Full-Scale Test to Failure of a Prestressed Concrete Bridge in Kiruna

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ABSTRACT

To calibrate methods for condition assessment of prestressed concrete (PC) bridges, tests are planned for a 50 year old five-span bridge with a length of 121 m in Kiruna in northern Sweden. Both non-destructive and destructive full-scale tests will be performed. This paper summarises the test programme, which comprises evaluation of the structural behaviour of the bridge, the residual forces in the prestressed steel, methods for strengthening using carbon fibre reinforced polymers (CFRP) and the shear resistance of the bridge slab.

Key words: Assessment, Pre-stress, Shear Resistance, Strengthening, Fibres, Reinforcement, Repair, Structural Design, Testing.

1. INTRODUCTION

Our bridge stock is growing at the same time as it is getting older. In order to enable optimal management methods, it becomes increasingly important to develop reliable models for condition assessment. There is a lack of knowledge about the structural behaviour, formation of cracks and the actual load-carrying capacity of prestressed concrete (PC) bridges. In this paper a programme for destructive and non-destructive full-scale testing of a PC bridge, the Kiruna Bridge, will be presented. The main tests are planned to be carried out in June 2014.

Figure 1. Photograph of the Kiruna Bridge, view from south (2014-02-19).

2. THE KIRUNA BRIDGE

The Kiruna Bridge, located in Kiruna in northern Sweden, is a 121.5 m long continuous PC beam bridge. It was constructed in 1960 and due to deformation of the ground, caused by mining activities, the owner (LKAB) decided to permanently close it in October 2013.

The bridge consists of five spans with the lengths 18.00, 20.50, 29.35, 27.15 and 26.50 m, see Figure 1-2. The western part (84.2 m) is curved with a radius of 500 m and the eastern part (37.2 m) is straight. Furthermore, the bridge has an inclination of 5.0 % in longitudinal direction and 2.5 % in transverse direction. The cross-section is 15.5 m wide with three longitudinal beams with a height of 1.92 m. The concrete quality was K 300 (f_{ck} = 21.5 MPa) in the substructure and K 400 (f_{ck} = 28.5 MPa) in the superstructure, and the reinforcing steel was Ks 40 (f_{yk} = 410 MPa) and Ks 60 (f_{yk} = 620 MPa). The prestressed reinforcing steel system BBRV was used with

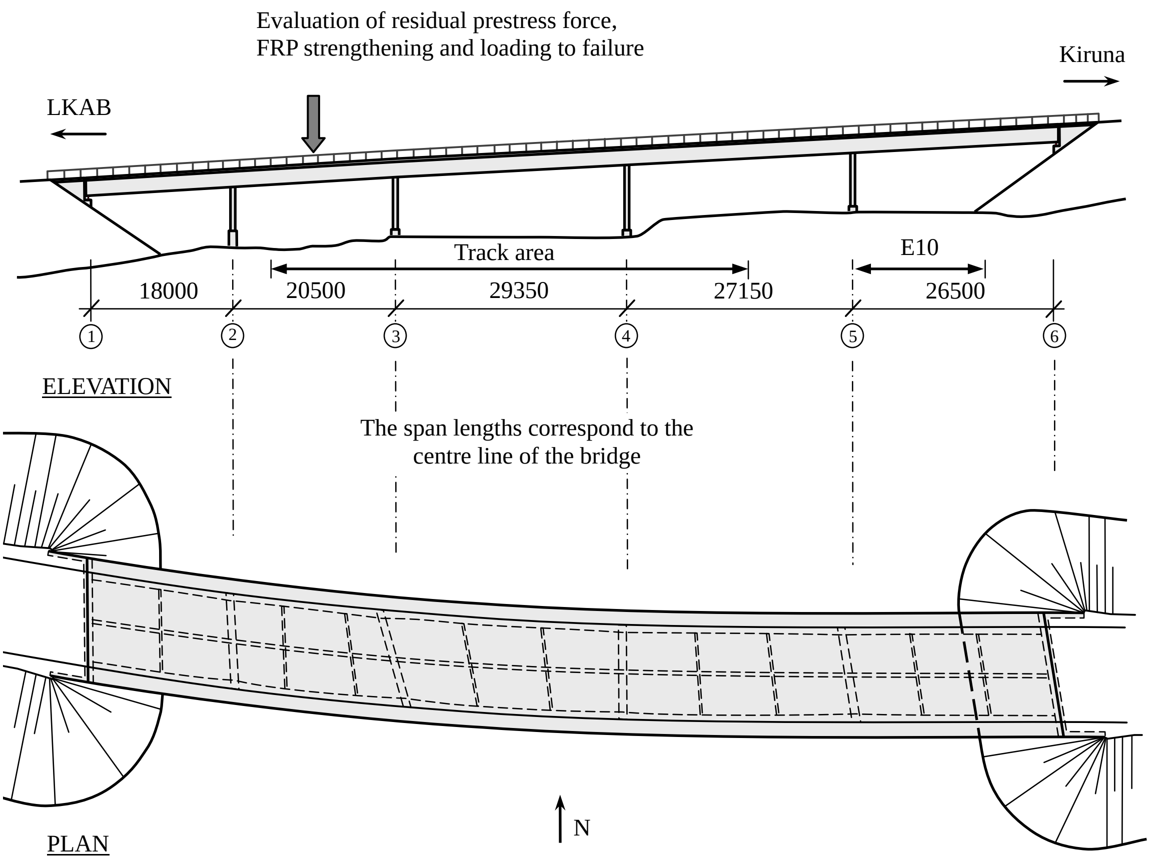

Figure 2. Geometry of the Kiruna Bridge and locations of the experimental study.

the quality denoted St 145/170 (f_{yk} = 1450 MPa, f_{uk} = 1700 MPa).

3. TEST PROGRAMME

The European route E10, passing under the span 5-6, will still be in use at the time of testing and therefore the tests will mainly be located in the spans 2-3, see Figure 1-2. The condition and the residual prestressed force will be investigated. Furthermore, two different techniques to increase the flexural moment resistance, using carbon fibre reinforced polymers (CFRP), will be studied in span 2-3 during the loading to failure. Finally, investigation of the shear resistance of the bridge slab is planned to take place.

3.1. Evaluation of residual prestressed force

In order to evaluate the residual force in the prestressed steel, non-destructive testing can be utilised. Measuring the evolution of strains on the bottom surface of the longitudinal beams, when isolating a concrete block by gradually saw cutting on each side of the strain gauge, the actual prestressed force can be determined (Kukay et al., 2010). Based on the load, the cross-section properties and the measured strain, when the saw cut no longer influences the concrete strain, the prestressed force can be calculated.

The cracking moment test (Osborn et al., 2012) will be utilised for calibration of the non-destructive testing. The bridge will be loaded until formation of cracks, the cracks will be marked and then the bridge will be unloaded. Crack opening displacement (COD) gages will be attached across the cracks and the bridge will be reloaded. The strain corresponding to reopening of the cracks will be used to determine the prestressed force.

3.2. CFRP strengthening and loading to failure of bridge beams

The bridge will be strengthened by two methods: (1) prestressed CFRP laminates applied to the northern and southern longitudinal beams and (2) near surface mounted (NSM) CFRP bars applied to the central longitudinal beam, see Figure 3.

The objective of the strengthening is to increase the flexural moment resistance, with the intention to obtain a shear related failure of the bridge. As it is a lack of knowledge about the behaviour at combined flexural and shear failure, especially for full-scale structures, the results from the testing programme are of importance for calibration of models for assessment of the

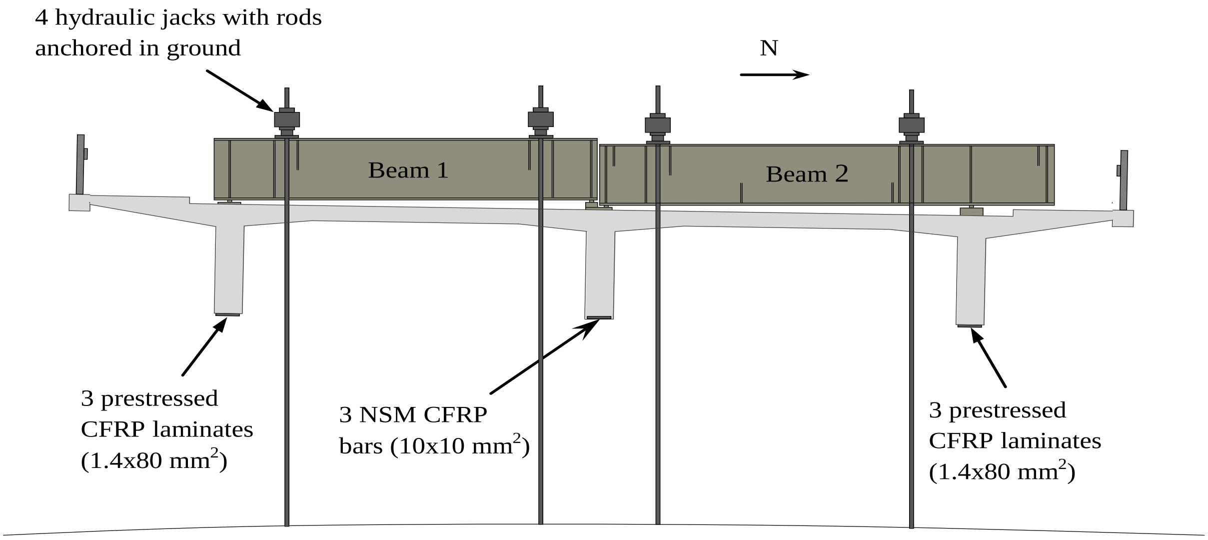

Figure 3. Arrangement for test of the load-carrying capacity in span 2-3 of the Kiruna Bridge.

shear force resistance, where the theoretical background appreciably differ between some of the most commonly used codes. Moreover, the testing in span 2-3 is aimed for investigation of the robustness of the structure and its ductility.

3.3. Shear capacity of bridge slab

In order to provide additional data for calibration of models for the shear resistance, the concrete slab is planned to be tested in span 2-3, after the testing procedure described in in previous section. The load will be applied approximately 800 from the centre of the northern longitudinal beam, using the hydraulic jack and rods anchored in the ground as illustrated in Figure 3. The test-setup will be based on the Load Model 2, LM2, in the Eurocode (CEN, 2003), specified by two load plates with the distance of 2.0 m between their centres and the dimensions 350 and 600 in the longitudinal and transversal direction, respectively. In contrast to the description in Eurocode, the arrangement will be placed perpendicular to the longitudinal axis of the bridge.
It is not uncommon that stirrups are required in bridge slabs according to the Eurocode. We will try to study how necessary this is from a structural point of view.

ACKNOWLEDGEMENT

The authors gratefully acknowledge financial support from Trafikverket/BBT, LKAB/HLRC, SBUF and Luleå University of Technology (LTU). They also thank their colleagues in the Swedish Universities of the Built Environment (LTH, Chalmers and KTH) for fruitful cooperation.

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