Assessment of concrete bridges -Structural capacity.
Experiences from full-scale testing to failure of a bridge in Kiruna




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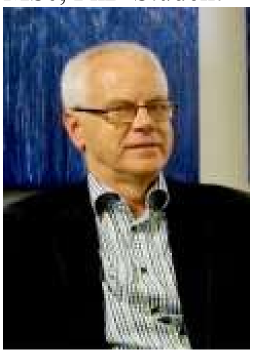


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ABSTRACT
To calibrate methods for condition assessment of prestressed concrete (PC) bridges, tests were carried out on a 55 year old five-span bridge with a length of 121 m in Kiruna in northern Sweden. Both non-destructive and destructive full-scale tests were performed. This paper presents results regarding methods for assessment of the structural capacity of concrete bridges.

Key words: Assessment, Cracking, Corrosion, Creep, Modelling, Pre-stress, Reinforcement, Structural Design, Sustainability, Testing.

1. INTRODUCTION

1.1 General

Assessment, repair and strengthening of existing bridges are required in order to meet current and future demands on sustainability of existing infrastructure. For instance, a survey carried out within the project MAINLINE (2015) [1], indicated a need in Europe for strengthening of 1500 bridges, replacement of 4500 bridges and replacement of 3000 bridge decks. It is believed that for some of these structures replacement can be avoided if more accurate assessment methods are used, see e.g. Sustainable Bridges (2007) [2], Nilimaa et al. (2016) [3] and Paulsson et al.(2016) [4].

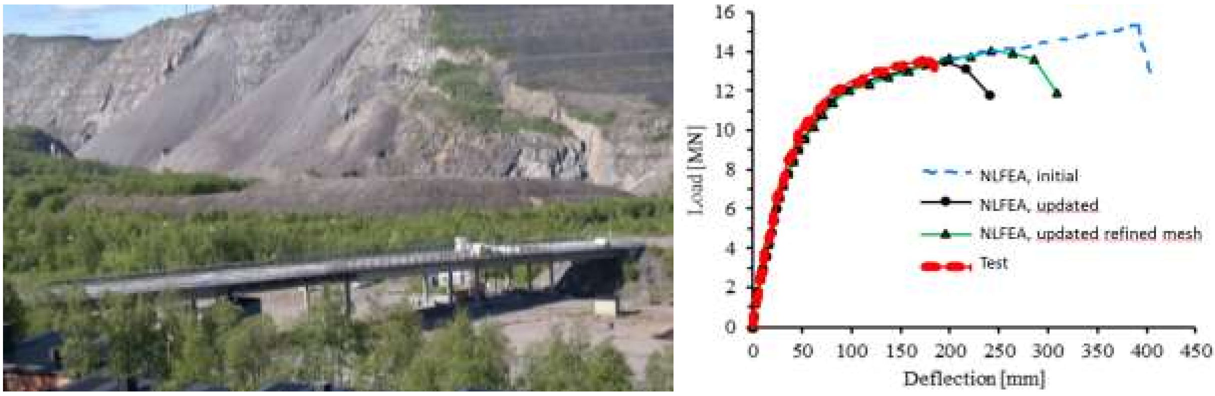

Figure 1. The Kiruna Bridge. Left: Photo with road E10 in the foreground behind birches, the earlier location of the Iron Ore Railway line and the LKAB iron mine in the background. Right: Load-deflection diagrams for the tested span (No 2 from the right): dashed thin blue - initial Non Linear Finite Element Analysis (NLFEA); black circles – updated NLFEA; black triangles with green line – updated NLFEA with refined mesh; and dashed thick red line – test results. Bagge (2017) [5].

1.2 The Kiruna Bridge

The test object, located in Kiruna, Sweden, was a viaduct across the European road E10, see Figure 1. It was constructed in 1959 as a part of the road connecting the city centre and the LKAB mining area. Due to underground mining, the entire area underwent excessive settlement. The owner of the bridge, LKAB, closed it in October 2013 and planned to tear it down in September 2014. Before demolition, the bridge was tested in a research project which will be discussed below [5]-[7].

2 ASSESSMENT METHODS

Structural analysis has a crucial role in bridge assessments. To support rational improvements of this analysis, a multi-level strategy has been developed, Bagge (2017) [5]. By gradually increasing the complexity, the structural response and the load-carrying capacity can be more accurately estimated. This methodology, see Figure 2, is an extension of the strategy developed for bridges in SB-LRA (2007) [8], MAINLINE 2014 [1], UIC 2009 [10], ISO 2015 [11], fib Model Code 2010 (2013) [12] and a procedure specialised for deck slabs by Plos et al. (2016) [9]. Various degrees of degradation and/or fatigue must also be taken into consideration, see e.g. Elfgren (2015) [14].

In order to enable a better representation of the structural behaviour in the intermediate Phase 2 of the assessment, three sublevels have been defined by Bagge (2017) [6]:

2A - Linear elastic analysis
2B - Linear elastic analysis with limited redistribution
2C - Plastic analysis

These methods utilize well-established procedures. For instance, methods for linear elastic analysis with limited redistribution are provided by design codes as e.g. the fib Model Code 2010 [12] and for plastic analysis by K.W.Johansen and M.P. Nielsen [13].

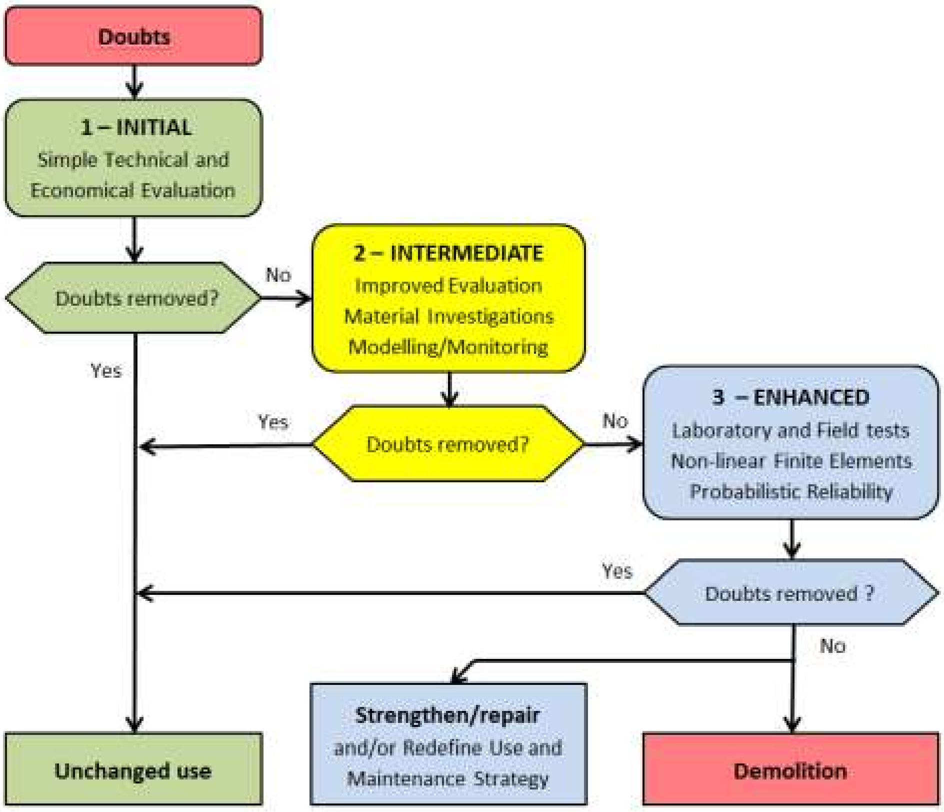

Figure 2. Assessment procedure in three phases: (1) Initial, (2) Intermediate and (3) Enhanced. Based on Sustainable Bridges 2007 [2], [8], Mainline 2014 [1], UIC 2009 [10], ISO 2015 [11], and Paulsson et al (2016) [4].

For structural assessment at enhanced levels, Phase 3, the FE method is a powerful tool. However, depending on the idealisations of the structure, different types of failures can be captured.. Since different modelling choices can necessitate varying computational demands, it is useful to define three levels of approximation for the enhanced structural analysis in Phase 3:

3A - Nonlinear finite elements analysis NLFEA able to calculate the capacity related to flexure.
3B - As 3A but also able to calculate shear-related failures
3C - As 3B but also able to calculate anchorage related failures.

In Figure 1 (right) four load-deflection diagrams are shown for the tested span 2 in the bridge. A Phase 3A initial Non Linear Finite Element Analysis (NLFEA) is shown with a thin dashed blue line. The model was updated with improved material and boundary conditions (partially built in columns) in Phase 3B, shown with black circles. Here a shear failure was captured which did not show up in Phase 3A. Smaller elements were also tested shown with black triangles and a green line. Finally the obtained test result is shown with a thick dashed red line. The Phase 3B with elements of ordinary size (black circles) showed the best correspondence to the test results.

4 SUMMARY AND CONCLUSIONS

A stepwise procedure is recommended for assessment with non-linear finite element calculations. Further research on assessment methods and life-cycle analysis of bridges should be carried out in order to get a more sustainable management.

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