Conference Proceedings 4th ICTB (2022)
https://doi.org/10.24451/40fy-m069

A Reliable Method For Moisture Content Measurement At Inspections And The Results From Nine Swedish Timber Bridges

Niclas Björngrim[1], Per-Anders Fjellström, Göran Berggren

1 Introduction

Timber bridges with stress laminated decks are commonly made of untreated spruce in Sweden and have a required technical life time of 80 years. To meet the lifetime requirement one important part is good water proofing, especially the detailing along the edges. The second part is reliable results from inspections and moisture content measurements. One problem at inspections is to measure moisture content of parts covered by cladding or beneath the water proof membrane. Out of experiences from inspections and commonly used methods a new sensor has been developed by the authors [1]. The sensor is cheap, robust and will last the lifetime of a bridge. Another feature of the sensor is the ability to measure moisture beneath the waterproofing membrane of thick decks. The sensor is a part of scalable system designed for manual measurements and continuous monitoring. As of today, 22 bridges are equipped with a monitoring system using the sensor.

2 Material and method

This paper presents focus on nine modern timber bridges built in Sweden between 1994 and 2020, the bridges are presented listed in Table 1. The Bridges in this study have been monitored and/or inspected by the second author several times over the years.

Moisture measurements

The moisture sensor measures at two depths at each sensor location. Surface moisture content (MC) at (0-45 mm) and internal MC (100 mm – directly under waterproofing membrane). For each bridge installation there is one to two temperature sensors to calibrate the measurements for the temperature. For continuous logging of MC wireless OmniSense S-160-0 sensors has been used.

Inspections

Bridge Main inspections are performed every six years, primary by visual assessment but also aided with tools as impact hammer, MC meter and knife. If damages are found a special inspection is performed to investigate the issue.

Table 1: Bridges in this study.

Bridge	Intended use	Bridge type	Monitoring	Condition
Klockarleden long	Road	Stress lam	Manual	Elevated MC
Klockarleden short	Road	Stress lam	Manual	Elevated MC
Älvsbacka	Pedestrian	Cable stayed	Manual/Continuous	Good
Tväràn	Pedestrian	Stress lam	Manual/Continuous	Elevated MC, condensation
Mobacken	Pedestrian	Stress lam	Manual	Good
Gislaved	Road	Arch/stress lam	Manual/Continuous	High MC at edges
Sundbron	Road	Stress lam	Manual/Continuous	Good
Hörle	Road	Stress lam	Manual	Good
Färgelanda	Pedestrian	Stress lam	Manual	Good

3 Results

The result section presents results from monitoring, inspection and examples of good and bad detailing from the bridges presented.

[1] Niclas Björngrim, Associate Senior Lecturer, Luleå University of Technology, Sweden, niclas.bjorngrim@ltu.se

3.1 Klockarleden short and long,1994

The two consecutive bridges that are similar in construction and appearance. An unusual detail is the outer beams made of oak. The sensors show high surface MC, this originates from a problem with detailing of the edges. On the long bridge this has been exchanged to a better solution and the surface moisture is now normal. The bridge deck underneath the waterproofing membrane show good MC values.

Figure 1. Wet outer beam from Klockarleden short.

3.2 Älvsbacka

Älvsbacka is one of the longest timber bridges in Sweden spaning 130 meters. Monitoring from an earlier system which is no longer operative is reported in [2] and [3]. Today the girders are monitored with twelve retrofitted sensors The bridge is in good condition with MC values around 17-18%.

3.3 Tväråån

A pedestrian bridge equipped with four sensors. The bridge has increased level of surface moisture due to water condesating (Figure 2), which has led to cupping of the bridge deck.

Figure 2. Condensation on bottom of the bridge deck.

3.4 Mobacken

The bridge is a pedestrian bridge with timber decking of treated pine (Figure 3). The bridge has ten sensors factory installed. The manual measurements is showing a MC between 12-16% under the membrane.

Figure 3. Stress laminated deck with a thin rubber membrane and plank decking.

3.5 Sundbron

The bridge is a single lane traffic bridge. During the assembly of the bridge one glulam beam, the outermost with sensors M1-M4 in Figure 4, partly fell in to the water. The wet beam was attached and stressed together with the deck in its wet state. The interface between the wet beam and its neighboring dry beam was monitored and it could be concluded that the high local MC dried down to normal levels after a few months. The placing of the sensors can be seen in Figure 4. The MC for 0-45mm in to the deck is shown in Table 2 and the MC 50-520 mm in to the deck is shown in Table 3. Logging of sensor M1, NV 0-45mm is shown in Figure 5. It can be seen that the MC dries down to around 15% from the initial high MC.

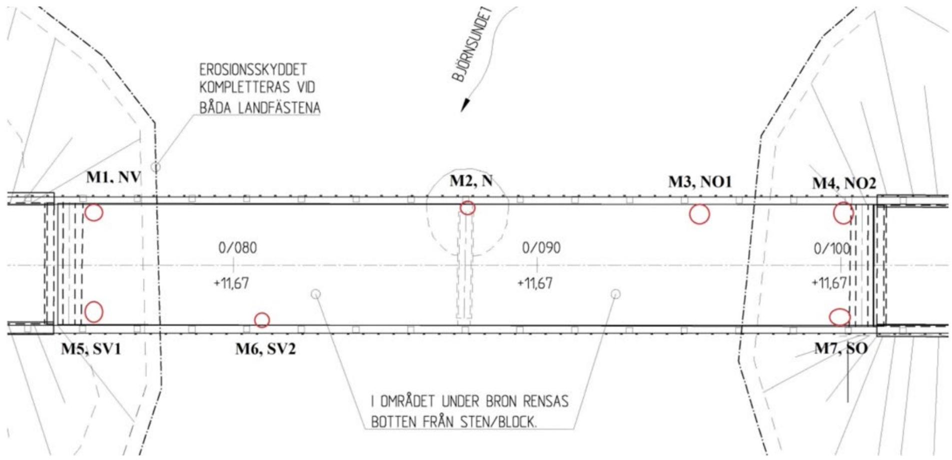

Figure 4. Sensor placing Sundbron.

*Table 2: MC measurements at 0-45mm depth for Sundbron. The * indicates a logger is attached at that measurement point.*

Sensor	6-12-15	26-12-15	11-2-16	28-6-16
M1, NV	23	17	39	*
M2, N	25	24	26	19
M3, NO1	36	30	25	19
M4, NO2	20	20	24	19
M5, SV1	21	22	25	17
M6, SV2	36	33	27	19
M7, SO	17	17	25	18
Temp	3	-3	1	16

Table 3: MC measurements at 50-520mm depth for Sundbron.

Sensor	6-12-15	26-12-15	11-2-16	28-6-16
M1, NV	15	15	22	18
M2, N	21	21	21	19
M3, NO1	27	24	21	18
M4, NO2	15	16	20	23
M5, SV1	15	16	17	17
M6, SV2	28	26	21	19
M7, SO	14	15	19	17

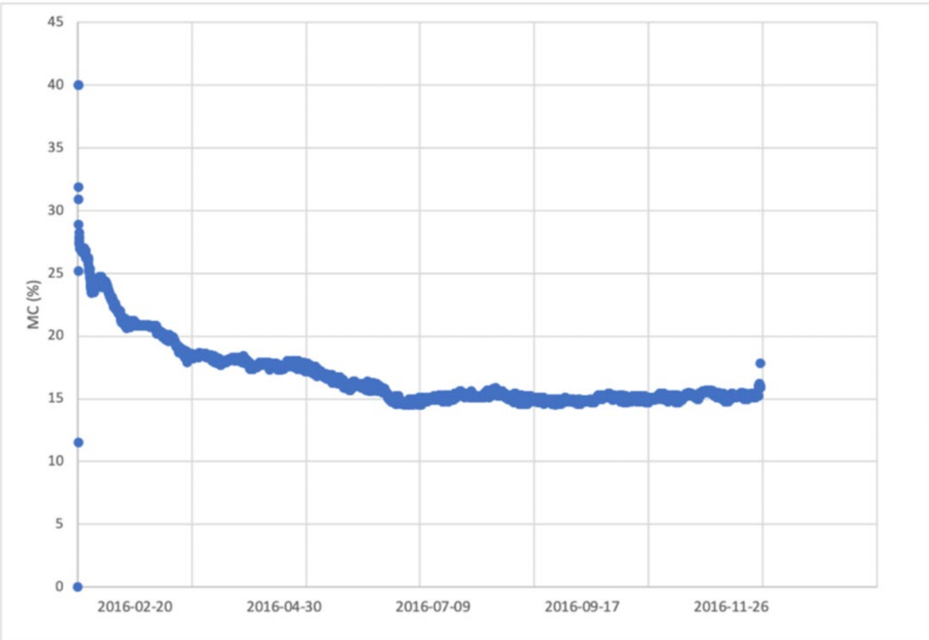

Figure 5. Logging of sensor M1, NV 0-45mm from 11-2-2016 to 15-10-2016.

3.6 Gislaved bridge

The Gislaved bridge is Swedens largest road bridge in timber [4]. The bridge is equipped with 16 retrofitted sensors. This bridge shows the importance of acting fast when monitoring data show high moisture content. Elevated moisture content was determined in 2015 and with no actions taken by the owner, areas with severe decay was found during inspections in 2020. After removing the asphalt several problems were found. The membrane strip on the edge of the deck still had the protective backing on (Figure 6) resulting in no adhesion to the deck. The membrane strip joints were not welded which leads to water penetrating in under the drip edge and into the wood deck.

Figure 6. Detail of Gislaved bridge. Membrane strip not properly attached. Decayed wood is also visible.

3.7 Hörle

A road bridge spanning a railroad with ten retrofitted sensors. The timber deck from three inspections show expected MC where good detailing such as examples in Figure 7 is a contributing reason.

Figure 7. Good detailing of expansion joint drainage and down pipe.

https://doi.org/10.24451/40fy-m069

3.8 Färgelanda

A pedestrian bridge with six factory installed sensors. The first inspection was in April 2019 four months after erection. The second inspection was performed in October 2020. In one of the corners of the bridge elevated MC was detected. The 24% measured is possibly condensated water and is expected to be lower during spring and summer.

4 Conclusions

The moisture measuring sensor is a reliable way for managing timber bridges together with inspections. Klockarleden short showed high MC values from the sensor system, but the inspection found that the wood was in good condition although the MC was over fiber saturation point. By improving some of the edge details the surface moisture will decrease as it has for the longer of the two bridges. The monitoring of Sundbron show that even tough water was introduced to the structure during the assembly, the bridge deck dried down to normal MC levels in five months. The Gislaved monitoring system found high MC from the beginning, and when the special inspection was performed flaws from the construction had resulted in decay at the edges of the bridge.

Bridges with good design and detailing, reliable moisture content measurements together with inspections is crucial for timber bridges to last or outlast the technical life time.

5 References

[1] Björngrim, N., Fjellström, P. A., and Hagman, O. (2017). "Factory-mounted and retrofit passive resistance sensors adapted to monitor moisture content in timber bridges," *BioRes.* 12(4), 7218-7227.

[2] Saracoglu, E., & Bergstrand, S. (2015). Continuous monitoring of a long-span cable-stayed timber bridge. *Journal of Civil Structural Health Monitoring*, *5*(2), 183-194.

[3] Kliger, R., Svensson, T., Jansson, H., & Svensson, I. (2013). Vibration response of long cable-stayed timber footbridge–case study. In *Proceedings of International Conference on Timber Bridges 2013-Las Vegas, Nevada USA*.

[4] EKHOLM, K., Nilsson, P., & Johansson, E. (2013). Case Study of the Longest Single Span Timber Bridge for Highway Loads in Sweden. In *Proceedings, 2nd International Conference on Timber Bridges. Washington, DC: WoodWorks–Wood Products Council*.