WIRELESS MONITORING FOR ASSESSMENT OF CONCRETE RAILWAY BRIDGES – EXPERIENCES FROM FIELD TESTS

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ABSTRACT

This paper focus on assessment on a prestressed three span concrete box bridge by the use of a wireless monitoring system in combination with visual inspection. The bridge is located in the very north of Sweden, in Abisko. A visual inspection of the bridge carried out the 18th of August in 2016 several crack patterns were mapped on the inside of the box girder bridge located near supports in the spans on both sides of the bridge. The cause of the cracks are not completely clear. To reveal the reason for cracking a long term project has been initiated by Trafikverket. Here a new developed wireless system has been used. Investigating change in crack widths by the use of LVDTs and strain gauges. Also accelerations are monitored together with the temperatures. In addition also fibre optic systems and non-destructive tests were carried out (not reported here). The results/conclusions presented in the paper are preliminary and final results will be presented 2021.

Key words: Wireless Monitoring, Fibre Optic System, Concrete, Bridges, Structural Assessment

1. INTRODUCTION

The infrastructure of today is getting older and problems caused by deterioration over time is affecting the service life of these structures. In Sweden most of the existing bridges were constructed 60 to 70 years ago, rising the need to determine the state of health of the bridges as the maintenance costs will increase heavily. Part of the above-mentioned cut of the bridges owned by Trafikverket (The Swedish Transport Administration) that was constructed 60 – 70 years ago are pre-stressed concrete bridges. Pre-stressing of concrete structures is today a commonly used technology that utilizes the beneficial characteristic of concrete, the compressive strength, to a further extent than reinforced concrete. This paper present monitoring and assessment of the Abiskojokk railway bridge located in the northern part of Sweden. The pre-stressed box girder bridge spans in total 86 m in three lengths of 30 m, 35 m respectively 21 m starting from the east abutment and is part of the Iron-Ore Line starting in Kiruna, Sweden, and ending in Narvik, Norway, drawings of the bridge is shown in Figure 1. This paper focus on the cracks that was mapped along the tendon positions on the inside of the box girder in the first span starting from the east abutment. There are also cracks in the other spans but these are not further discussed (it is assumed that it is the same reason behind all cracks). The hypothesis is that the cracks are caused by temperature loads and normal forces obtained from the tendons at the thickening of the cross-sections. The NDT (Non Destructive Testing) also shows that there are thick unreinforced concrete covers in these sections, between 50 – 80 mm. The research questions in this paper are; what the monitoring program shows and if it is possible to prove the hypothesis by using of a FE-model considering the gravity loads, temperature loads and the pre-stressing. In order to determine the cause of the cracks on the inside of the box girder and investigate the behaviour of the bridge a wireless monitoring program was installed, measuring the crack development over time along with the acceleration and temperatures of the bridge

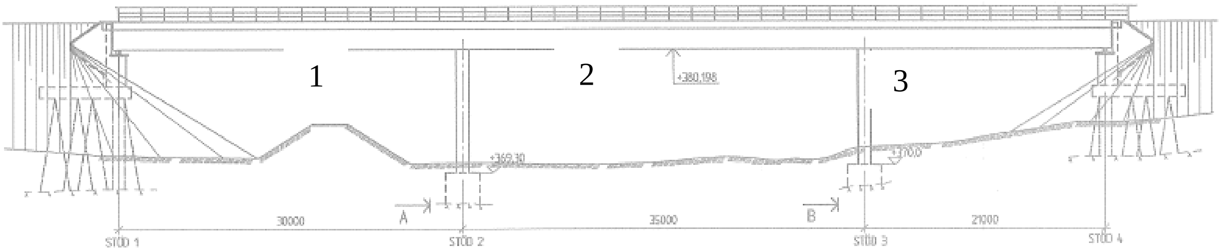

Figure 1 – Overview of the bridge, part of drawing from [1].

2. MONITORING SYSTEM

In Figure 2 the principle for the system is shown. To a node a sensor is connected, from the nodes the data are then transferred wirelessly to a base station and from the base station the real-time data are downloaded to the cloud. The system installed on the bridge is shown in Table 1, where also an explanation to the different devices are presented, together with the placement in the first section of the bridge, se also figure 3. In Figure 4 the fiber optic system used is presented. The FOS is used only to monitor a pre-set intervals.

Figure 2 – Wireless monitoring system – in general.

Table 1 – Wireless system installed in the bridge.

Device	Description	Device	Description
	Base station with 220 V power supply. Antenna placed outside. All data are transferred from the nodes to the base-station. The data is then transferred to the cloud via a 4g router. It is equipped with a back-up battery for 24 hours.		Node to which the sensors are connected. The data are also stored locally on the node. Data can also be downloaded directly from the node. On the node an antenna is placed to transfer the data to the base station. N_1 and N_2
	LVDT, Crack sensor placed over identified cracks. Its placed in a plastic box or protection. The sensor is connected to a node. L_1, L_2, L_3 and L_4.		Strain gage placed over a crack. This is an advanced strain gage which is protected from the environment and can also easily be moved to other locations. S_1 and S_2
	Accelerometer, A_1. The accelerometer is also placed inside a protecting box.		Node for thermo-elements. In total 6 thermo-elements were installed in the flanges, outside, center and inside. T_N and T_S

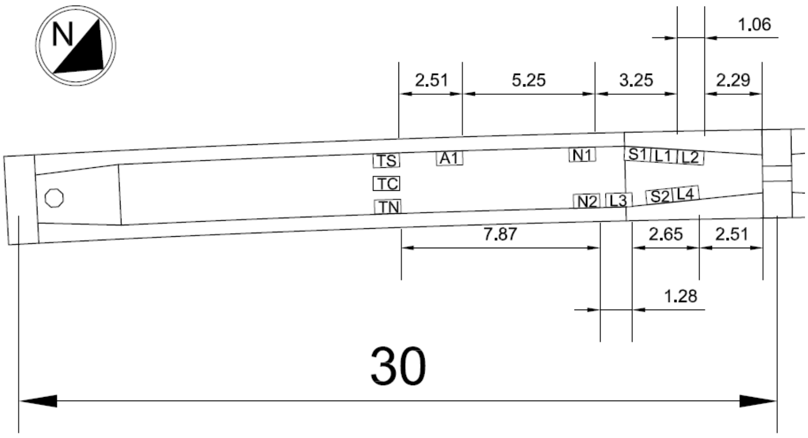

Figure 3 – Placement of sensors in section 1, see also Figure 1.

Figure 4 – a) Fibre Optic System. This platform is configured to measure standard "Rayleigh" High-Definition Fiber Optic Sensors (HD-FOS). HD-FOS operation is based on the measurement of the Rayleigh backscatter in optical fiber and delivers maximum spatial resolution for static and quasi-static applications. b) Installation of fibre optics in section where we also have a crack (LVDT) and a strain gage. c) Optical results from the FOS monitoring

3. RESULTS AND ANALYSIS

The monitored data showed that there are negative temperature gradients occurring during the spring that are larger in size than the conservative positive gradients prescribed in the EC2. From the LVDT's it is concluded that the largest crack opening (approximately 0,05 mm during train passage) occur in the second span. From the strain gauges it is concluded that they more precise captures the crack behaviour during train passages. Hence, they may be used as validation of the LVDT's and that they correspond very well to the data obtained from the FOS monitoring. An optical representation of the FOS is shown in Figure 4. From the results of the accelerometers it is concluded that the accelerations do not correlate well with the assumed loads of the trains during the studied passages. The FE-model is linear and it shows that there might be a relation between cracking and temperature, but that is not completely verified and more analyses are needed.

4. CONCLUSIONS AND FUTURE WORK

The study presented in this paper shows that on site monitoring and FE-analysis can be used for assessment. Furthermore: A large amount of data is obtained – it is important to know what data to measure and how to use it. Wireless monitoring simplify the assessment procedure and minimize the cost for monitoring over time. Nondestructive testing is needed to obtain necessary input for FE-models and to obtain placement of reinforcement, cracking and crack depth. The next steps in evaluating the bridge is to increase the NDT tests, evaluate test data that have been run over summer and winter seasons and improve the analysis with partly non-linear FE analysis.

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