Project number: CZ/011/LLP-LdV/TOI/134005

Seminar: Assessment of existing structures

Codes and Procedures

Dimitris Diamantidis

Regensburg University of Applied Sciences

- **Need and criteria for codes and recommendations**
- **Example codes**
- **Example contents with illustrations**
- **Safety acceptance – performance criteria**
- **Applicability to case studies**
- **Future tendencies**

Pisa March 15, 2013

flood

Failures

Vehicle

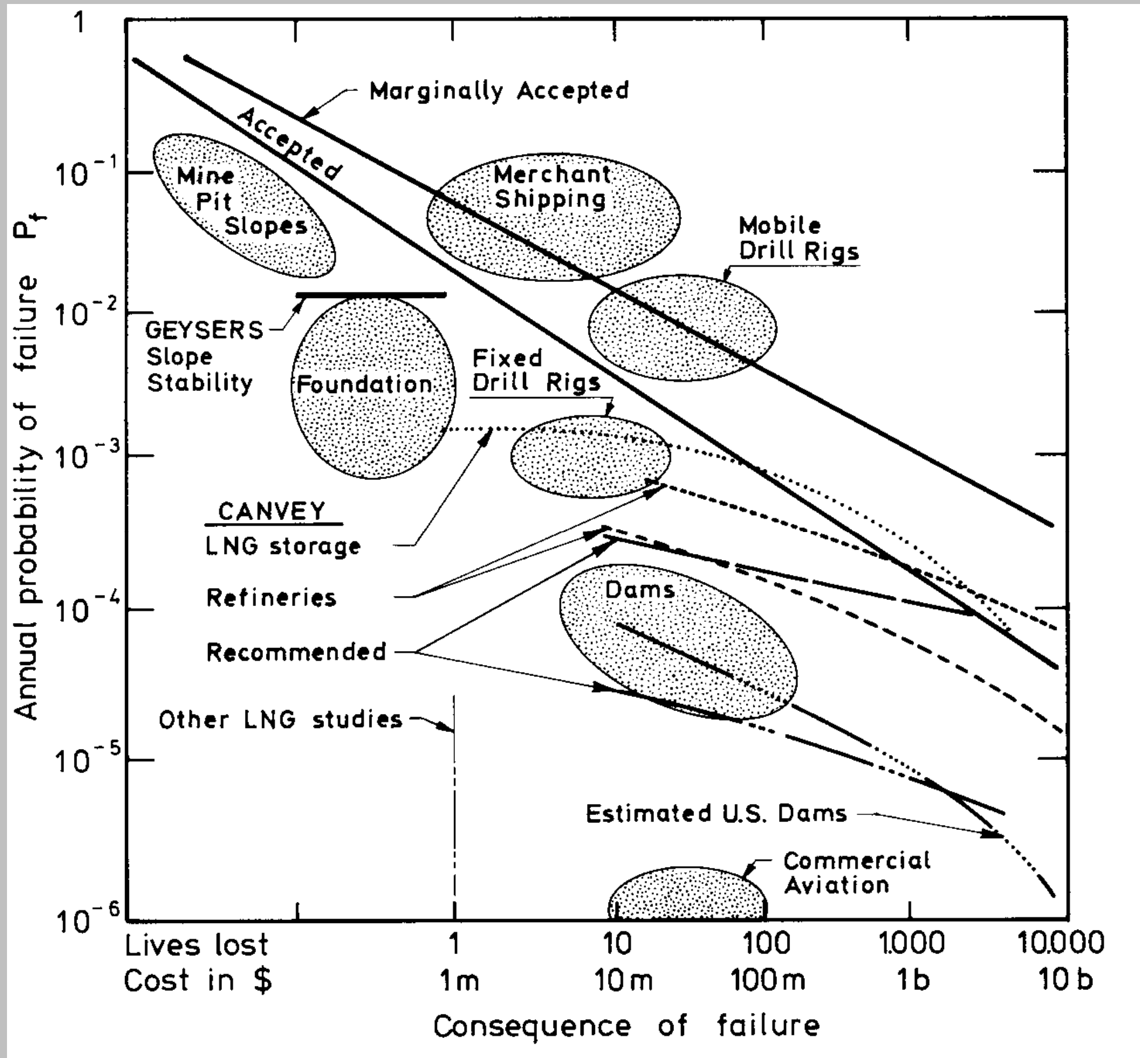
Snow load

Damages: Cracks in buildings

Why reassess an existing structure?

- **Deviations from original design**
- **Doubts about safety**
- **Adverse inspection results**
- **Change of use**
- **Lifetime prolongation**
- **Inadequate serviceability**

Structural failures experience



Typical questions

- What type of inspections are necessary?
- What type of measurements shall be taken?
- What analyses shall be performed?
- What is the future risk in using the structure?

How to find the Answers

- **No classical code approach**
- **New information becomes available**
- **New techniques can be implemented**
- **New material technologies can be used**
- **New decision criteria under new uncertainties**

Questions related to codes

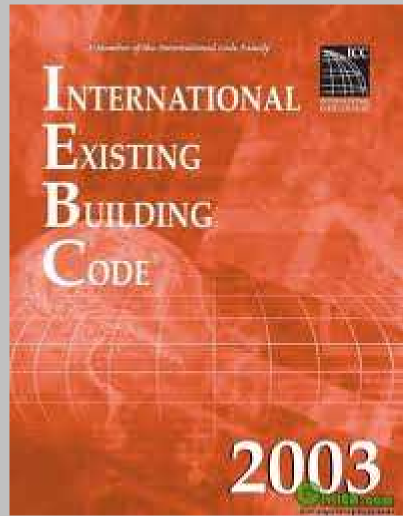
- Are existing structures covered by codes for new structures?
- Is there a separate code and to which type of buildings does it apply?
- Do codes allow for relaxation or lower performance?
- What aspects are covered (inspections etc.)?
- What are the governmental regulatory bodies behind?

Possible requirements for a code on existing structures

- **Applicability**: the code should be applicable to typical assessment cases.
- **Compatibility to codes for new structures**: the code should use the same philosophy as current codes for new structures.
- **Flexibility**: the code should be flexible to include additional information gained by inspection.
- **Ease of use**: the code should be understandable to engineers and easy to use in practice.

Example: Building Code

- 1997 UBC: 2 pages
- 2000 IBC: 14 pages
- 2003 International Existing Building Code: 67 pages +214 pages Annexes
- 2012 new version 290 pages



Prenormative and regulatory tools

- ISO 13822, 2003
- ICC Existing Buildings Code, 2009
- SIA 462 (Switzerland), 1994
- Danish Technical Research Council
- ASCE Seismic Evaluation, 2003
- ACI 437R -03, 2003
- JCSS Recommendations, 2001

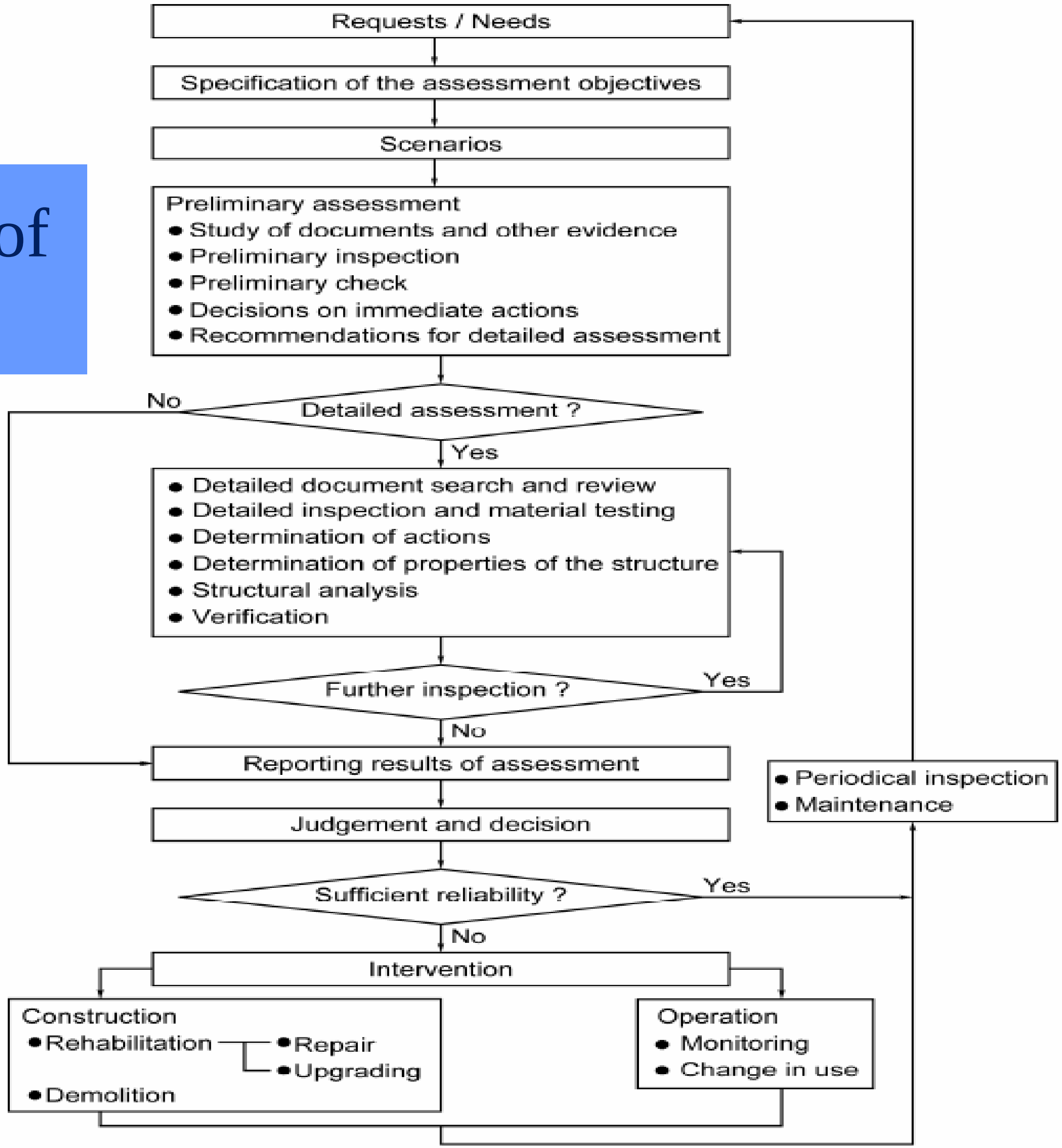
ISO 13822

- **General Framework of Assessment**
- **Data for assessment**
- **Structural Analysis**
- **Verification (Limit State)**
- **Assessment based on satisfactory past performance**
- **Interventions**
- **Report**
- **Judgement and Decisions**

Procedures

General flow of assessment

ISO 13822



JCSS Recommendations for Existing Structures

- **Preface**
- **Part 1: General (Guidelines, Codification)**
- **Part 2: Reliability Updating**
- **Part 3: Acceptability Criteria**
- **Part 4: Examples and case studies**
- **Annex:Reliability Analysis Principles**

Phase: Preliminary Assessment

- **Visual inspection**
- **Review of documentation**
- **Code compatibility**
- **Scoring system:**
  1. **age of the structure**
  2. **general condition**
  3. **loading (modifications)**
  4. **structural system**
  5. **residual working life**

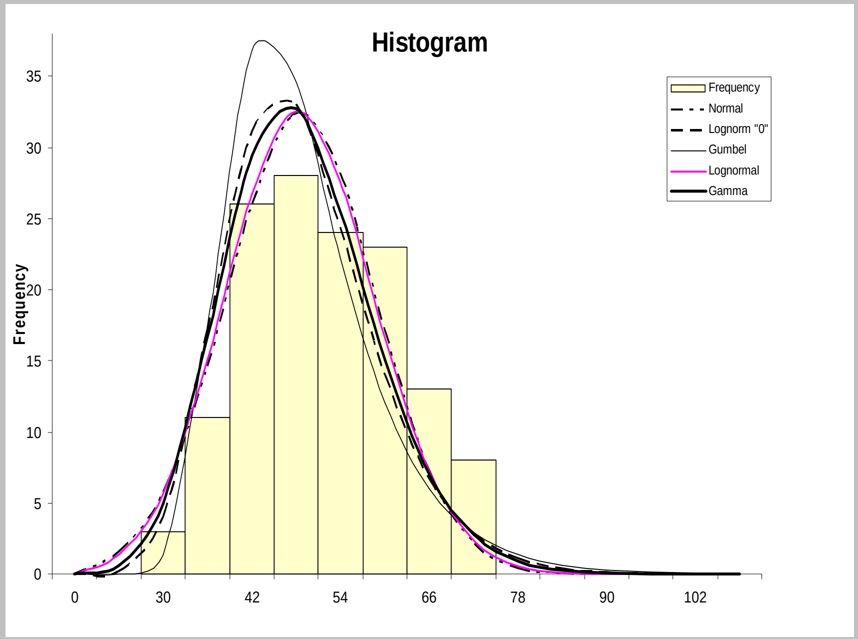
Phase: Detailed assessment

- Additional inspections
- More detailed analyses

1. progressive collapse
2. full probabilistic
3. sensitivity analyses
4. risk analyses

Phase: Detailed Assessment

- Quantitative inspections
- Updating of information
- Structural reanalysis
- Reliability analysis
- Acceptance criteria

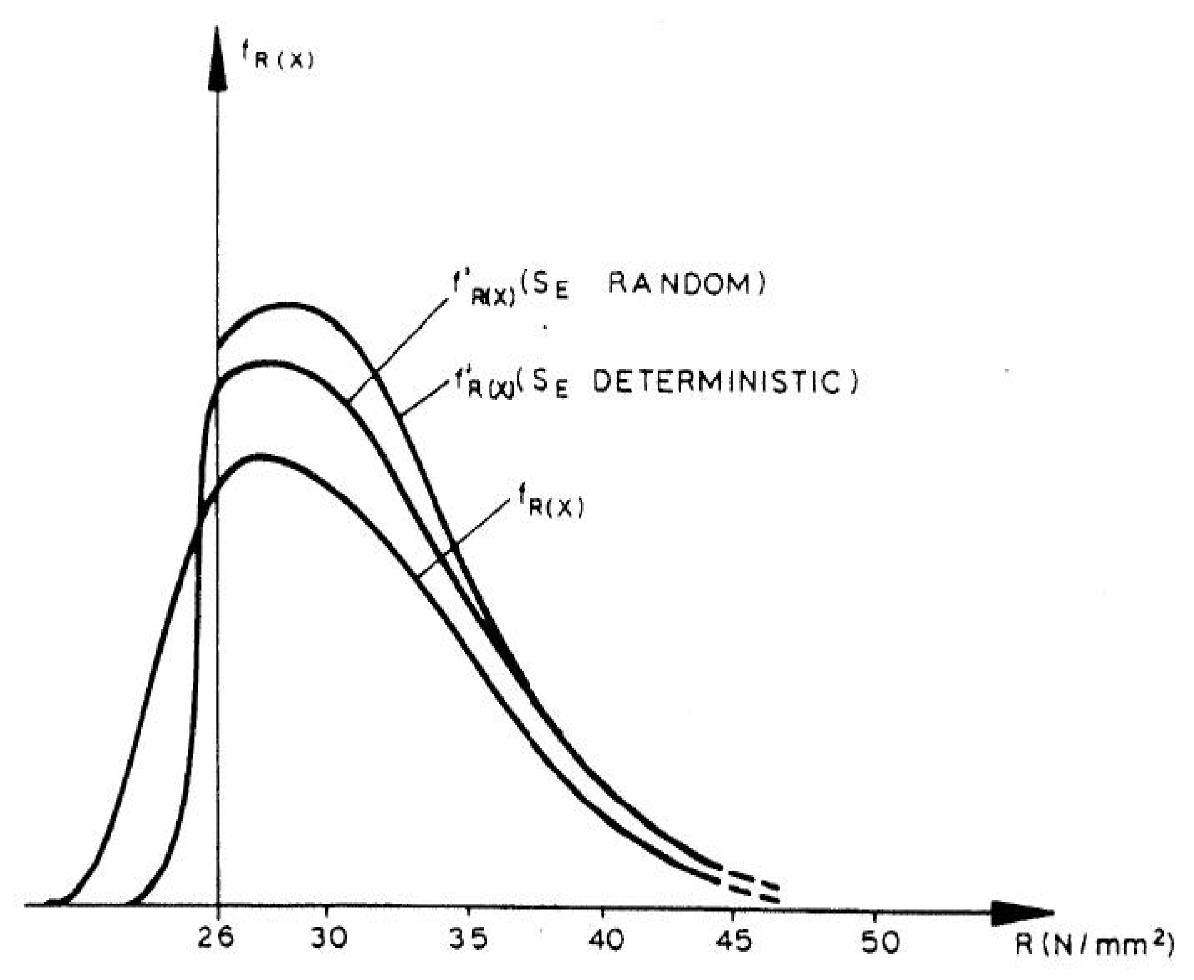


New Information (Updating)

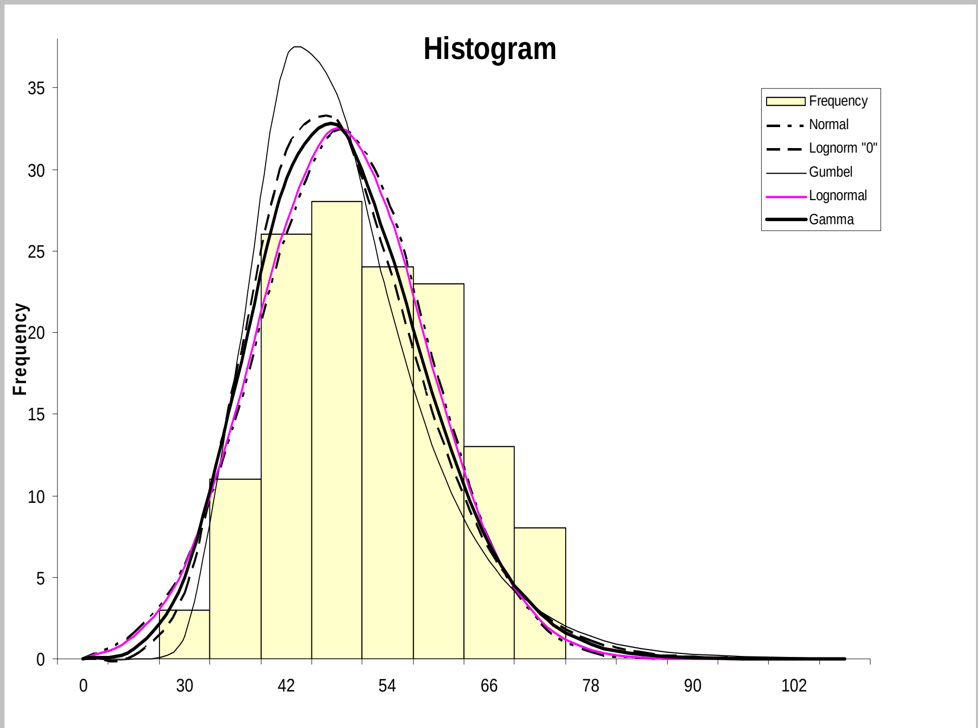
A) Proof Load

B) Variables (concrete strength)

A) Example: Proof Loading (Survival of a load)
# >	Updating of resistance



B) Example: Concrete strength data



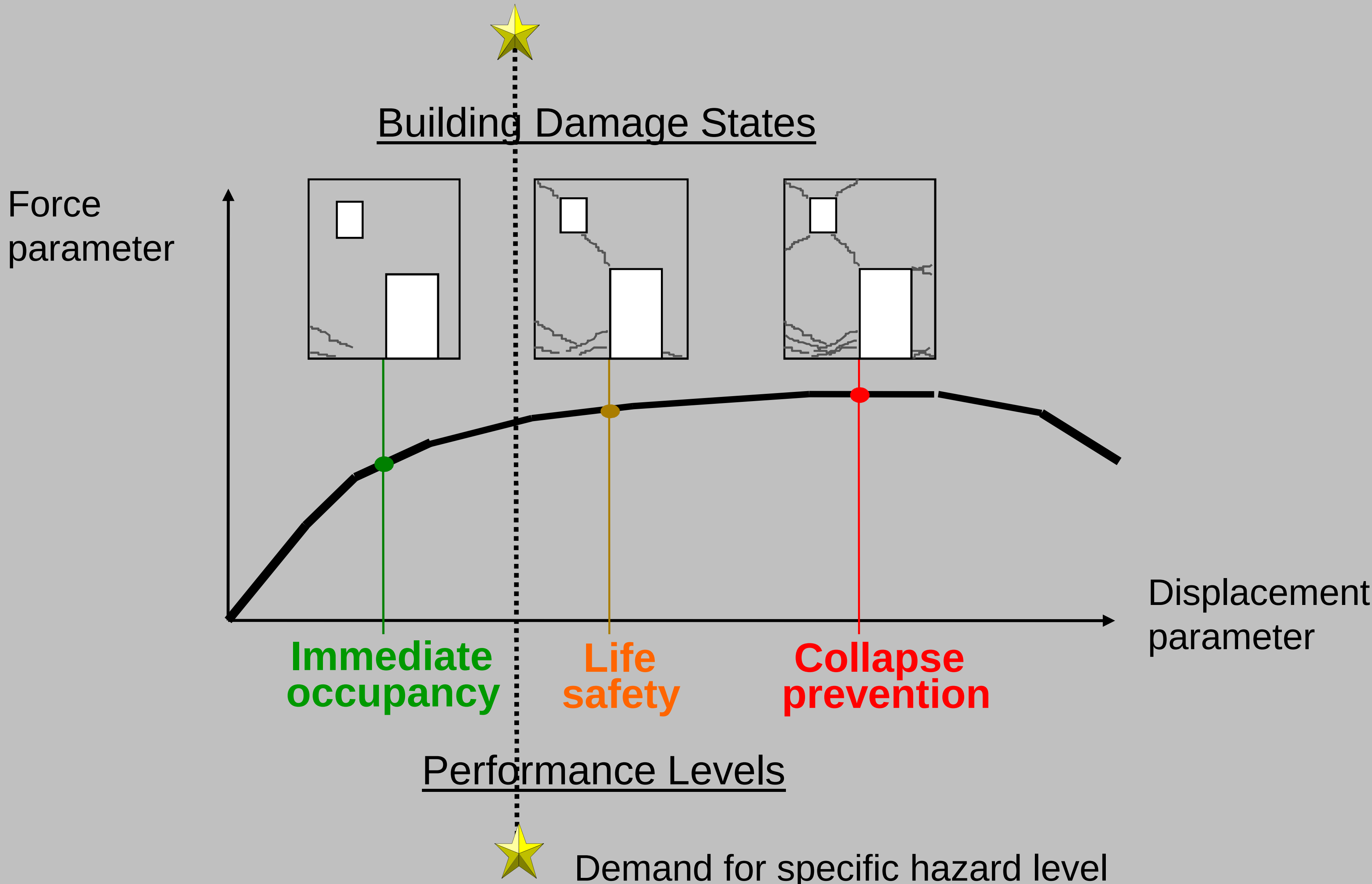
Decision Criteria

- Target reliability
- Economical considerations
- Time constraints
- Sociopolotical aspects
- Codes and standards
- Complexity of analysis
- Experience in other fields

Safety Acceptance Criteria

- European Experience (limit state verification)
- New practice in the US (performance based design)
- Optimisation based on LQI
- Judgement

Example: Earthquake performance requirements



Performance based criteria

$$p_E \cdot p_{NP|E} < p_A$$

p_E : propability of event

$p_{NP|E}$: conditional probability of no performance given event

p_A : acceptable probability

PBD criteria (new structure)

$$p_E \cdot p_{NP|E} < p_A$$

p_E : 2% in 50 years

$p_{NP|E}$: 10%

p_A : $4x10^{-5}$ per year

PBD criteria (old structure)

$$p_E \cdot p_{NP|E} < p_A$$

p_E : 4% in 50 years

$p_{NP|E}$: 25%

p_A : 2×10^{-4} per year (5 times larger)

Conclusions regarding reliability acceptance

- **A lower safety level compared to a new structure is acceptable**
- **Various criteria have been proposed in the literature**
- **Acceptance criteria depend on cost of safety, consequences of failure, desired residual lifetime**
- **A decrease of the acceptable reliability index ß by 0.5 can be recommended**

Application: Old Railway Bridges (single span systems)

Old railway bridges
Preliminary Assessment Procedure

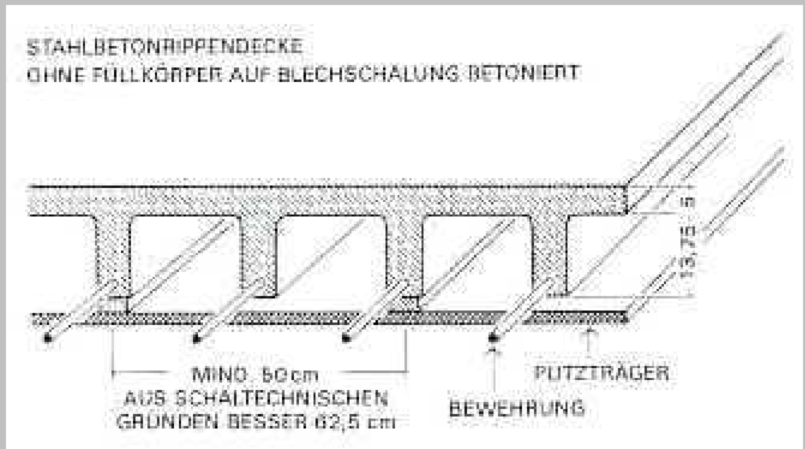
Railway Bridges

- 100 years old
- Scoring system verification
  (foundation, corrosion, joints, supports)
- R (steel resistance) from code on old bridges
- S (train load) from DB
  (German Railways)
- Durability problems

Phase detailed assessment R.C. Buildings in Germany

- Office building
- Concrete construction
- 70 years old
- Reduced load in order to satisfy minimum safety

Example: Concrete floor structure (Detailed Procedure)



Reassessment of r.c. floor structure

flexural limit state function

$$g = M_u - M_a$$

M_u: Ultimate Bending Moment

M_a: Acting Bending Moment

Updating of random variables (due to destructive tests)

Variable	Distribution	c.o.v.
Steel strength	Lognormal	0.06
Concrete Strength	Lognormal	0.14
Cover thickness	Lognormal	0.25

Reliability index ß is increased from 3.70 (prior information) to 3.80, due to reduced variability of the parameters

Example: Solar structures subjected to wind action

- design lifetime 20 years
- steel or aluminum profiles
- design load combination
  wind + snow + dead load
- durability
- maintenance

Steel road bridges

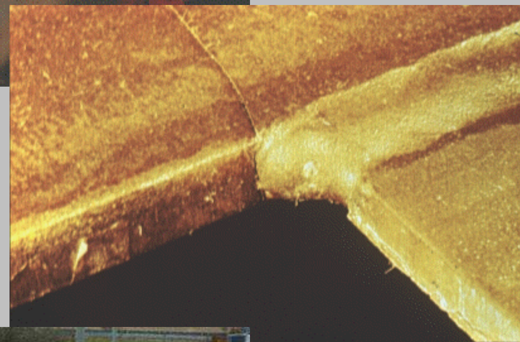
(Phase 3 Procedure)

Typical limit states

- extreme load

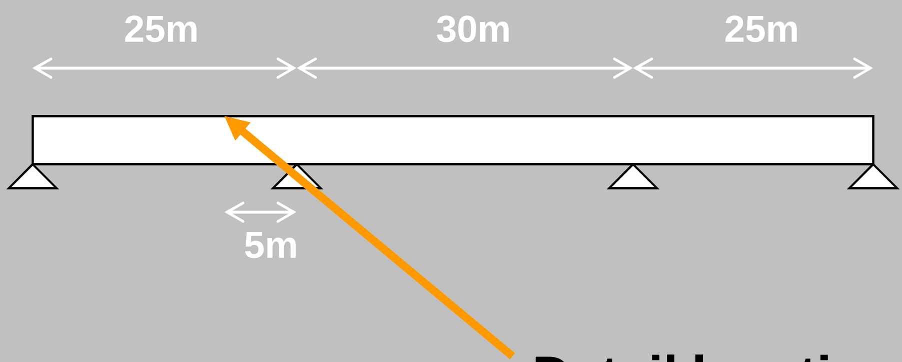
- Fatigue

Which measures are necessary in order to meet acceptance criteria (residual life time 20 years)?

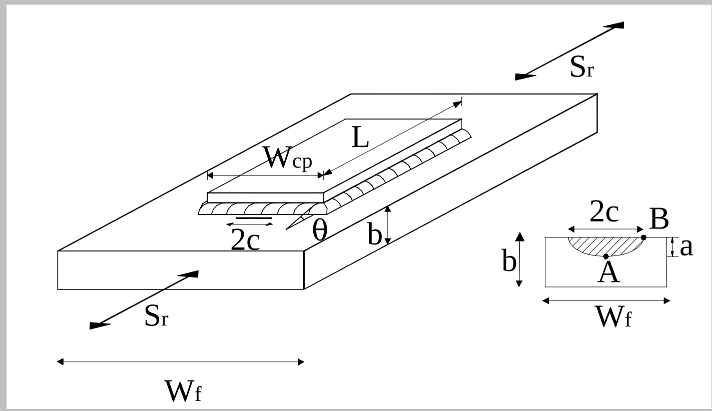


Fatigue models

- Fracture Mechanics approach
- Crack growth propagation
- Influence of inspections (measurement of cracks)



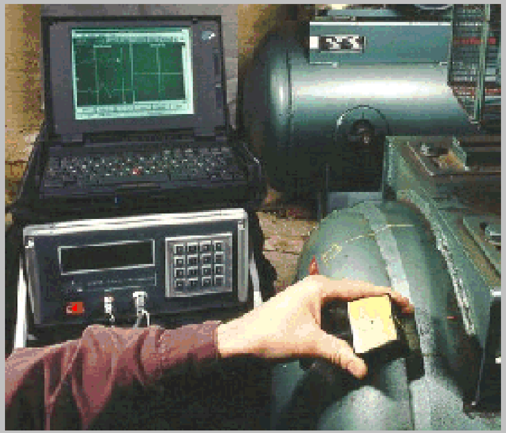
Detail location



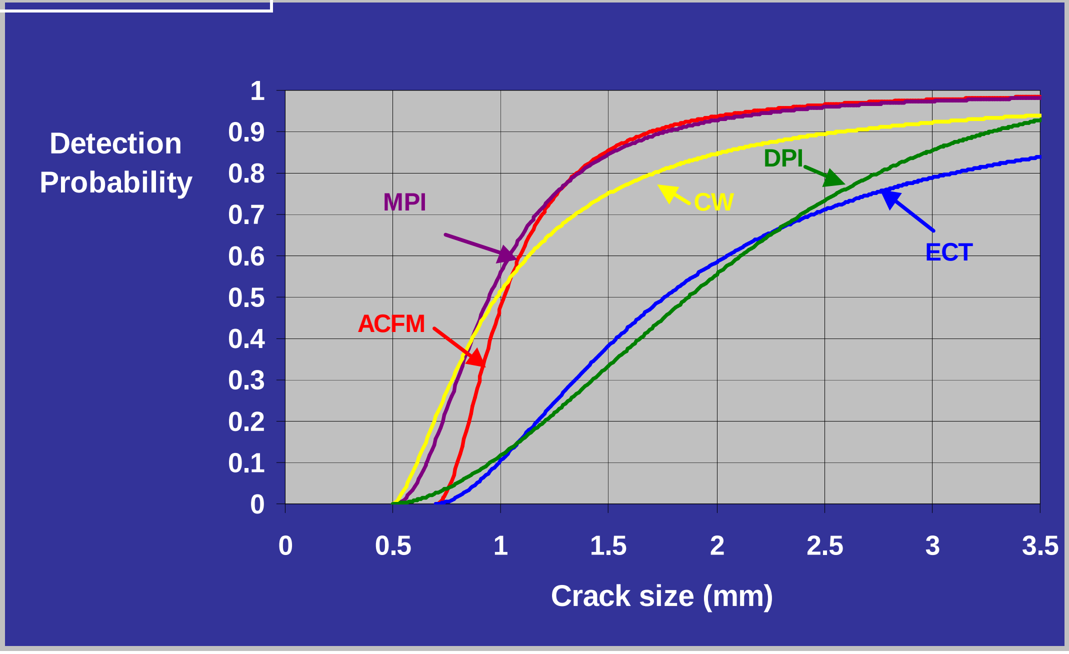
Cover plate detail

Fatigue assessment: Random Variables (examples)

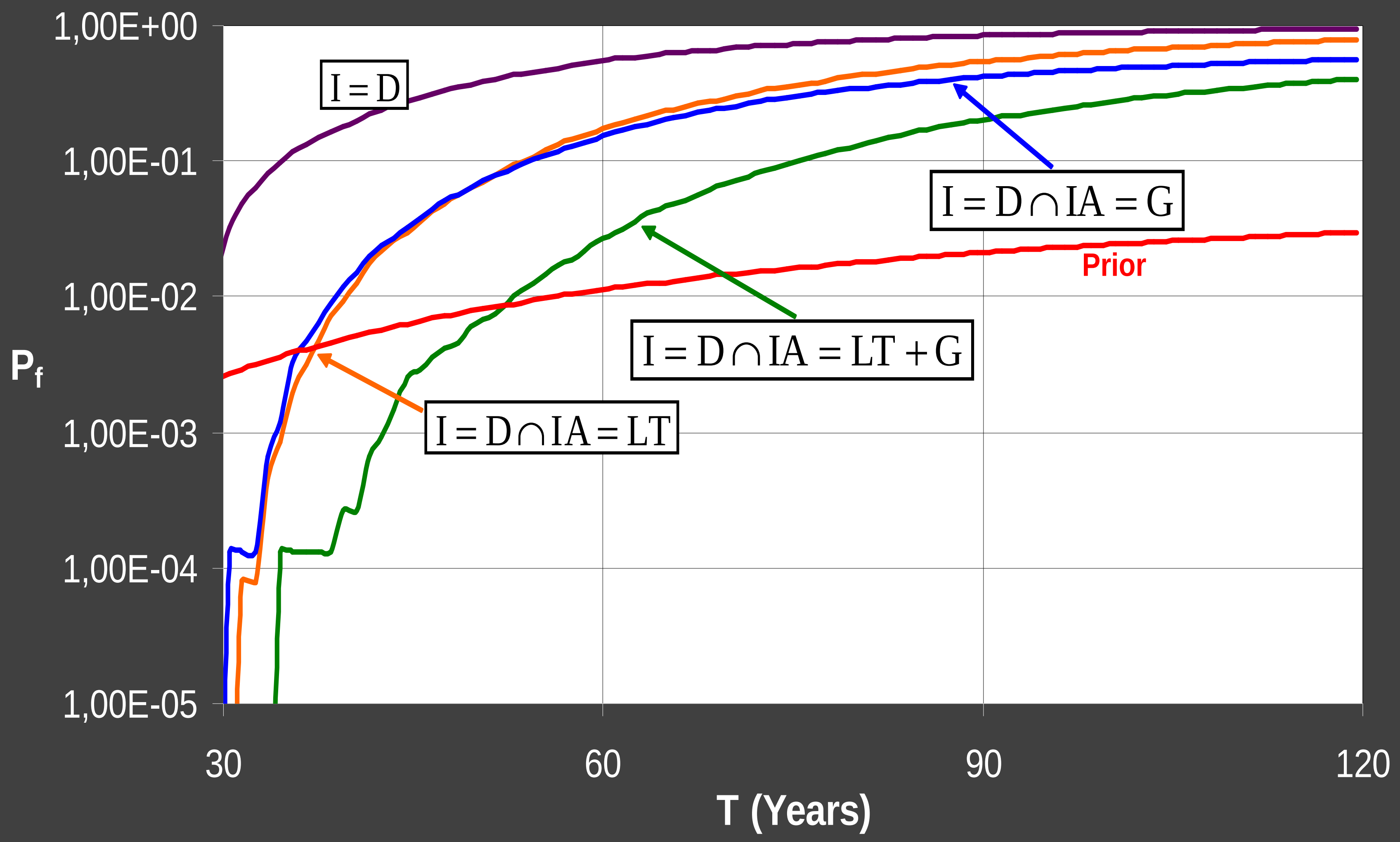
Variable	Distribution	Type
a_d	POD*	Inspection
a_g	Uniform	Repair
a_{fail}	Derived	Mixed
S_r	Rayleigh	Load
S_{max}	Gumbel	



* POD for MPI used in case study



Fatigue assessment: typical results



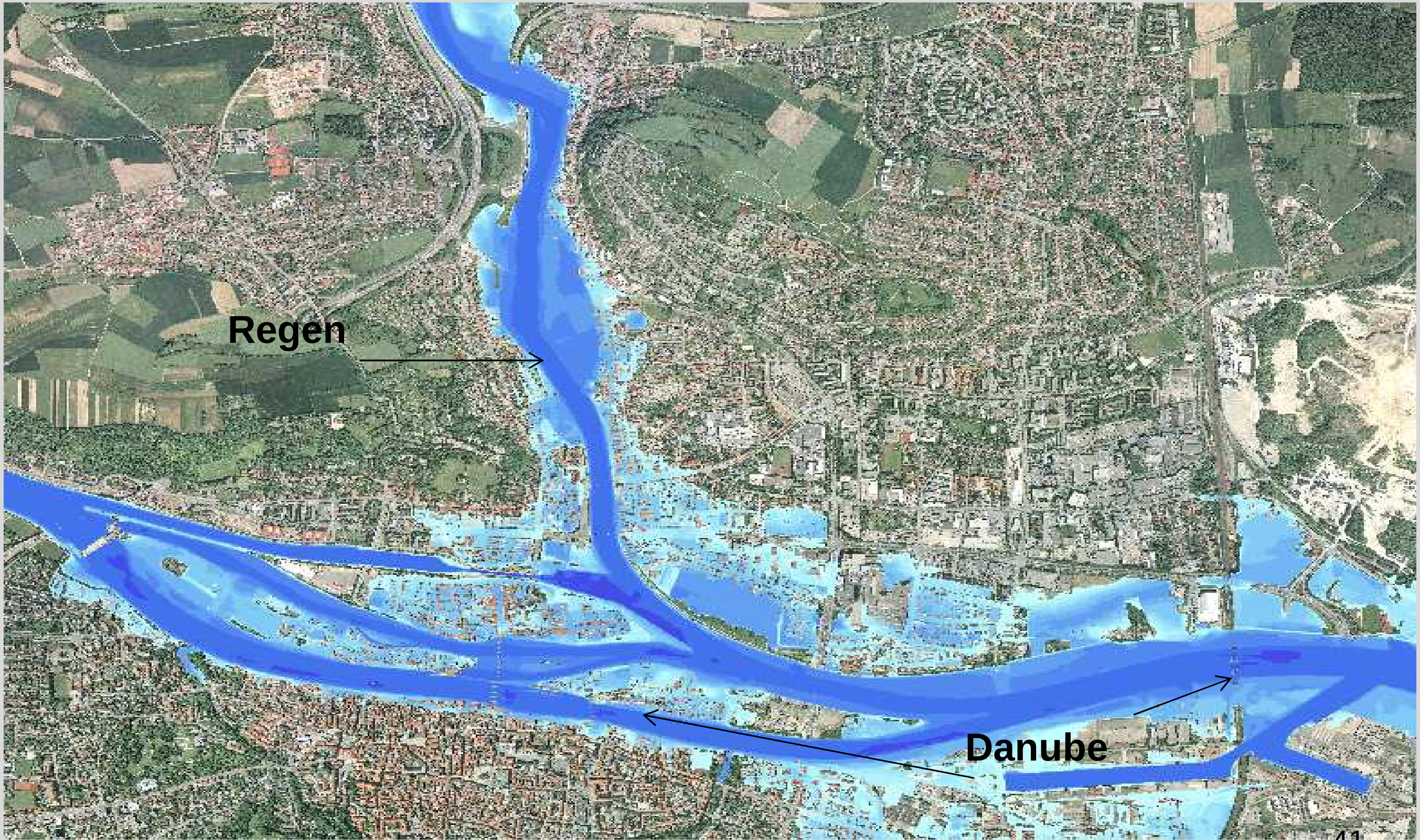
I: Inspection, D=Detection

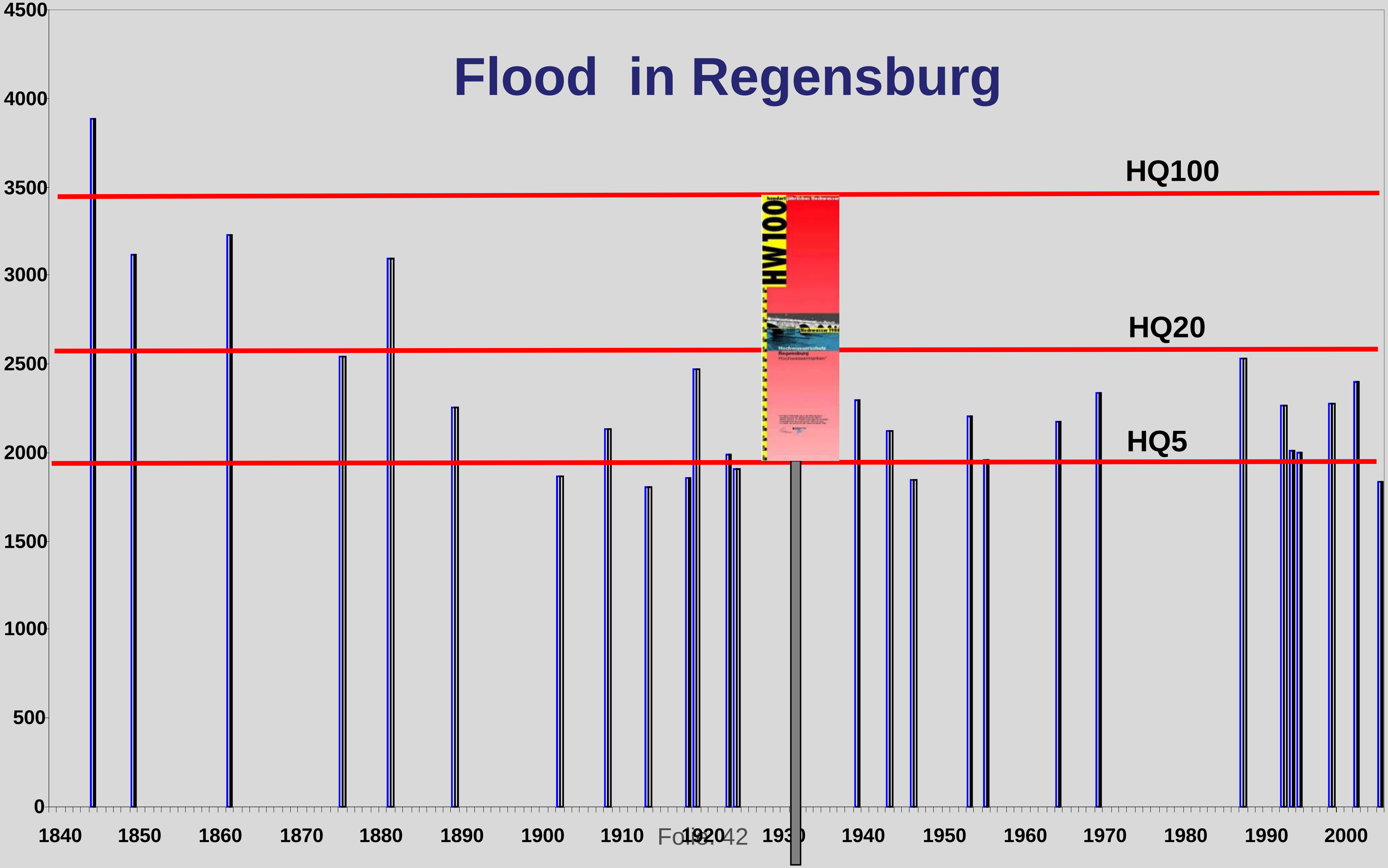
IA: Invasive Action, LT=Load Truncation, G=Weld Toe Grinding

Fatigue assessment: scenarios

- **Inspection and crack detection at T=30y**
- **Alternatives considered:**
  1. **Load truncation (LT)**
  2. **Weld toe grinding (G)**
  3. **Load truncation + weld toe grinding (LT+G)**

Example: flood protection Regensburg




Flood in Regensburg
HQ100
HQ20
HQ5
HW100
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1840
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000

Flood protection Danube river

(s. Rogowsky, 2012)

Grazie per l´ attenzione!