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Optimum Target Reliability Levels for Industrial Heritage Structures

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A/CZ0046/2/0013 ASSESSMENT OF HISTORICAL IMMOVABLES www.heritage.cvut.cz

Introduction

• ***Industrial heritage*** - structures of significant architectural, historic or technological value

• Part of ***urban landscape***, visual historical landmarks

• Insufficient attention to recognizing, declaring and protecting - gradual ***extinction***

• ***Re-use*** and ***adaptations*** – integration into an urban lifestyle (heritage protection, recycling of resources, economic regeneration)

• The ***contribution*** is aimed to:
- propose a general framework for the ***assessment*** of the industrial heritage
- indicate ***optimum target reliability levels*** using the probabilistic optimisation
- illustrate the proposed techniques on ***numerical example***.

General aspects of the reliability assessment

• ***Minimisation*** of ***construction interventions*** (respect to the original conception, durability), but sufficient reliability

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

• ***Economic*** aspects - additional costs to increase reliability

• ***Sustainable development*** - recycling of materials

• ***Deterministic*** design procedures ***conservative*** (expensive repairs, losses of cultural and heritage value)

• ***Probabilistic procedures*** improving the reliability assessment by:
- better description of ***uncertainties***
- facilitating inclusion of the results of ***inspections*** and ***testing*** and ***satisfactory past performance***

Probabilistic assessment

$$p_f(t_D|I) = P\{Z[\mathbf{X}(t_D)] < 0 \cap I\} / P\{I\} \leq p_t$$

or, alternatively

$$\beta(t_D|I) = -\Phi^{-1}[p_f(t_D|I)] \geq \beta_t$$

• ***Resistance*** - decreasing function, ***loads*** – stochastic processes

• ***New information*** related to structural conditions:

- ***inspections*** (deterioration)

- ***tests***, measurements (materials, geometry)

- ***satisfactory past performance*** (factory might have survived loads greater than those expected for future use)

Target reliability levels

• ***ISO 2394***:
- the target reliability level - level implied by acceptance criteria defined in proved and accepted ***design codes***
- moderate ***failure consequences*** and moderate costs of ***safety measures*** - $\beta_t = 3.1$

• ***ISO 13822***: lower target levels - justified on the basis of social, cultural, economical, and sustainable development considerations

• ***Empirical model*** by Schueremans & Van Gemert (2004):
- social, activity, economical and warning factors, number of endangered persons, and *remaining working life*
- $\beta_t \approx 2.7$ - 3.4

• The target level - balance between the consequences of failure and the costs of safety measures, ***minimisation*** of the ***total working-life cost***

Cost minimisation

$\min_{\mathbf{p}} E[C_{tot}(t_D;\mathbf{p}|I)] = E[C_{IM}(t_D;\mathbf{p}|I)] + E[C_R(t_D;\mathbf{p}|I)] + E[C_f(t_D;\mathbf{p}|I)]$

• ***Repair cost*** - cost of ***immediate*** and ***future*** repairs:
- ***direct*** cost (surveys, design, construction, and loss of the cultural heritage value),
- ***indirect*** cost (possible business interruptions)

→ estimation based on ***previous experience***

• ***Failure cost***:
- ***direct*** cost - cost of repair or replacement, loss of the cultural heritage value,
- ***indirect*** cost (economic losses, societal consequences, etc.)

→ estimation using ***consequence analysis*** or the JCSS ***failure classification*** with the rate between societal and economic consequences over construction cost $\rho' \approx$ 1-4

• The ***loss*** of a ***cultural heritage value*** – qualitative expert judgements, few quantitative methods available

Numerical example

• Reliability assessment of steel member of a 100-year textile mill

• Deterministic verification - actual resistance lower by 40 % than required by Eurocodes

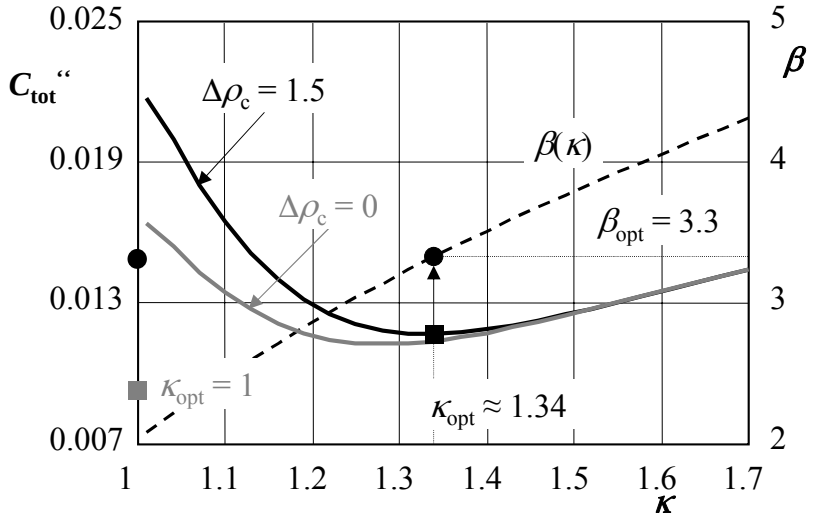
• Probabilistic assessment (structure survived overloading)

$$Z(\mathbf{X},t) = K_R R - K_E [G + Q(t)] \rightarrow \beta \approx 2.6$$

Variable	Sym.	Dist.	m_X / x_k	V_X
Resistance	R	LN	1.19	0.08
Perm. load	G	N	1	0.05
Imposed load (50 years)	Q_{50}	GU	0.6	0.35
Resistance uncertainties	K_R	LN	1.15	0.05
Load effect uncertainties	K_E	LN	1	0.1

Cost optimisation

• The discount rate q = 3 %, moderate consequences (ρ' = 2.5), the loss of the cultural heritage value considered ($\Delta\rho'$ = 1.5)



(resistance after repair over resistance before repair)

Conclusions

• ***Protection*** of the industrial heritage contributes to the ***sustainable development***; insufficient attention may lead to its ***extinction***.

• ***Probabilistic methods*** allow to consider uncertainties, results of inspections and tests and satisfactory past performance.

• ***Target reliability*** levels are dependent on costs of ***safety measures*** and ***failure consequences*** including loss of the heritage value, and may be specified by the ***cost optimisation***.

• The target reliability might be lower than 3.8 recommended in Eurocodes; it may vary from ***2.7 to 3.4 for moderate consequences***.

• The ***decision*** about the immediate repair may be influenced by ***estimation*** of the cultural ***heritage value*** of a structure.

• Desired protection requires a ***public recognition*** of the industrial heritage to be equally important as any other cultural heritage; ***educational programs*** and relevant ***legislation*** are needed.

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www.heritage.cvut.cz (handbook, software tools)

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Thank you for your attention.