Lifelong Learning Programme

NAEP
Národní agentura pro evropské vzdělávací programy

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

Seminar: Assessment of existing structures

# Codes for existing structures

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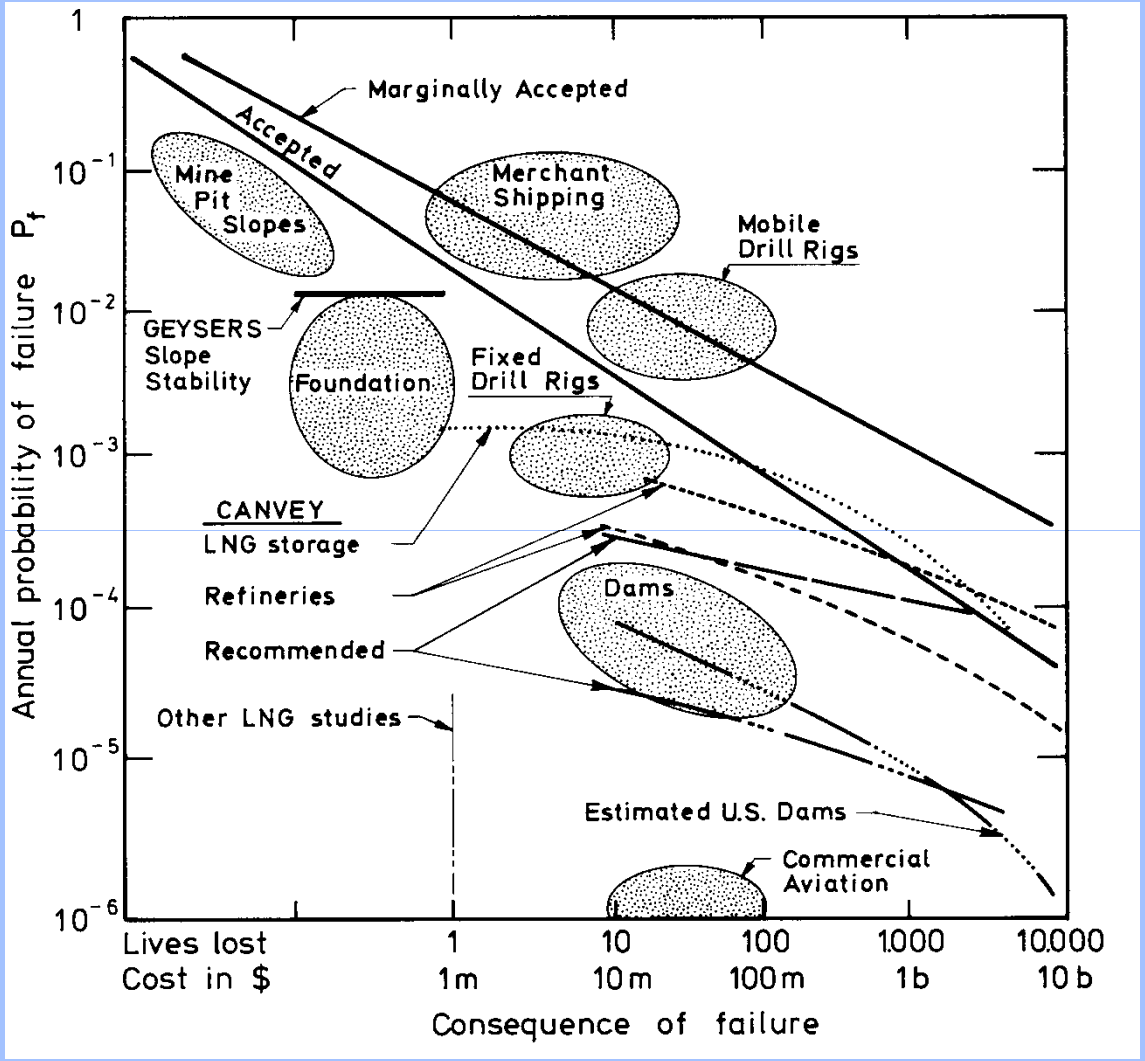
- **Need and criteria for codes and recommendations**
- **Example codes**
- **Example contents with illustrations**
- **Safety acceptance – performance criteria**
- **Applicability to case studies**
- **Future tendencies**

Lucca, Dicembre 2013

# 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?**

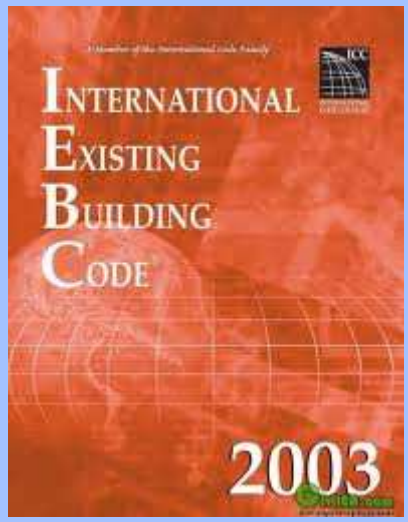
# Possible requirements for a code on existing structures

- **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**
- **Eurocode 8 – Part 3**
- **NTC2008**

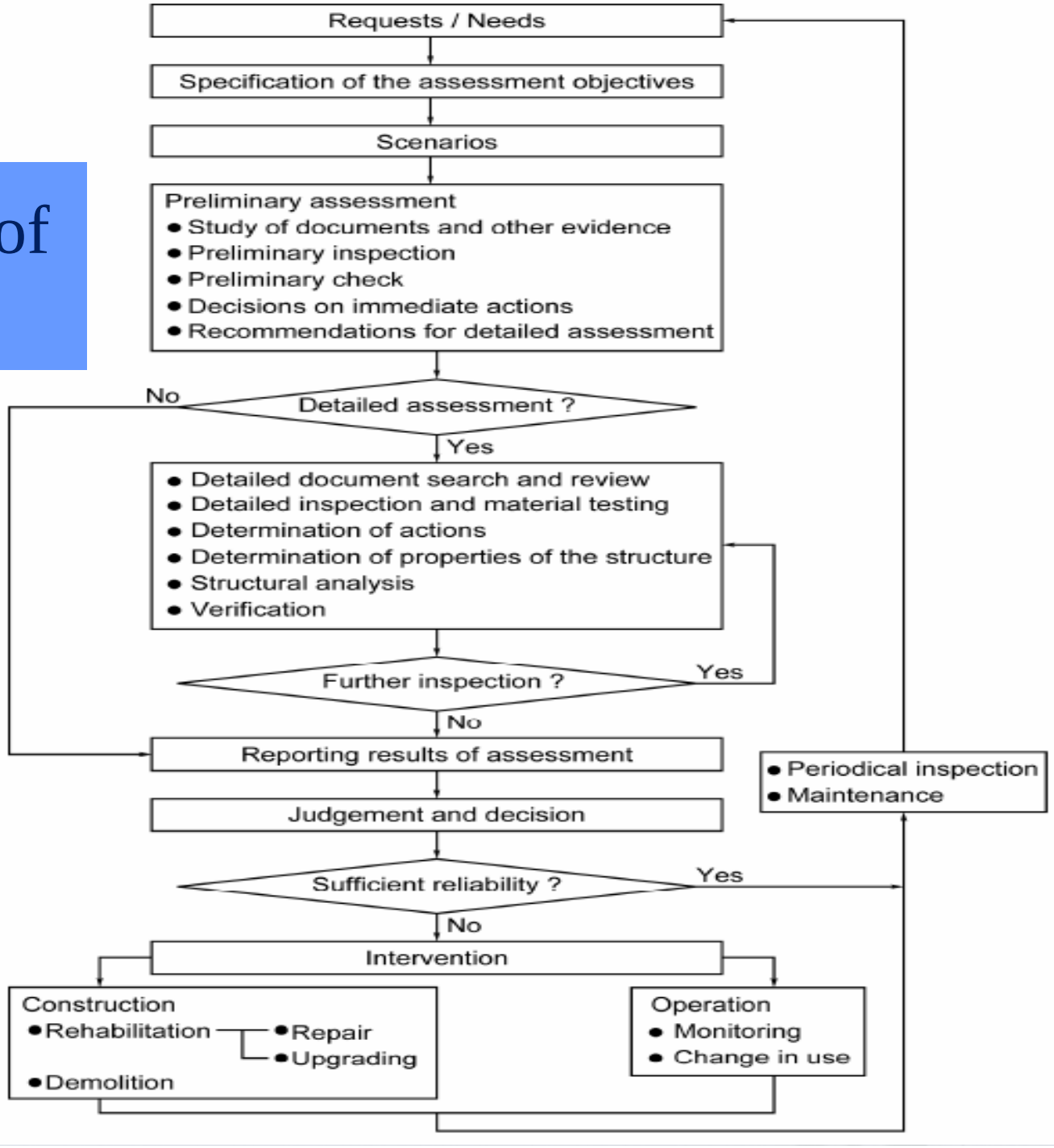
# ISO 13822

- 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



# 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

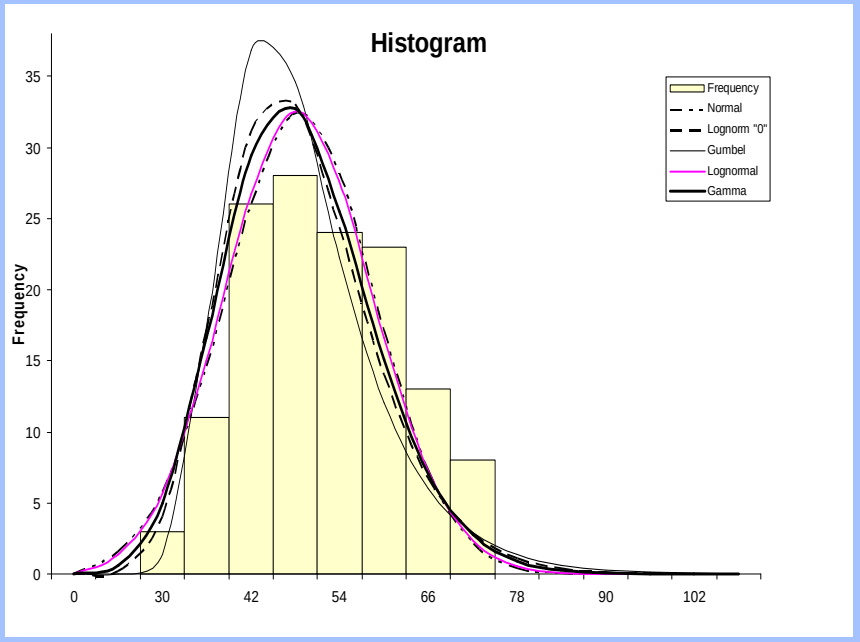
# Phase: Detailed assessment

- **Additional inspections**
- **More detailed analyses**

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

# Phase: Detailed Assessment

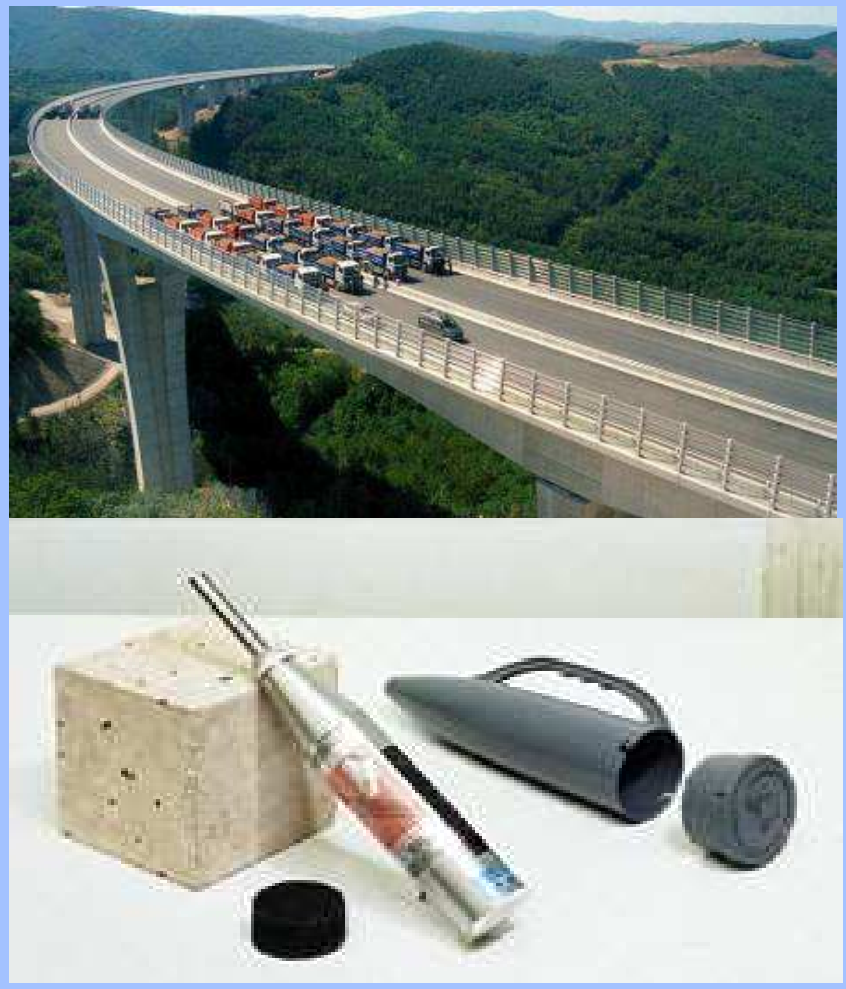
- Quantitative inspections
- Updating of information
- Structural reanalysis
- Reliability analysis
- Acceptance criteria



# New Information (Updating)

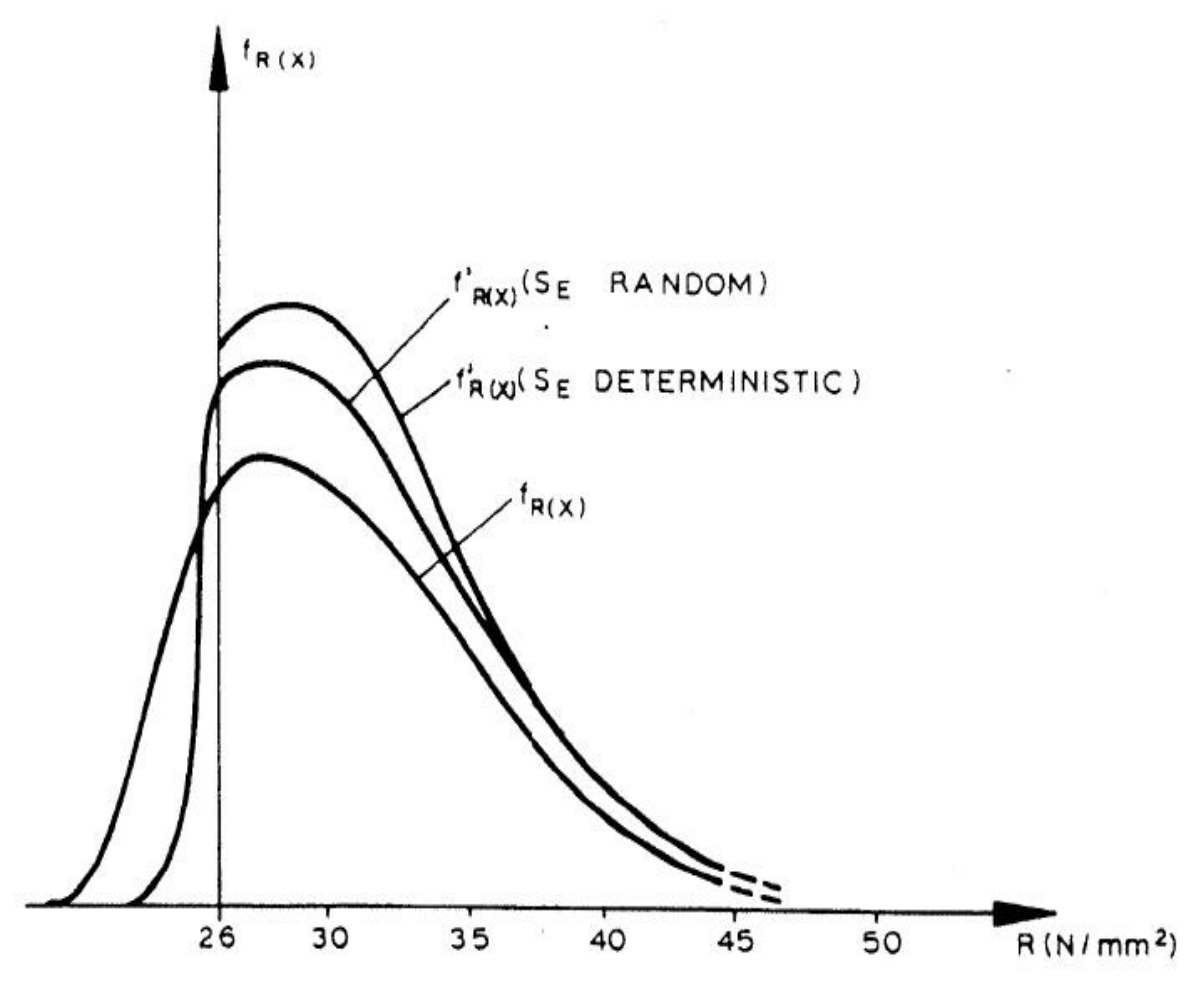
**A) Proof Load**

**B) Variables (concrete strength)**

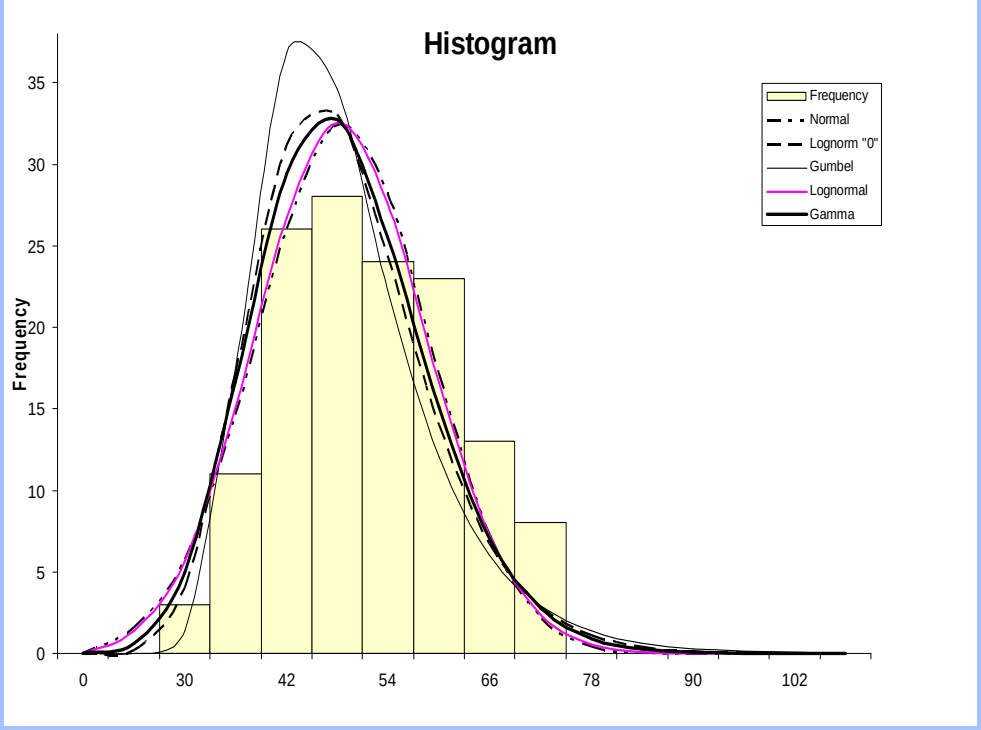


# A) Example: Proof Loading (Survival of a load)

## > 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

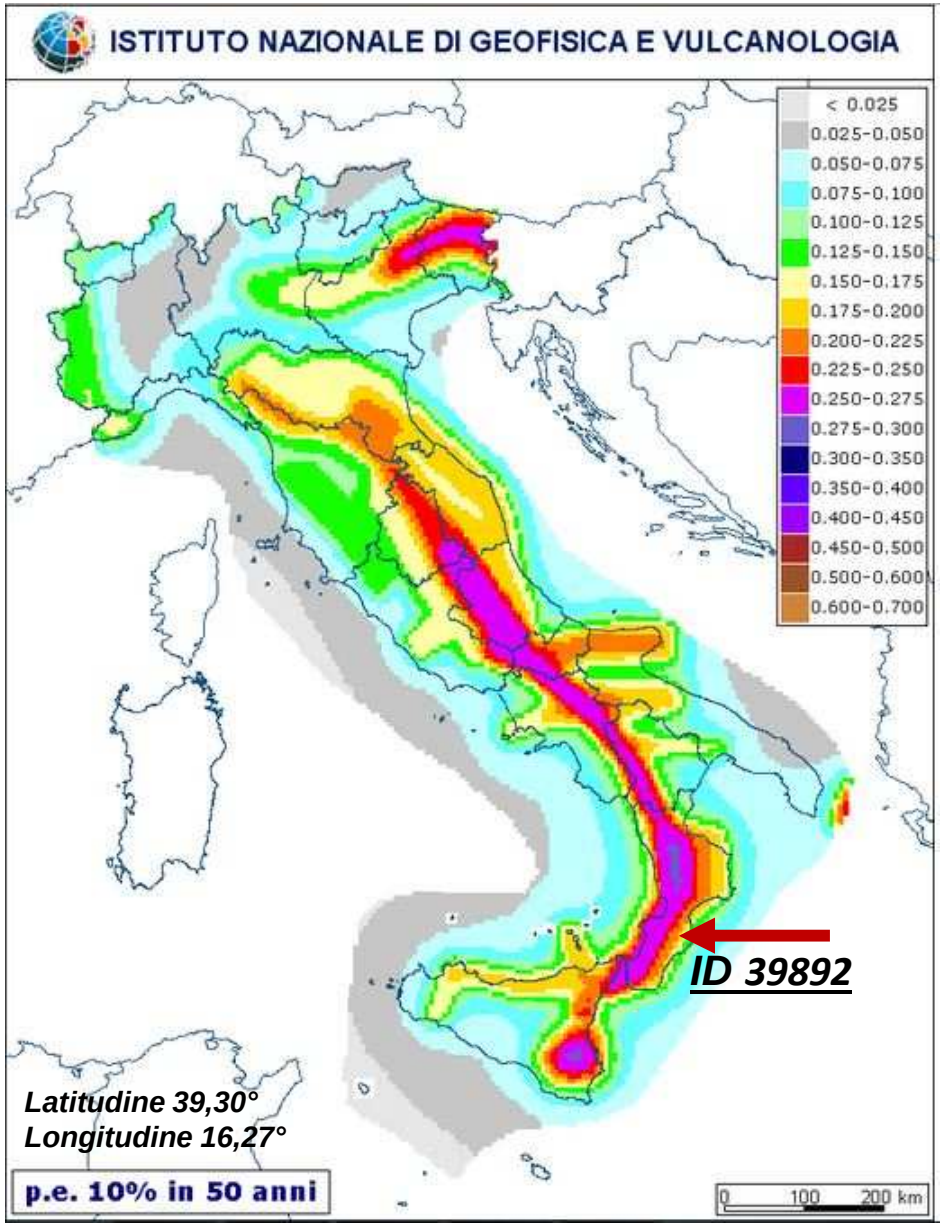
# Safety Acceptance Criteria

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

# Conclusions regarding reliability acceptance

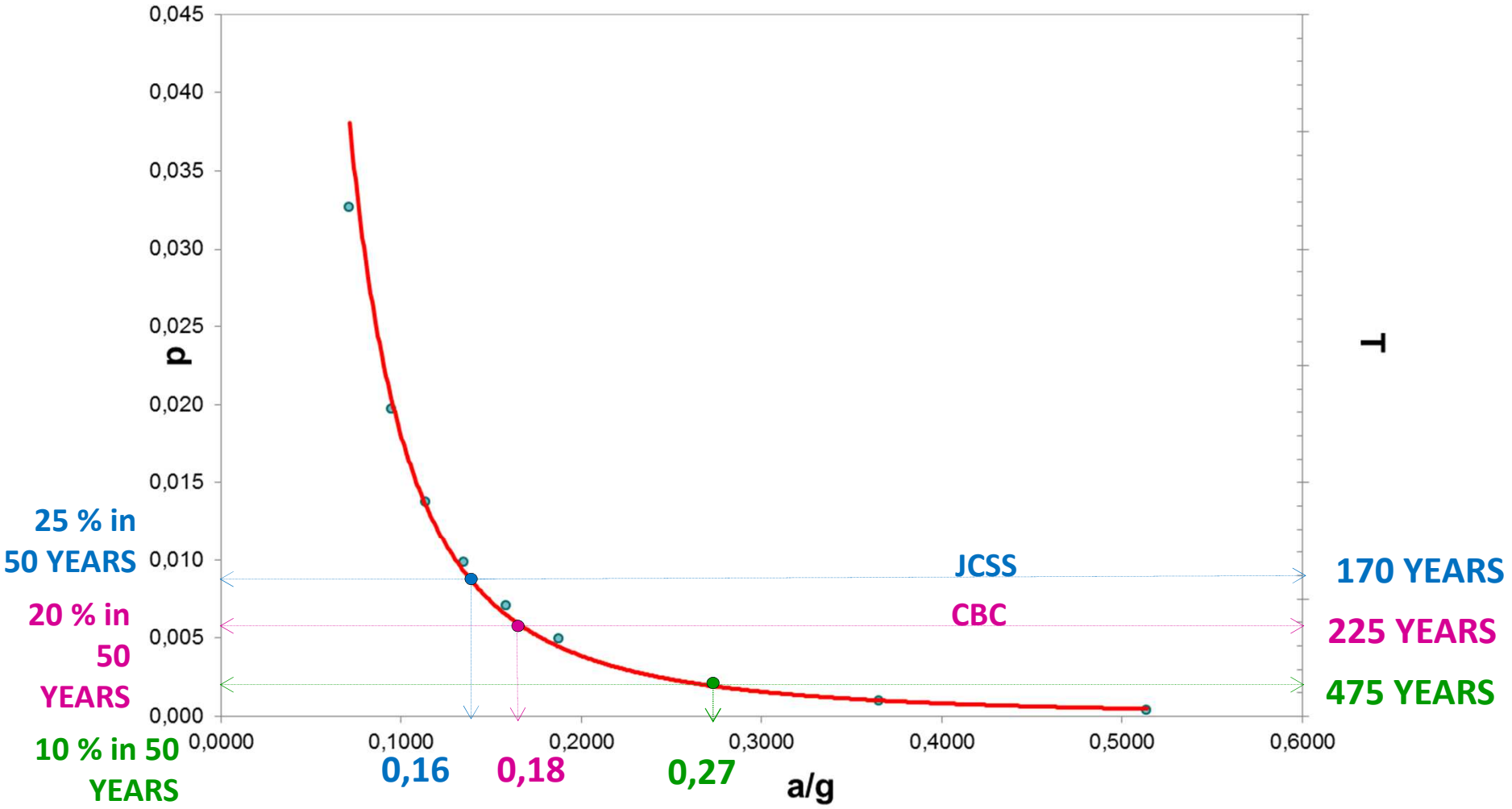
- A lower safety level compared to a new structure is acceptable
- Various criteria have been proposed in the literature
- Acceptance criteria depend on cost of safety, consequences of failure, desired residual lifetime
- A decrease of the acceptable reliability index ß by 0.5 can be recommended

# Example: Updated earthquake acceleration




| Curva di Pericolosità Sismica | | | |
|---|---|---|---|
| a [g] | T [anni] | $p_{50}$ [%] | p [%] |
| 0,0713 | 30 | 81 | 3,333 |
| 0,0944 | 50 | 63 | 2,000 |
| 0,1137 | 72 | 50 | 1,389 |
| 0,1349 | 101 | 39 | 0,990 |
| 0,1581 | 140 | 30 | 0,714 |
| 0,1875 | 201 | 22 | 0,498 |
| 0,27 | 475 | 10 | 0,211 |
| 0,3651 | 975 | 5 | 0,103 |
| 0,5138 | 2475 | 2 | 0,040 |

# Seismic hazard curve and updated value due to relaxed acceptance criteria



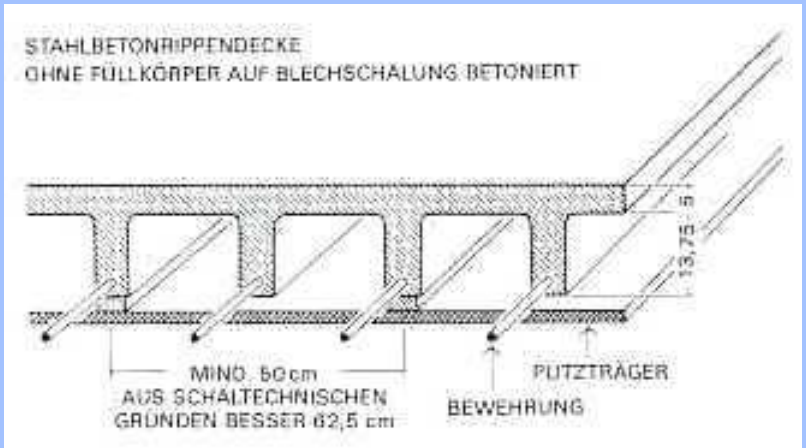
# Railway Bridges

- 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

# 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**

# Steel road bridges

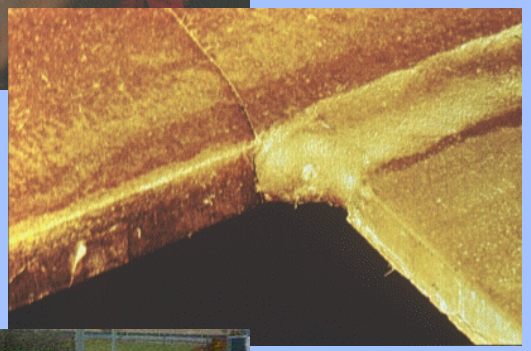
# (Phase 3 Procedure)

**Typical limit states**

**- extreme load**

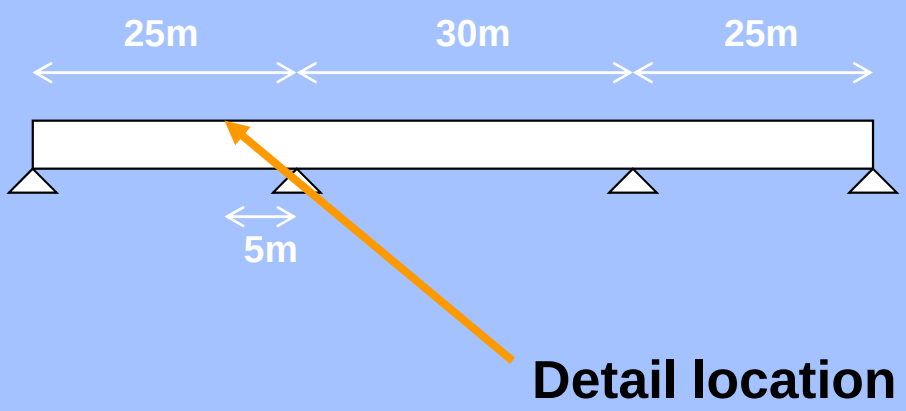
**- Fatigue**

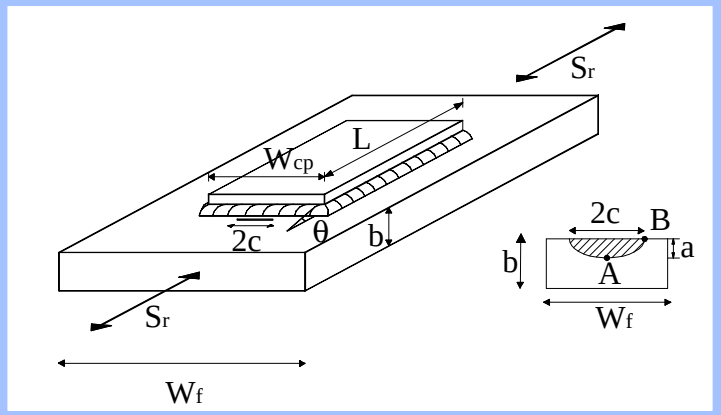
**Which measures are necessary in order to meet acceptance criteria (residual life time 20 years)?**



# Fatigue models

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



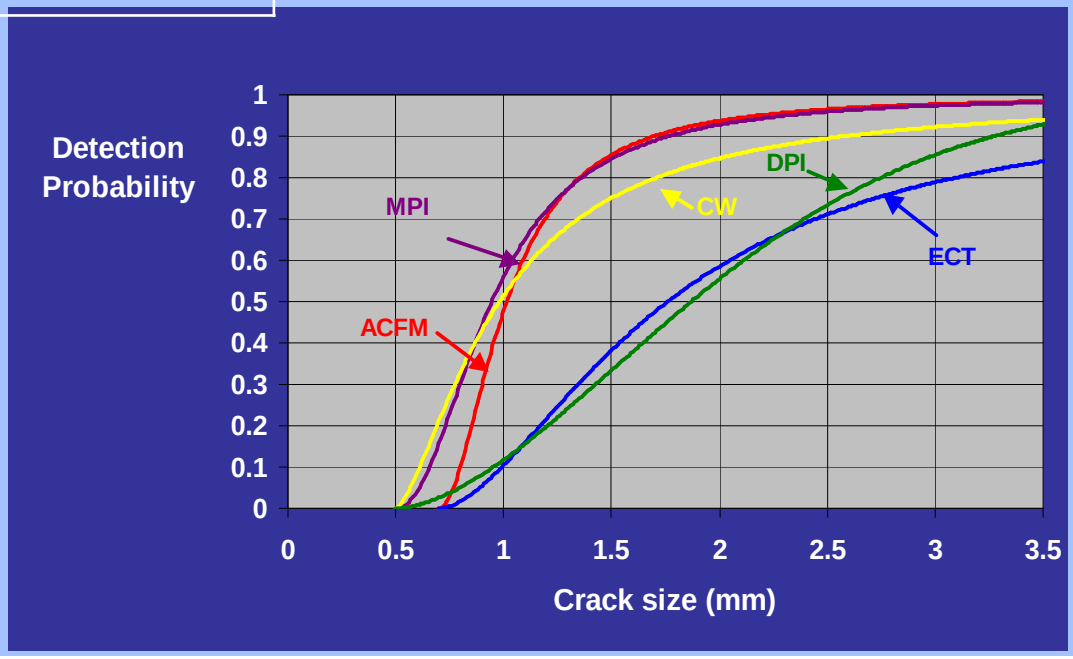




**Cover plate detail**

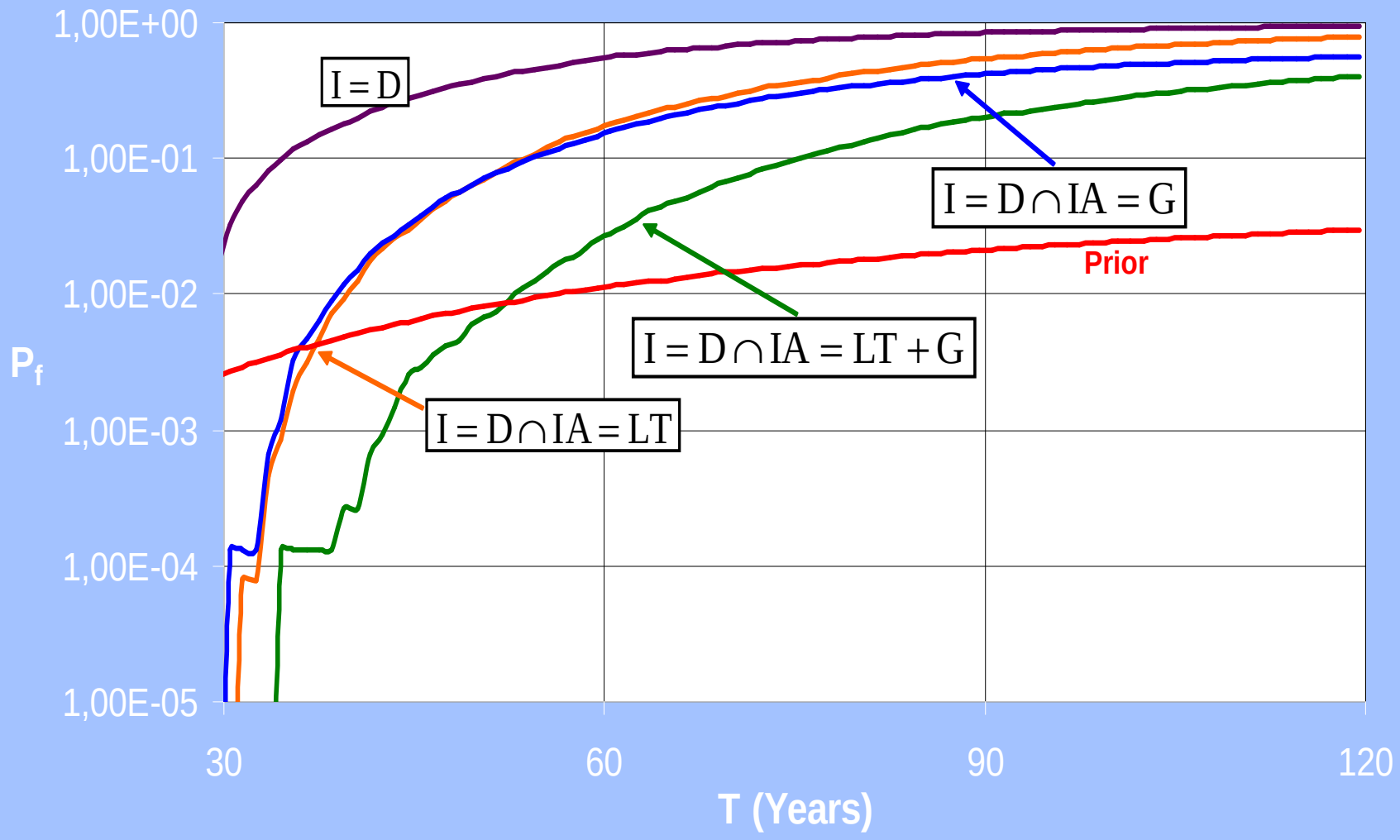
# Fatigue assessment: Random Variables (examples)

| 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)**

# Future tendencies

- No classical code approach
- Quantification of new information
- Updated design values
- Uncertainties (climate change etc.)
- Relaxed acceptance criteria
- Robustness aspects

# Vita nominale di progetto

NTC 2008

**Tabella 2.4.I –** *Vita nominale* $V_N$ *per diversi tipi di opere*

| TIPO | DESCRIZIONE | Vita Nominale $V_N$ (in anni) |
|---|---|---|
| 1 | Opere provvisorie – Opere provvisionali – Strutture in fase costruttiva[(1)] | ≤ 10 |
| 2 | Opere ordinarie, ponti, opere infrastrutturali e dighe, di dimensioni contenute, o di importanza normale | ≥ 50 |
| 3 | Opere, ponti, opere infrastrutturali e dighe, di grandi dimensioni, o di rilevante importanza | ≥ 100 |

[1] Le verifiche sismiche di opere provvisorie o strutture in fase costruttiva possono omettersi quando le relative durate previste in progetto siano inferiori a 2 anni.

**Tab. 2.4.I –** *Valori minimi della Vita nominale* $V_N$ *di progetto per i diversi tipi di costruzioni*

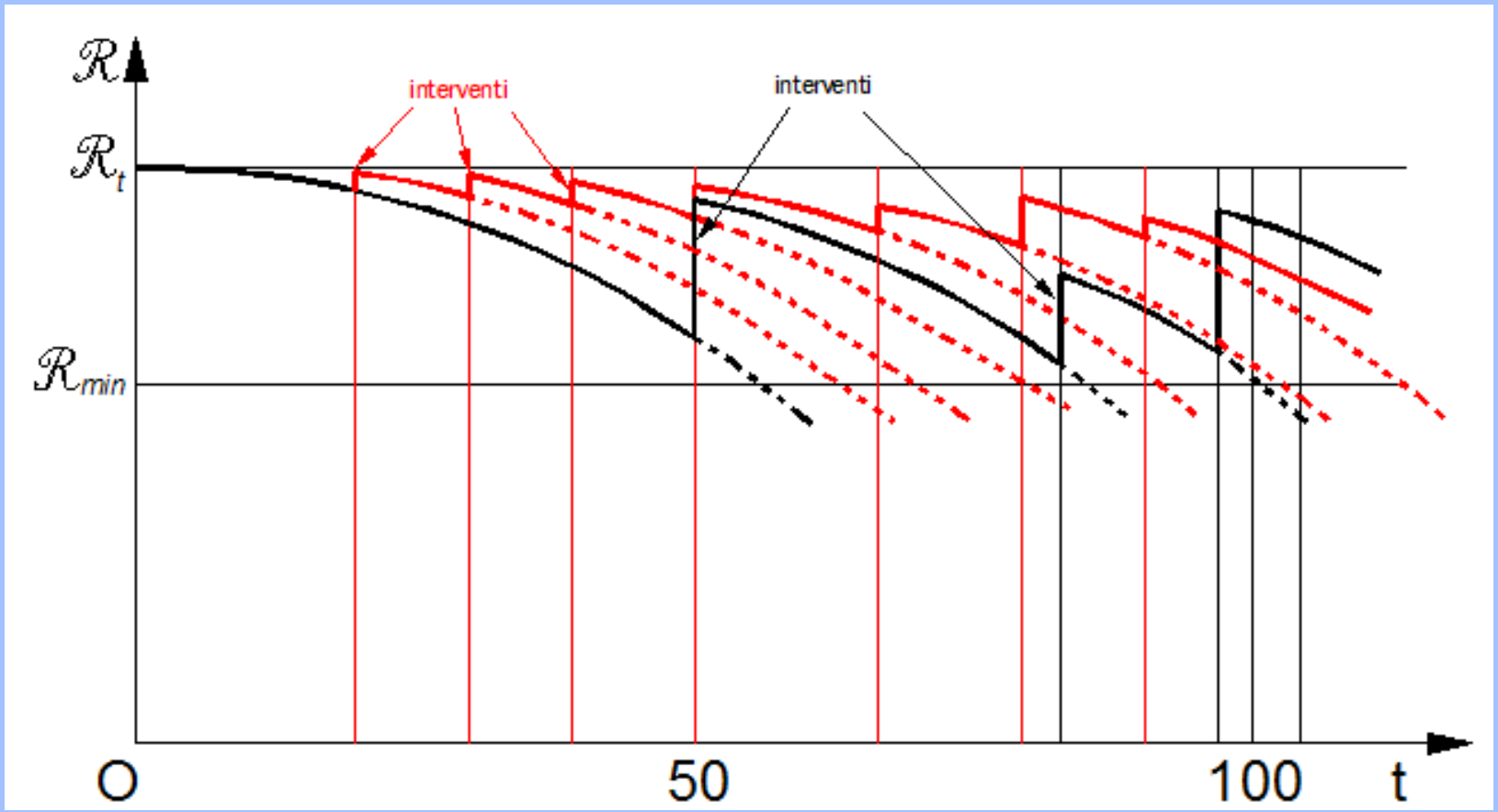
| | TIPI DI COSTRUZIONI DI NUOVA REALIZZAZIONE | Valori minimi di $V_N$ (anni) |
|---|---|---|
| 1 | Costruzioni temporanee[(1)] (provvisorie) | 10 |
| 2 | Costruzioni con livelli di prestazioni ordinari | 50 |
| 3 | Costruzioni con livelli di prestazioni elevati | 100 |

[(1)] Costruzioni o parti di esse che possono essere smantellate con l'intento di essere riutilizzate non sono da considerarsi temporanee

# Vita nominale di progetto

La vita nominale di progetto $V_N$ di un'opera è convenzionalmente definita come il numero di anni nel quale l'opera, purché soggetta alla manutenzione ordinaria così come prevista in sede di progetto, è previsto che mantenga i livelli prestazionali per i quali è stata progettata.

Non è una vita intesa in senso biologico



**Thank you for your attention**