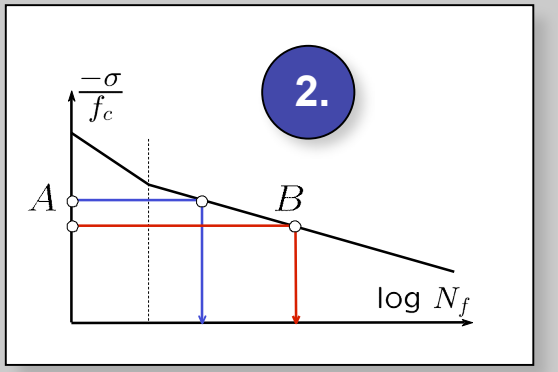
Joining the different scientific fields together to holistic design concepts with respect to:

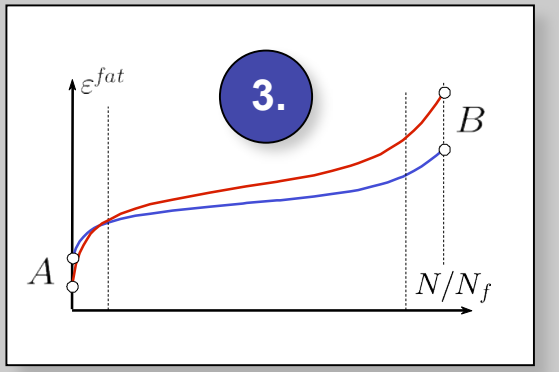
- interactive degradation effects
- stochastic aspects

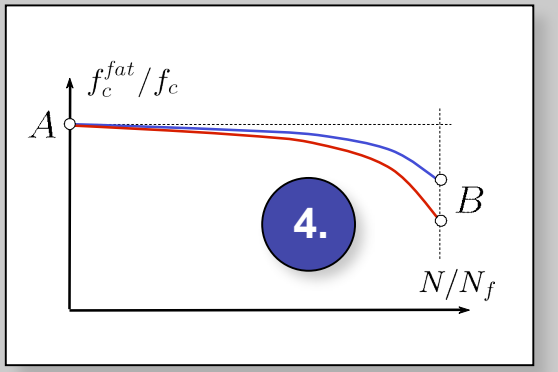
Fatigue Damage (Concrete)

1. Material model for instantaneous response
2. Fatigue lifetime based on ($\frac{-\sigma}{f_c}$)-N curves
3. Evolution of strain and damage
4. Degradation of compressive strength
5. Degraded material behavior

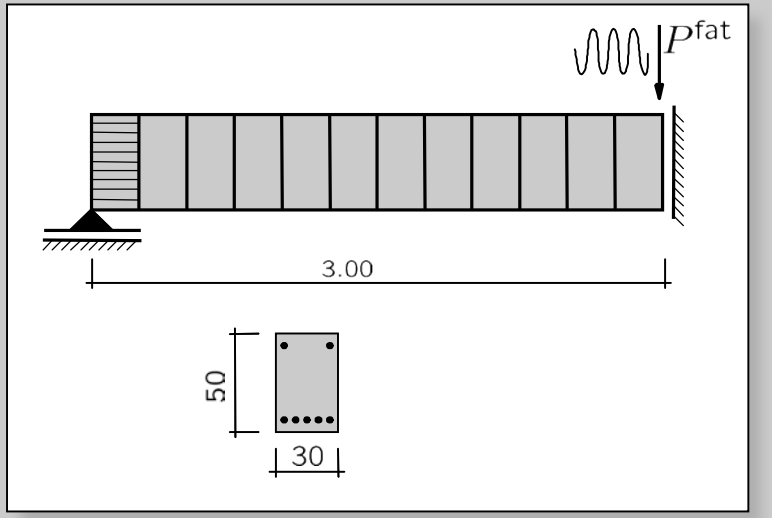


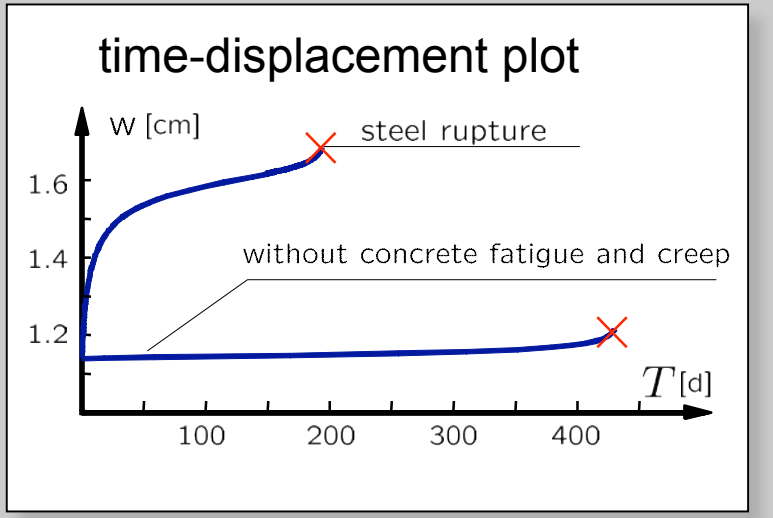






Example: Beam under Fatigue Loading



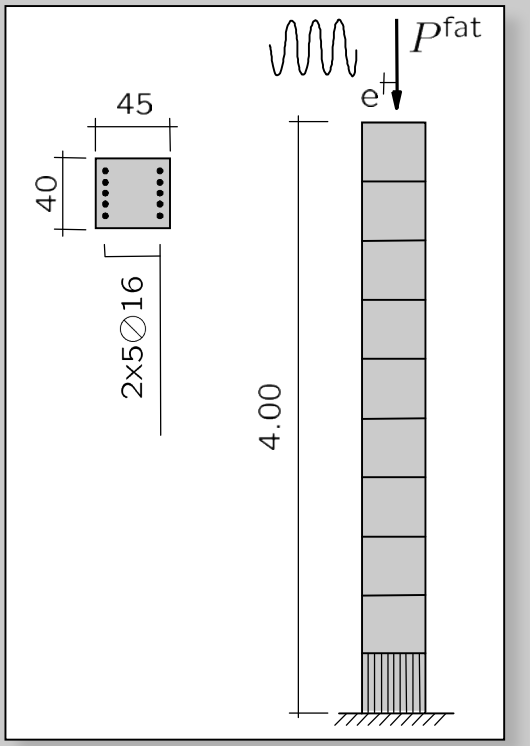


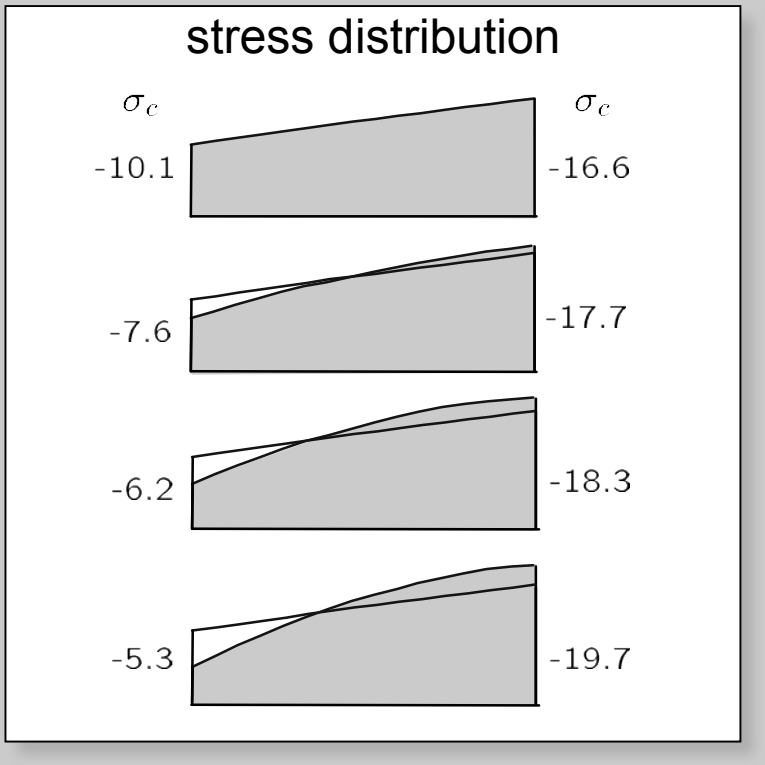
single span beam

12 shell elements,
10 concrete layers,
2 steel layers

$$P_{\text{fat,max}} = 0.5 P_{\text{stat,max}}$$

Example: Column under Fatigue Loading

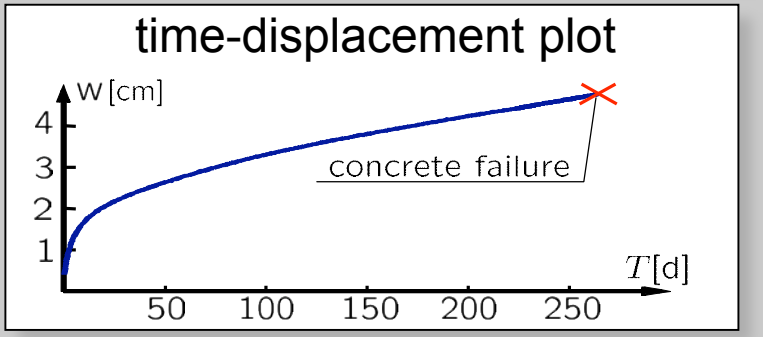




column

10 shell elements,
8 concrete layers,
2 steel layers

$P_{fat} = 0.45 P_{stat}, e = 10mm$



Reference Project *Hünxer Brücke*

Lifetime: 53 years

Challenge for lifetime oriented research

- SFB 398
- SFB 477
- SFB 524

Related SFBs

SFB 477

Sicherstellung der Nutzungsfähigkeit von Bauwerken mit Hilfe innovativer Bauwerksüberwachung

Life Cycle Assessment of Structures via Innovative Monitoring

Sonderforschungsbereich 524
Werkstoffe und Konstruktionen für die Revitalisierung von Bauwerken
Materials and Structures in Revitalisation of Buildings
Bauhaus-Universität Weimar
Dieses Projekt wird von der Deutschen Forschungsgemeinschaft gefördert.
DFG

Werkstoffe und Konstruktionen für die Revitalisierung von Bauwerken

Materials and Structures in Revitalisation of Buildings

SFB 398

Lebensdauerorientierte Entwurfskonzepte unter Schädigungs- und Deteriorationsaspekten

Lifetime Oriented Design Concepts

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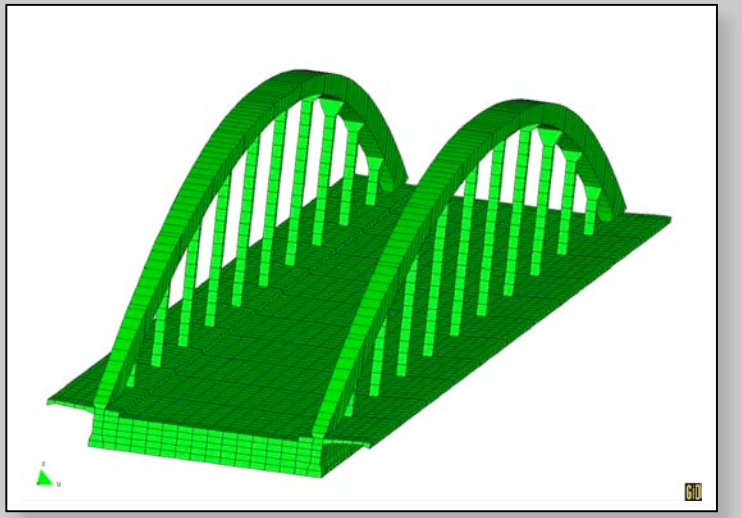


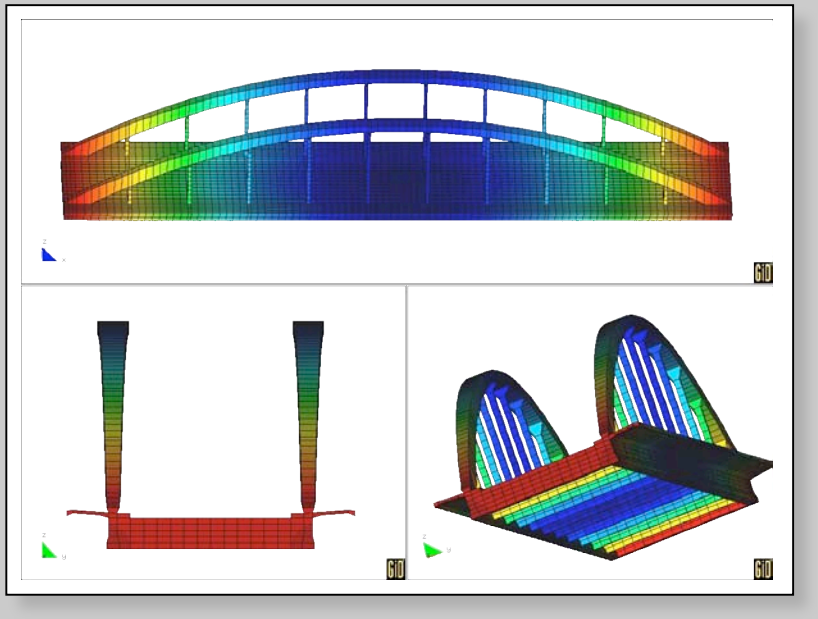
Discretisation:

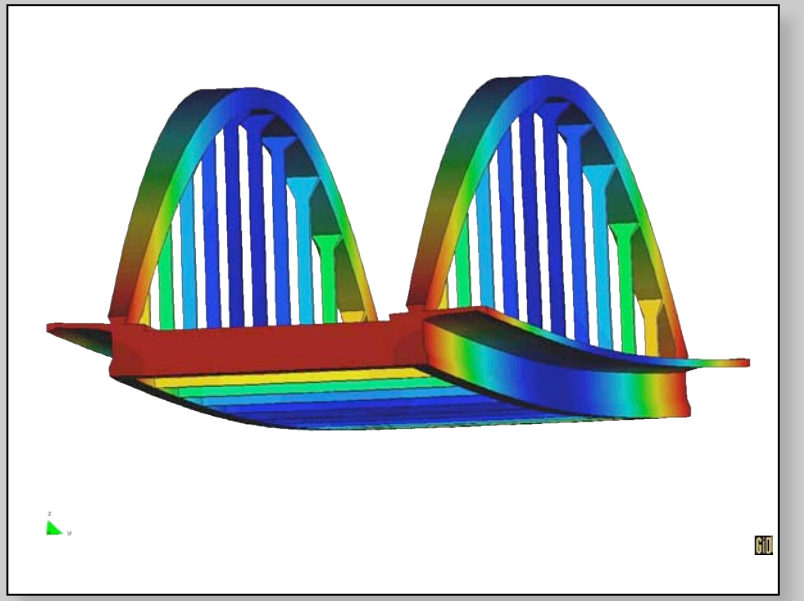
5200 shell elements

about 33,000 DOF

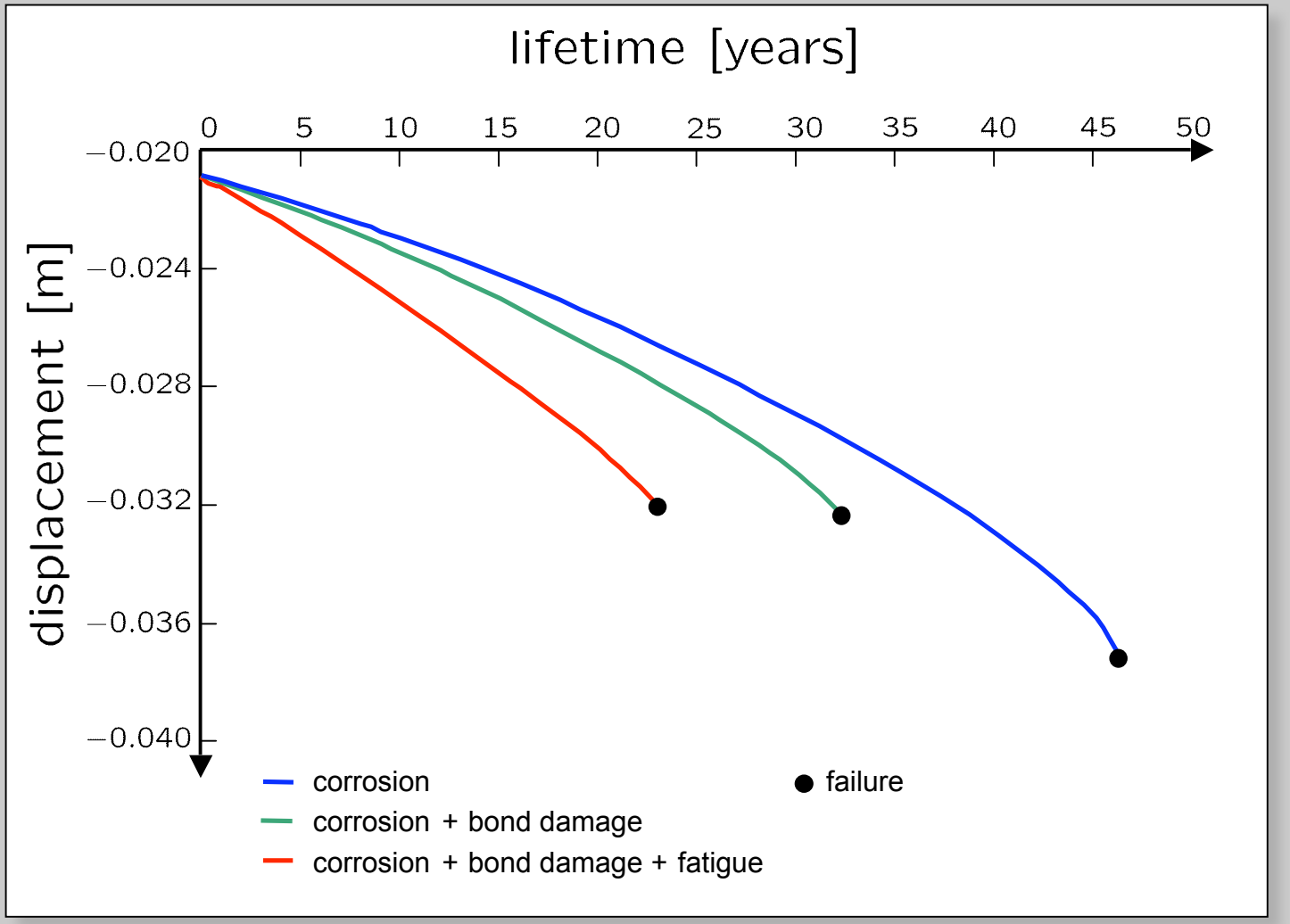
Reference Project *Hünxer Brücke*

Deformation under dead load





Hünxer Brücke: Interaction of Deterioration Phenomena



SFB 398: Current Projects

Project Group A: Modelling of lifetime effects

A5 structural concrete

A8 cyclically loaded soil

A9 structural mechanics

A11 concrete technology

A13 concrete fatigue

Project Group B: Methods for lifetime-oriented structural analyses

B1 damage mechanics of steel

B3 simulation technology

B4 damage diagnosis and localization

B8 multi-scale damage simulation

B9 simulation strategies

Project Group C: Future lifespan-oriented design strategies

C1 simulation methodology

C2 prognosis concepts for concrete

C4 prognosis concepts for steel

C5 holistic simulation concepts

C8 composite structures

C10 crack development simulation

Project Group D: Evaluation on a reference structure

D1 reference structure: roadbridge