Assessment of damaged Concrete Bridges based on a visual Inspection

Thomas BRAML
Scientific Assistant
University of the German Armed Forces Munich
Neubiberg, Germany
Thomas.Braml@unibw.de

Thomas Braml, born 1976, received his civil engineering degree from the University of Applied Sciences in Deggendorf and from the Technical University of Dresden. Following a period of engineering design he is now a scientific assistant at the Institute for Structural Engineering

Manfred KEUSER
Professor
University of the German Armed Forces Munich
Neubiberg, Germany
Manfred.Keuser@unibw.de

Manfred Keuser, born 1952, received his civil engineering degree and his PhD from the Technical University of Darmstadt and is now a professor at the Institute for Structural Engineering at the University of the German Armed Forces Munich, Germany.

Summary

Regular bridge inspection is of great importance for the reliable use of the traffic infrastructure. This paper describes and explains a method which supports the engineers in the assessment of damaged bridges during or directly after the inspection. Based on this initial estimate, an urgent measure - i.e. a lower permitted bridge class - can be carried out before more detailed inspections and calculations are done. The reliability analyses for the damaged bridges are carried out using first order and second order reliability methods (FORM and SORM). The probability of failure, p_f or the safety index β of the system, respectively are the main results of the calculation procedure.

Keywords: Reliability, existing bridges, visual inspection, damaged concrete bridges, corrosion, ultimate limit state, assessment

1. Typical defects and damage conditions of reinforced concrete bridges

1.1 Classification of damage in categories

Bridges are subject to all kinds of stress and strain. In addition to effects caused by climatic conditions and chloride pollution caused by winter road maintenance, the structures have to sustain heavily increasing traffic and mechanical influences. The typical kinds of damage found in reinforced concrete bridges which influence the ultimate limit state can be differentiated as:

- damage caused to the concrete (efflorescence and concrete corrosion)
- damage caused to the concrete with effects on the reinforcement steel (chloride damage, carbonation, cracks)
- damage caused to the reinforcement steel (corrosion of the reinforcement steel)

In the case of a visual bridge inspection the effect of the various kinds of damage on the structure´s load-carrying capacity and the ultimate limit state can only be determined on the basis of the results of the inspection. The effects on the serviceability limit state are not considered in this paper.

1.2 Influence of the damage on the ultimate limit state

The major conditions or defects *causing damage to the concrete* in a bridge structure which can be identified during a visual inspection include efflorescence and concrete corrosion as a result of chemical attack and the action of deicing salt. *Efflorescence* mostly results in an undesirable appearance but only rarely impairs the mechanical properties or the durability of the concrete. These defects are, however, a clear indication of possible damage to the structure, such as porous areas and cracks, for example. Concrete corrosion in bridges is caused primarily by physical attack

https://doi.org/10.2749/222137809796078649

and, less frequently, by chemical attack. Due to progressive weathering and spalling of the concrete surface as a result of water freezing in the capillary pores (an increase in volume of 9 %), the concrete bond keeps deteriorating and the concrete cross section decreases in size. Initial test results [1] have shown a reduction in concrete strength of up to 35 %. The compressive strength of the concrete damaged by freezing $f_{c,damaged}$ [MPa] as a function of the compressive strength of the undamaged concrete $f_{c,o}$ [MPa] is given in [1] as follows:

$$f_{c,damaged} = 0.96 * f_{c,o} - 9 \quad (1)$$

The chloride damage, the carbonation of the concrete and cracks belong to the *damage caused to the concrete with effects on the reinforcement steel*. This type of damage has a major influence on the serviceability limit state. The effects on the material properties which influence the ultimate limit state are currently under investigation. Due to the large variety of influences, the reduction in concrete compressive strength cannot be defined more precisely at the moment. As the sensitivity analyses in the reliability calculation have shown the influence on the reliability index β of the height of the concrete strength class in comparison to the other basis variables i.e. traffic load, is rather low.

In reinforced concrete bridges, *corrosion of the reinforcement steel* is the major damage condition with regard to the load – carrying capacity. The corrosion can normally be easily identified by a visual inspection, but it is difficult to quantify. For the reliability calculation, the reduction of the cross section of the reinforcement steel and the effects on the tensile strength must be considered.

2. Probabilistic calculation and assessment

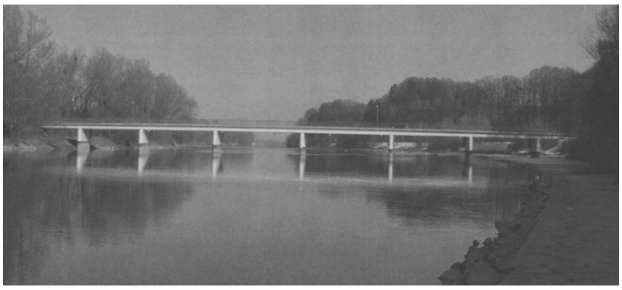

Fig. 1: View of the bridge to be assessed

The assessment of the damaged bridges is carried out with a reliability analysis (FORM and SORM). The traffic, the model uncertainty and the tensile strength of the reinforcement and thus the residual cross section of the reinforcement bars have a major influence on the reliability index β. The statistic distributions for the basis variable of the loads and resistance were chosen with reference to JCSS [2].

The diagram developed in Figure 2 for the example bridge in Figure 1 allows an assessment of the load-carrying capacity of the superstructure of the bridge after a visual bridge inspection.

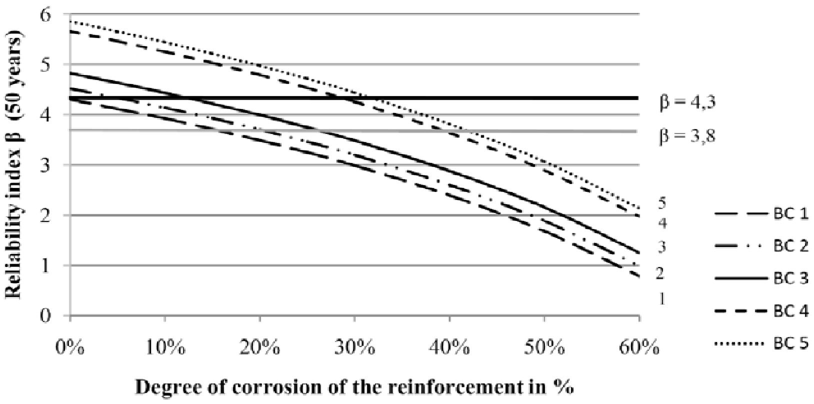

Fig. 2: Reliability index β as function of the degree of corrosion

The diagram shows the permissible traffic load class depending on the degree of corrosion of the reinforcement bar in order to ensure the required level of safety. The target reliability for bridges according to [2] is β = 4,3 for a return period of 50 years. For the assessment of existing structures, the target reliability may be reduced by 0,5 to 3,8.

3. References

[1] CONVECTED: Manual for assessing concrete structures affected by frost. Lund Institute of Technology, Sweden, 2001.

[2] JOINT COMMITTEE ON STRUCTURAL SAFETY (JCSS): Probabilistic Model Code 12th draft. http://www.jcss.ethz.ch, 17th May 2002