18th International Conference
ENGINEERING MECHANICS 2012
Svratka, Czech Republic, May 14 – 17, 2012

pp. 310–311
Paper #100

RELIABILITY ASSESSMENT OF INDUSTRIAL HERITAGE BUILDINGS

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Abstract: *At present considerable effort of architects and civil engineers is aimed at re-use of industrial buildings in order to preserve their cultural and heritage value and to avoid wasting energy. However, heritage structures usually do not fulfil requirements of present codes of practice. Simplified conservative procedures of design of new structures given in present codes may lead to expensive repairs and losses of the cultural and heritage value when applied to existing structures. In accordance with EN 1990 (2002) and ISO 13822 (2003), probabilistic procedure is proposed to improve the reliability assessment of industrial heritage buildings. The procedure is applied in the reliability assessment of a steel member.*

Keywords: ***Industrial heritage, reliability assessment, probabilistic methods.***

1. Introduction

A number of factories, warehouses, power plants and other industrial buildings has been worldwide registered as industrial cultural heritage. According to the International Committee on the Conservation of the Industrial Heritage, such structures are mostly of significant architectural, historic, technological or social value.

It is indicated that protection (including adaptations and re-use) of the industrial heritage structures is an important issue since it often positively contributes to the sustainable development of urban areas by the following:

- Preservation of cultural values (the industrial heritage often forms a part of the urban landscape and provide the cityscape with a visual historical landmark),

- Recycling of potential resources and avoiding wasting energy,

- Facilitating the economic regeneration of regions in decline.

However, insufficient attention seems to be paid to systematic recognizing, declaring and protecting the industrial heritage in most countries. This is an alarming situation as the lack of attention and awareness of the industrial structures may gradually lead to their extinction.

Decisions about adequate construction interventions should be based on the complex assessment of a structure. It has been recognised that many heritage structures do not fulfil requirements of present codes of practice. Minimisation of construction interventions is required in rehabilitation and upgrades, but sufficient reliability should also be guaranteed. Application of simplified procedures used for design of new structures may lead to expensive repairs and losses of the cultural and heritage value. In the paper a general probabilistic procedure is thus proposed to improve the reliability assessment of industrial heritage buildings particularly with respect to:

- Better description of uncertainties related to the assessment and

- Facilitating inclusion of results of inspections and tests and the satisfactory past performance of a structure.

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2. Principles of probabilistic analysis

Probabilistic methods may be useful for the assessment of existing structures where appropriate data can be obtained. Uncertainties that can be greater than in structural design (such as uncertainties related to inaccessible members and connections where construction details cannot be inspected and verified) can be adequately described by such methods. On the contrary, some of the uncertainties reflected (often implicitly) in the load and resistance factors (modelling approximations, deviations from specified dimensions and strengths) may be less than in new construction, particularly when in-situ measurements are taken.

The failure probability, related to the period from the assessment to the end of a working life t_D, can be obtained from a general probabilistic relationship:

$$p_f(t_D) = P\{\min Z[\mathbf{X}(\tau)] < 0 \text{ for } 0 < \tau < t_D\} = P\{F(t_D)\} < p_t \quad (1)$$

where $Z(\cdot)$ = limit state function; $\mathbf{X}(\cdot)$ = vector of basic variables including model uncertainties, resistance, permanent and variable actions; $F(t_D)$ = failure in the interval $(0,t_D)$; and p_t = target failure probability. When additional new information I related to structural conditions is available, the failure probability may be updated according to ISO 13822 (2003) as follows:

$$p_f''(t_D|I) = P\{F(t_D) \cap I\} / P(I) \quad (2)$$

The target reliability level β_t can be taken as the level of reliability implied by acceptance criteria defined in proved and accepted design codes. For the industrial heritage buildings, moderate consequences of failure and moderate costs of safety measures may often be assumed. In this case ISO 2394 (1998) indicates the target reliability index of 3.1.

3. Numerical example

The proposed procedure is applied in the example of reliability assessment of a steel member of a 100-year old building registered as the industrial heritage. The building, originally built as a part of a textile mill, will be used as an office building. The selected structural member is exposed to bending moment due to permanent and imposed loads.

The deterministic verification reveals that reliability of the member is insufficient as the actual resistance is approximately by 40 % lower than required by Eurocodes.

The probabilistic reliability verification is firstly based on Eq. (1) (no new information) and reliability index $\beta \approx 2.0$ is obtained. Secondly, the reliability is updated considering the satisfactory past performance to improve this estimate. It is known from previous performance of the structure that the member has survived the load S equal to 1.2-times the characteristic value of the imposed load. Given the survival of the load S, the updated reliability index obtained from Eq. (2) is still rather low, $\beta'' \approx 2.45$. Several options how to handle this situation in practice are discussed in the full paper.

4. Conclusions

Reliability verifications of the industrial heritage buildings should be backed up by inspection including collection of appropriate data. Assessments based on simplified conservative procedures used for structural design may lead to expensive repairs and losses of the cultural and heritage value. Probabilistic methods can thus be applied to better describe uncertainties and take into account results of inspections and tests as well as satisfactory past performance. Target reliability levels are primarily dependent on the costs of safety measures and consequences of failure including loss of the cultural heritage value.

Acknowledgements

This study is an outcome of the research project DF12P01OVV040 “Assessment of safety and working life of industrial heritage buildings”, supported by the Ministry of Culture of the Czech Republic.