Assessment of existing bridges based on probabilistic methods – Background and proposal for a practical approach

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Summary

The maintenance of existing civil engineering structures is becoming ever more important. The consequence of this is that the realistic assessment of existing structures both from a static - design point of view as well as in respect of the remaining service lifetime will be one of the main tasks of engineers in the future. Amongst the various scientific methods for assessing the load bearing capacity and serviceability are probabilistic calculation methods. Using these methods, it is possible, based on stochastic models for the loads and resistances to determine, in particular, the failure probability or the reliability of civil engineering structures. The report presents a practical procedure for the assessment of existing structures with the help of probabilistic calculation methods. The advantages of these methods are demonstrated using the example of a 440 m long existing prestressed concrete bridge.

Keywords: Reliability, existing bridges, load-bearing capacity, practical approach, probabilistic methods, stochastic models, monitoring

1. Probabilistic methods

In contrast to deterministic and semi-probabilistic calculation methods, probabilistic methods make possible the direct determination of the mathematical failure probability of a structure or component based on the actual material properties and the local loading situation. Uncertainties and scatter in the decisive variables on the load and resistance side are in this way reduced to the individual structure. Consequently it is possible to make an assessment based on the actual existing properties. The reliability of a structure is strictly defined as a complement to the failure probability, p_f. The general limit state function is given by:

$$g(R,E) = R - E \tag{1}$$

Failure occurs if the load E is greater that the resistance R. Here in general R and E are random variables that are described by a statistical distribution. Now the probability of failure p_f can be calculated as:

$$p_f = p\ (g < 0) \tag{2}$$

and the reliability p_s as

$$p_s = 1 - p_f \tag{3}$$

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In civil engineering design, the reliability index β is a measure for the reliability of a component, which is introduced as the so-called 'generalized reliability index' [1].

$$\beta = -\Phi^{-1}(p_f) = \Phi^{-1}(1 - p_f) \qquad (4)$$

2. Practical approach

Figure 1 presents a possible practical procedure in the assessment of existing structures using probabilistic calculation methods. After selection of the limit state to be considered, a sensitivity analysis can be carried out to determine the crucial parameters of the structure where reliability is concerned. Against this background, existing documents and records, e.g. existing inspection reports, can be re-evaluated or additional inspections can accurately initiated. As the decisive parameters are known, additionally in preparation a 'fictitious' model update can be carried out to demonstrate what effect the limiting of uncertainties has on the reliability level of the structure.

If new findings become available after additional structural surveys, then the base variables and the underlying stochastic model can be rendered more precisely and adjusted to match the latest relationships as part of a model update. Observed or suspected damage can also be incorporated in this model update.

The final assessment of the structure takes after a renewed computation run. This primarily concerns the assessment of the computational reliability level. If additional monitoring systems are considered for further recording of the structural state, then these can be precisely prepared with an awareness of the decisive parameters where reliability is concerned. Moreover, maintenance and upgrading measures that are to be considered can be planned from the point of view of their effect on the structural reliability and service lifetime.

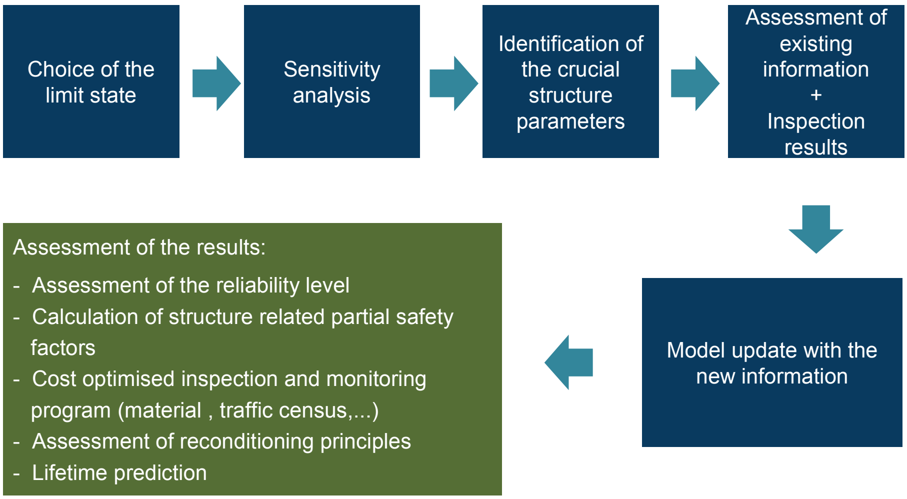

Fig 1. Approach for the probabilistic assessment of existing structures

References

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