Reliability Assessment of Industrial Heritage Structures and Application to a Light-Weight Steel Roof

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1 INTRODUCTION

A number of factories, warehouses, power plants and other industrial buildings has been registered as industrial culture heritage. These structures are mostly of significant architectural, historic, technological, social, and/or scientific value. However, it appears that insufficient attention has been paid by experts to specific issues of reliability assessment of such structures so far. The present paper is aimed to promote discussion between civil engineers and architects on sustainable use of the industrial heritage structures and provide a framework for reliability assessment of such structures.

Re-use and adaptation to hotels, residential parks, commercial centres etc. allow for integration of the industrial heritage buildings into a modern urban lifestyle and help preserve cities' cultural heritage. Minimisation of construction interventions is required in rehabilitation and upgrades, but sufficient reliability should also be guaranteed. It has been recognised that many heritage structures do not fulfil requirements of present codes of practice. Decisions about adequate construction interventions should be based on the complex assessment of a structure considering actual material properties and environmental conditions.

A general probabilistic procedure is thus proposed to improve the reliability assessment of industrial heritage buildings. The procedure allows for inclusion of results of inspections, testing and consideration of successful past performance of a structure.

2 PROBABILISTIC ASSESSMENT OF THE INDUSTRIAL HERITAGE STRUCTURES

Reliability verification of a heritage structure should be backed up by inspection including collection of appropriate data. The satisfactory past performance of a structure during a period to the time of assessment t_A may be included in the reliability analysis considering the conditional failure probability that a structure will fail during a working life t_D given that it has survived the period t_A. When the load to which the structure has been exposed during the period t_A is known, the resistance or a joint distribution of time-invariant variables may be appropriately truncated (a lower bound is set to the value of load). Alternatively, the updated failure probability may be determined as:

$$p_{f,upd}(t_D|t_A) = C_{upd}(t_D,t_A)C_{SORM}(t_D)\Phi[-\beta(t_D)] \quad (1)$$

where C_{upd} = factor accounting for the satisfactory past performance; C_{SORM} = curvature correction factor; Φ = cumulative distribution function of the standardised normal variable; and β = FORM reliability index. Reliability verification may be based on the following relationship:

$$\beta_{upd}(t_D|t_A) = -\Phi^{-1}[p_{f,upd}(t_D|t_A)] \geq \beta_t \quad (2)$$

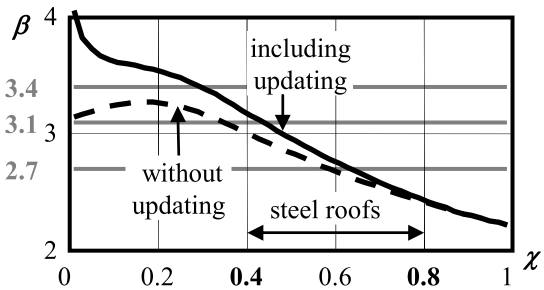

Figure 1. Variation of the reliability index with the load ratio.

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 (1998) indicates $\beta_t = 3.1$.

The target reliability level can also be established taking into account the required performance level of the structure, reference period, cost of upgrades (including potential losses of the cultural and heritage value) and possible consequences of failure or malfunction. A simple model for estimation of the target reliability level proposed by Schueremans & Van Gemert (2004) yields the range of the target reliability level from 2.7 up to 3.4.

3 NUMERICAL EXAMPLE

The proposed procedure is applied in the reliability assessment of a member of steel roof of a 100-year old building registered as the industrial heritage. A deterministic verification reveals that reliability of the member is insufficient (the actual resistance being by 15 % lower than required). In the probabilistic verification, it is considered that the member has been exposed to a characteristic value of the snow load. The resulting reliability index is $\beta_{upd} = 2.76$.

Parametric study is conducted for the load ratio χ given as the fraction of the characteristic variable actions over the total characteristic load. It follows from Figure 1 that the probabilistic updating improves the estimates of the reliability level particularly for structures exposed to dominant permanent actions (for low load ratios $\chi < 0.4$). However, the influence of the updating seems to be insignificant for light-weight roofs.

4 CONCLUDING REMARKS

The present paper indicates that the assessment of the industrial heritage structures can be based on probabilistic methods. The target reliability for the industrial heritage buildings may vary in the broad range from 2.7 to 3.4. The probabilistic updating, accounting for the satisfactory past performance, may particularly improve the estimates of the reliability level for structures exposed to dominant permanent actions.

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REFERENCES

ISO 1998. *ISO 2394:1998, General principles on reliability for structures*.

Schueremans, L. & Van Gemert, D. 2004. Assessing the safety of existing structures: reliability based assessment framework, examples and application. *J Civil Engineering and Management* X(2): 131-141.