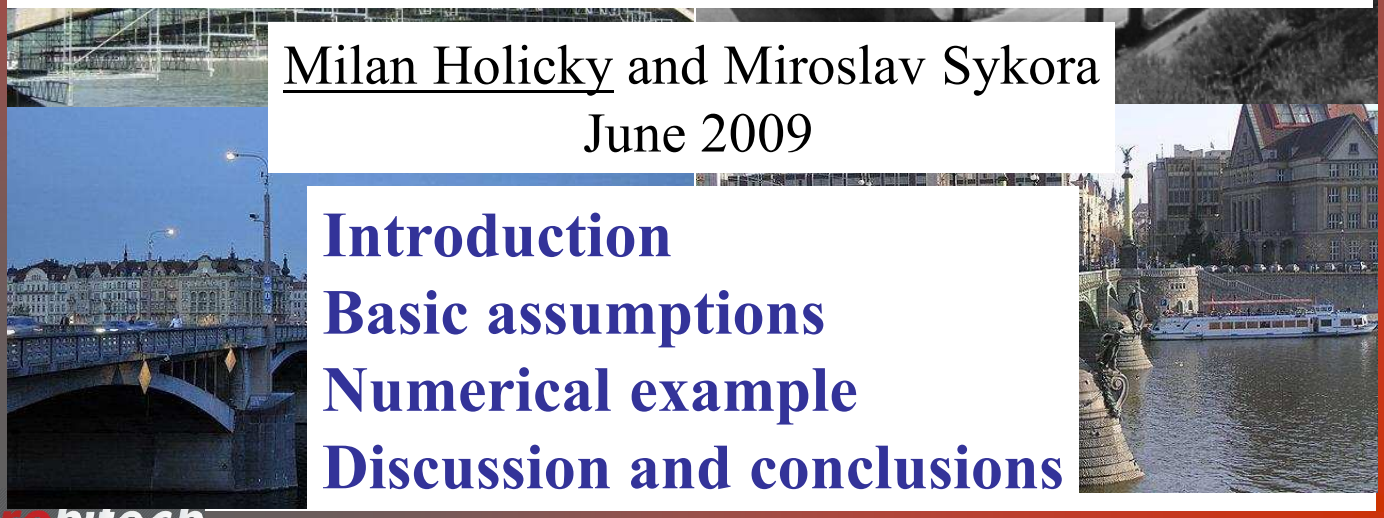
Supported by a grant from Iceland, Liechtenstein and Norway through the EEA Financial Mechanism and the Norwegian Financial Mechanism

A/CZ0046/2/0013 ASSESSMENT OF HISTORICAL IMMOVABLES

Assessment of Existing Reinforced Concrete Bridges for Effective Rehabilitation



Milan Holicky and Miroslav Sykora
June 2009

Introduction
Basic assumptions
Numerical example
Discussion and conclusions

Introduction

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

• Simplified conservative procedures using methods applied for new structures lead to ***expensive repairs***

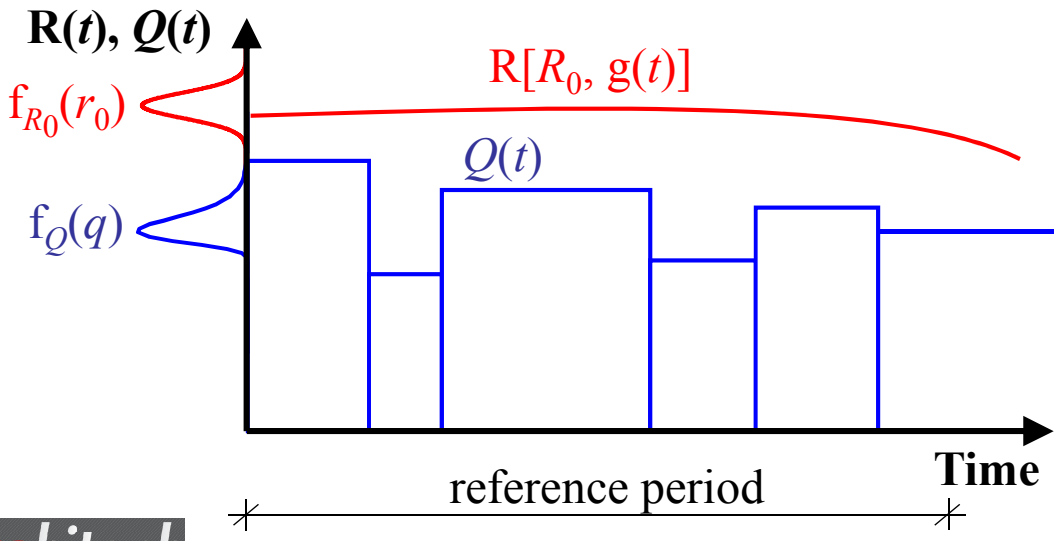
• Decisions should be based on the reliability assessment considering ***deterioration aspects*** and ***actual loadings***

• The ***present study***:
- development of ***methods*** for the ***reliability assessment*** of existing reinforced concrete bridges considering new Eurocodes EN 1990 and EN 1991-2 as well as ISO 13822 and ISO 2394
- determination of ***partial safety factors*** by probabilistic methods
- procedures applied in a ***numerical example*** of a short-span bridge

Basic assumptions

• ***Resistance*** described by a ***monotonically decreasing function***
- R_0 initial resistance
- g(t) - degradation function by Vu and Stewart 2000 (chlorides) or Enright and Frangopol 1999 (empirical functions)

• Occurrence of a ***traffic load*** $Q(t)$ approximated by a rectangular wave ***renewal process*** (conservatively no intermittencies)



Numerical example

• ***Reliability*** of a simply supported reinforced concrete slab bridge

• ***30-year old*** road bridge exposed to repeated application of de-icing salts

• Bending moments of the ***traffic load models*** included in EN 1991-2 compared by a deterministic finite element analysis (LM 1)

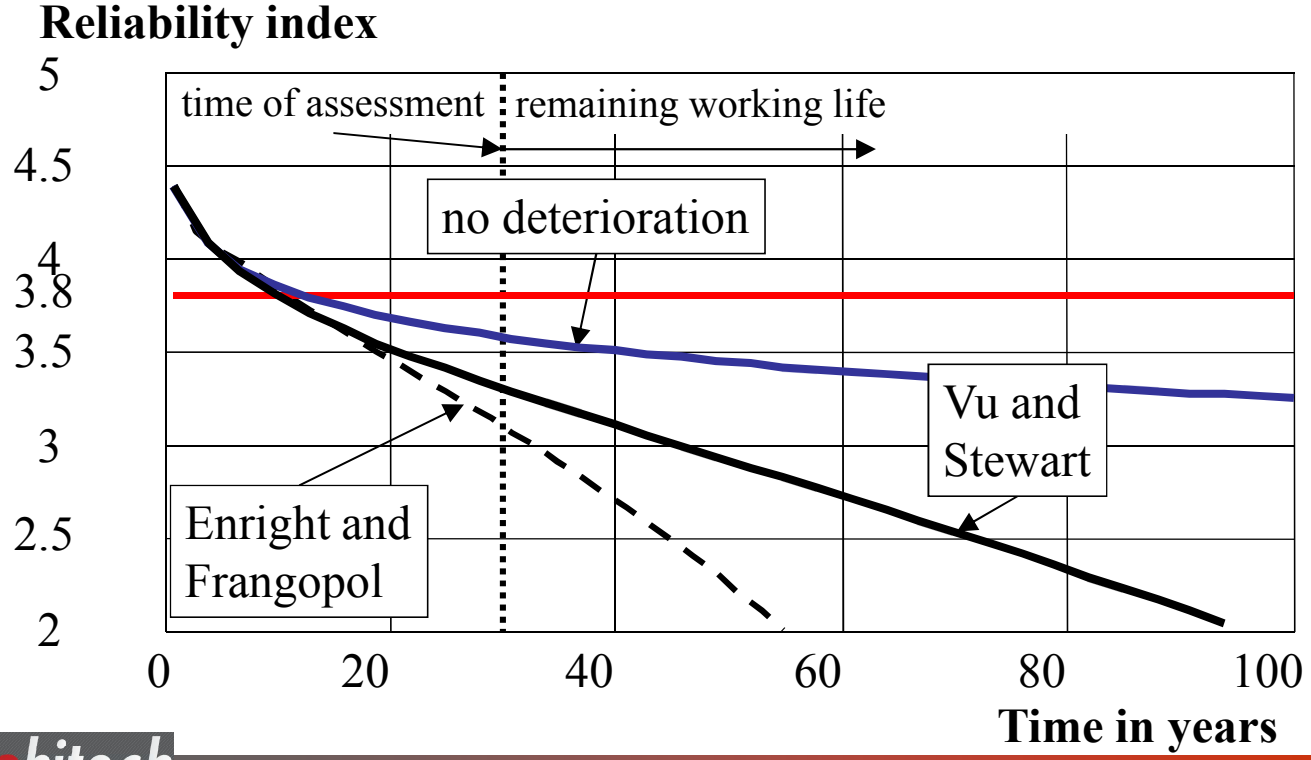
• Probabilistic model based on traffic data collected within the ***development of EN 1991-2***

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	1.08	0.1
Q	Traffic load (annual extreme)	kN	Gum	715	0.03
θ_Q	Model unc. - traffic load effect	-	LN0	1.0	0.15
G	Permanent action	-	N	G_{nom}	0.1

Reliability analysis

• ***Limit state*** function (bending moment)

$$Z(t) = \theta_R \mathrm{R}[R_0, \mathrm{g}(t)] - \mathrm{E}(G) - \theta_Q \varphi \mathrm{E}[Q(t)]$$



Partial factors for assessment of the existing bridge

• ***Time of assessment*** – 30 years, remaining working life – 30 years

Target reliability	Measure-ments	Partial factors			
		steel	concrete	permanent l.	traffic l.
3.8	no	1.54	1.64	1.11	1.30
3.3	no	1.46	1.61	1.10	1.25
3.3	yes	1.36	1.56	1.01	1.33
2.7	yes	1.29	1.51	1.01	1.27

• The partial factor for ***steel***, covering resistance uncertainties, yield strength variability and degradation effects, varies from ***1.3*** to ***1.6***.

• The derived partial factors for ***concrete*** strength and ***traffic load*** correspond to the ***recommended values*** 1.5 and 1.35.

• The partial factor for ***permanent actions*** may be reduced to 1.0 – 1.1 when ***information*** on an actual action is available.

Conclusions

• ***Target reliability*** of ***existing bridges*** may be ***different*** from those of new bridges and ***should be related to*** economic and societal ***consequences of failure*** and ***costs of upgrades***.

• ***Partial factors*** for the assessment of existing bridges depend on a modified target reliability level and models of basic variables updated by inspections.

• Due to degradation effects the theoretical partial factor for ***steel*** varies from ***1.3 to 1.6***.

• The partial factors for ***concrete*** strength and ***traffic load*** correspond to the ***recommended values*** 1.5 and 1.35.

• The partial factor for ***permanent actions*** may be reduced to the values 1.0 – 1.1 when information on an ***actual action*** is available.

Conclusions

• Indicated reliability levels and partial factors are ***conservative*** as they are based on ***upper bound*** on failure probability and influence of possible ***upgrades*** is not included.

• The obtained ***results*** are significantly ***dependent*** on the assumed ***probabilistic models*** and should be considered as informative only.

• The resulting reliability level varies for different ***models of deterioration***.

• ***Bridges*** should be regularly ***re-assessed*** taking into account ***traffic conditions*** and resistance of a ***deteriorating*** structure

• The following aspects will be considered in ***further research***:
- different ***span lengths***
- ***shear*** failure criterion
- target reliability levels specified by ***cost optimisation***.

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

Milan Holicky and Miroslav Sykora
Assessment of Existing Reinforced Concrete Bridges for Effective Rehabilitation

Thank you for your attention.

REFERENCES

• **Allen** (1993) Safety Criteria for the Evaluation of Existing Structures. In Proc. IABSE Colloq. on Remaining Structural Capacity, Copenhagen, Denmark.

• **Enright & Frangopol** (1999) Reliability-based condition assessment of deteriorating concrete bridges considering load redistribution. Struct. Saf. 21(2).

• **Rackwitz** (1997) A Concept for Deriving Partial Safety Factors for Time-variant Reliability. Proceedings of ESREL'97.

• **Schueremans & Van Gemert** (2004) Assessing the safety of existing structures: reliability based assessment framework, examples and application. J Civ Eng and Manag X.

• **Vu & Stewart** (2000) Structural reliability of concrete bridges including improved chloride-induced corrosion models. Struct. Safety, Vol. 22(4).