eea grants
Iceland liechtenstein norway
norway grants
Supported by a grant from
Iceland, Liechtenstein and Norway
through the EEA Financial Mechanism
and the Norwegian Financial Mechanism

A/CZ0046/2/0013 ASSESSMENT OF HISTORICAL IMMOVABLES

Assessment of bridges registered as industrial heritage

J. Markova, M. Holicky & M. Sykora, CTU in Prague
K. Kvaal & T. Thiis, Norwegian University of Life Sciences
June 2010

Introduction
General aspects of the assessment
Target reliability
Conclusions

Introduction

• ***Industrial heritage*** - structures of significant architectural, historic or technological value (350 bridges in the Czech Republic)

•***Rehabilitation of existing reinforced concrete road bridges*** including those registered as industrial heritage - urgent issue

• Simplified conservative procedures based on design methods - ***expensive repairs*** and losses of cultural heritage value

• Decisions - reliability assessment considering ***deterioration*** and ***increasing traffic*** loads

• The ***present study***:
- ***methods*** for the ***reliability assessment*** of existing reinforced concrete bridges considering EN 1990, EN 1991-2, ISO 13822 and ISO 2394
- general framework for specification of ***optimum target reliability***

• Application – numerical ***example***

Initiatives concerning the industrial heritage

• Protection of the industrial heritage - ***multidisciplinary topic*** (historical, architectonic, civil engineering and ecological aspects)

• In 1978 the ***International Committee on the Conservation of the Industrial Heritage*** (TICCIH) founded to study, protect, conserve and explain the remains of industrialization

• In the Czech Republic ***Research Centre for Industrial Heritage*** - coordinating platform for architects and civil engineers, database of the Czech industrial monuments, search for new uses of industrial heritage

• The Czech Technical University in Prague and the University of Applied Sciences in Ås (Norway) - research ***project Assessment of historical immovables***, mainly focused on assessment of the industrial heritage structures

General aspects of the assessment

• Minimisation of construction interventions, but ***sufficient reliability***

• Social and cultural aspects - loss of ***cultural and heritage values***

• Economic aspects - ***additional costs*** of measures to increase reliability of an existing bridge and ***decommissioning costs***

• Principles of the ***sustainable development*** - waste reduction and recycling of materials

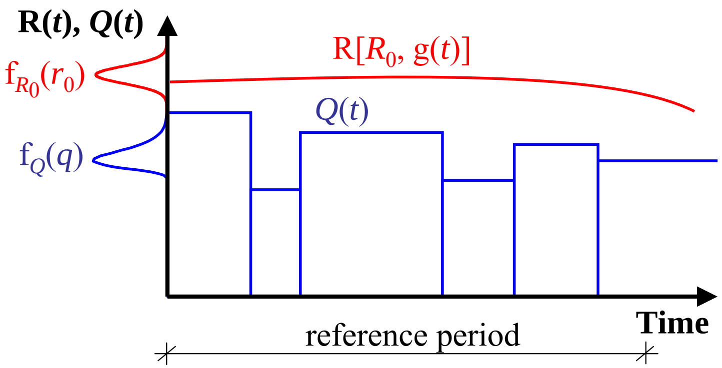
• Lack of information - ***testing*** of material properties ***expensive***, but important (variability, changes due to deterioration and damage)

• Significant uncertainties - ***deterministic*** design ***procedures conservative*** (expensive repairs, losses of cultural and heritage value)

• ***Probabilistic procedure*** proposed to:
- improve the reliability assessment
- describe better the uncertainties
- allow for inclusion of results of inspections, testing and consideration of the satisfactory past performance

Time-variant reliability analysis

- ***Resistance*** described by a ***monotonically decreasing function*** (initial resistance, degradation function)
- ***Traffic load*** - rectangular wave ***renewal process*** (no intermittencies)
- ***New information*** *I* related to structural conditions:
  - inspections, measurements (deterioration, materials, geometry)
  - consideration of the satisfactory past performance



Target reliability

- ***ISO 2394*** - moderate consequences of failure and moderate costs of safety measures - β_t = ***3.1,*** empirical models - broad range ***2.7*** - ***3.4***
- Economic point of view – minimisation of the total working-life cost:
  - preventative ***inspections*** and ***maintenance***
  - ***repairs***:
    - -- direct cost - surveys, design, construction, loss of the cultural heritage value
    - -- indirect cost - economic losses due to traffic restrictions and detours, environmental consequences (increased emissions)
  - ***failure consequences***:
    - -- direct - cost of repair or replacement, loss of the cultural heritage value
    - -- indirect - economic losses, societal consequences, unfavourable environmental and psychological effects
- Failure consequences approximated by ratio $\rho = (C_f + C_0) / C_0$ (JCSS)

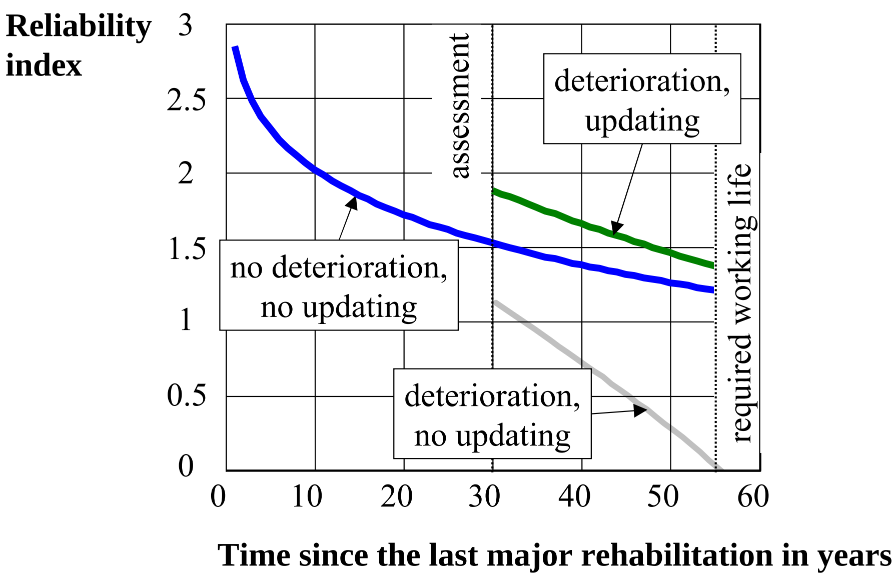
Numerical example

- ***Reliability*** of a reinforced concrete bridge – ***30 years*** since last major rehabilitation, repeated application of de-icing salts
- Deterministic verification - actual resistance lower by 30 % than required by Eurocodes
- Probabilistic model for traffic loads based on data collected within the ***development of EN 1991-2***

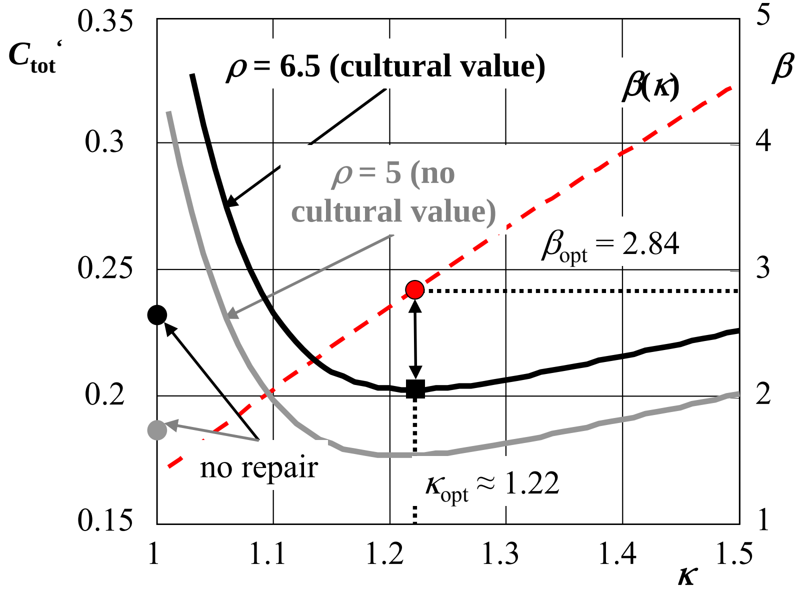
Symbol	Variable	Unit	Distr.	Mean	CoV
A_s	Reinforcement area	m^2/m	N	$A_{s,nom}$	0.03
f_y	Yield strength of reinforcement	MPa	LN0	560	0.054
c	Concrete cover	mm	Gamma	60	0.17
f_c	Concrete compressive strength	MPa	LN0	37.5	0.13
θ_R	Model uncertainty of resistance	-	N	1.1	0.08
Q	Traffic load (annual extreme)	MNm/m	LN0	0.28	0.15
G	Permanent action	MNm/m	N	0.30	0.03

Reliability analysis

- ***Limit state*** function (bending moment): $Z(t) = \theta_R R[R_0, g(t)] - G - Q(t)$



Optimum repair strategy - cost minimisation



Conclusions

- Reliability verifications of industrial heritage bridges should be backed up by ***inspection*** including collection of appropriate ***data***.
- ***Probabilistic methods*** can be applied to describe uncertainties and take into account results of inspections and the satisfactory past performance.
- ***Target reliability levels*** are primarily dependent on costs of safety measures and consequences of failure including loss of the cultural heritage value.
- Total ***cost optimisation*** may be used to specify target reliability levels.
- Numerical example indicates that the reliability level is considerably decreasing when the ***deterioration*** is taken into account.
- The target reliability index for the analysed bridge is assessed to be 2.8.
- Applications of the cost optimisation in practice should be based on carefully formulated ***objective functions***, well assessed ***costs***, specified ***reference period*** and the discount rate.

eea grants Iceland liechtenstein norway
norway grants
Supported by a grant from Iceland, Liechtenstein and Norway through the EEA Financial Mechanism and the Norwegian Financial Mechanism

A/CZ0046/2/0013 ASSESSMENT OF HISTORICAL IMMOVABLES

J. Markova et al.

Assessment of bridges registered as industrial heritage

Thank you for your attention.