Assessment of concrete bridges - Prestress forces
Experiences from full-scale testing to failure of a bridge in Kiruna




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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 the residual forces in the prestressed reinforcement.

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 with road E10 to the right and Iron Ore Railway line to the left (2010-03-23).

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]-[11].

2 PRESTRESSING FORCES

There are some 850 prestressed concrete bridges in Sweden and they represent about 5% of the total amount of bridges maintained by Trafikverket [12]. When assessing prestressed concrete bridges, it is essential to take the current condition of the prestressing system into account. For instance, the quality of reinforcement protection (e.g. grout), steel corrosion and residual prestress force are all aspects that are crucial and require special attention, SB-LRA (2007) [13]. The residual prestress force influences the structural response both at the service-load and ultimate-load levels. By preventing cracks or limiting their formation, prestressing also reduces environmental exposure and, consequently, has a favourable impact on structures in harsh environments. However, there are often many uncertainties associated with the residual prestress force, especially after a longer time in service and, therefore, it can be useful to calibrate theoretically-based methods using experimental data from the assessed structure.

Due to its expected use on full-scale bridge members reinforced with post-tensioned tendons, the saw-cut method was further investigated in Bagge (2017) [6]. The principle of the method is to measure the development of longitudinal strain at the surface (top or bottom) of a member when a block of concrete is isolated from the loads acting on it. The isolation is carried out gradually by introducing transverse saw-cuts on each side of the position of measured strains and the concrete block is regarded as isolated when increasing the depth of saw-cuts does not cause further changes in the strains at the measured surface. The saw-cutting can be simulated in a FE model by gradually removing FE elements corresponding to the saw-cuts in the experiments (see Figure 2). Therefore, using this method, it is possible to avoid any damage to the structure which might be difficult to repair.

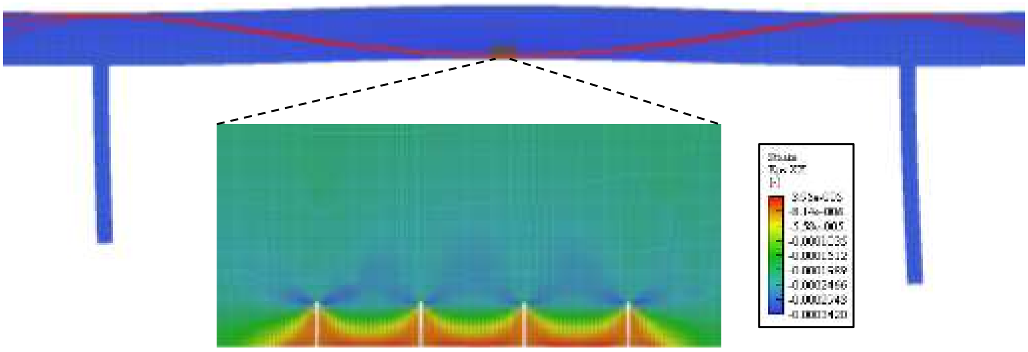

Figure 2. A part of a FE model for simulation of the strain distribution as saw-cuts are introduced transversally at the base of a concrete member (Bagge 2017) [6].

Figure 3 shows the results from the measurements on the south girder in Sections A close to midspan 1, indicating consistent measurements and also an incomplete isolation of the concrete blocks from the acting stresses, which would be characterised by a plateau in the response. In the tests the remaining prestress force varied between some 10 to 85% of the original prestress force of some 85% of the yield stress (a yield stress f_y = 1600 MPa for the 32 wires of 6 mm in a cable in the BBRV System gives an intial prestress force of some 1300 kN/cable).

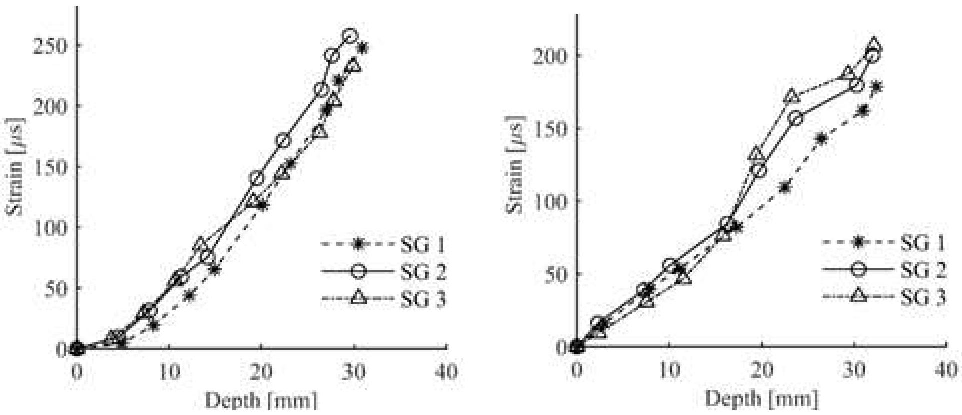

Figure 3. Measured development of strains as function of saw-cut depth for non-destructive determination of the residual prestress force in the south girder, Left: Section A close to midspan 1. Right: Section D at midspan 3. Bagge (2017) [6].

4 SUMMARY AND CONCLUSIONS

Tests have been carried out to check the remaining prestress level in 55 year old bridge. The level was found to vary between some 10 and 85 % of the original force of about 1300 kN/cable. 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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