Reliability of Long-Term Monitoring Data

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Abstract

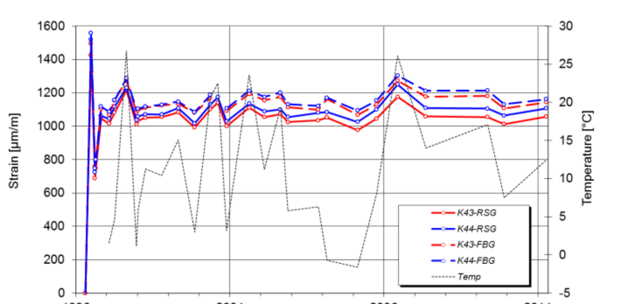
Increasing loads, aging, new construction materials like CFRP (carbon reinforced plastic) and also cost pressure are influences for fitness of traffic infrastructures, especially bridges. Prolonged health monitoring can be a means to compete with these challenges. The lifetime of infrastructure can reach 100 years, while that of sensors is typically much shorter. Therefore, sensors need to be long-term qualified and might have to be replaced by new sensors or even another sensor system during the life cycle of a structure. A reliable system for data acquisition and data analysis will be essential: Do the measurement data really relate to the monitored infrastructure and are not an effect of the degradation of the sensing system? Measurement uncertainty and reliability of data obtained by different sensors types, including resistance strain gages, fiber optical sensors and other sensors systems which are in service up to 17 years are discussed.

The Bridges, Measuring Methods and Results

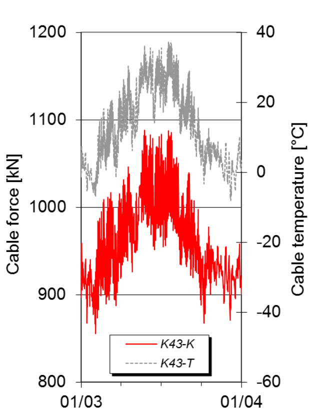
Storchenbruecke, Winterthur (Switzerland)

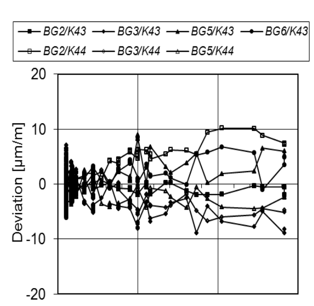
This symmetric cable-stayed bridge was built in 1996 and monitored since then. It has a length of 120 m. Two of the 24 cables were made of CFRP, each consisting of 241 CFRP-wires, 5 mm in diameter. The wire strains are in the range of 1300 µm/m.

Surface adhered resistance strain gages (RSGs) and fiber Bragg grating sensors (FBGs) measure the wire strain. Loaded and unloaded dummy wires for temperature compensation and indication for the loss of long-term stability were added. Displacement sensor measures the pull-in between anchorage cone and CFRP wire bundle .



RSG and FBG measurements of average strain on the CFRP-wires of cables K43 and K44 including the pretensioning phase



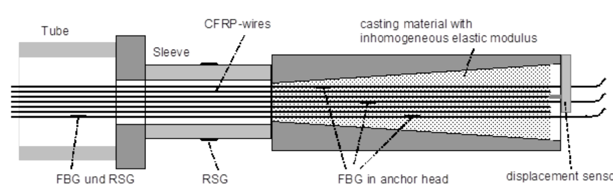


Deviation of FBGs on dummy wires from mean value. Measurement uncertainty (1σ) about 3µm/m

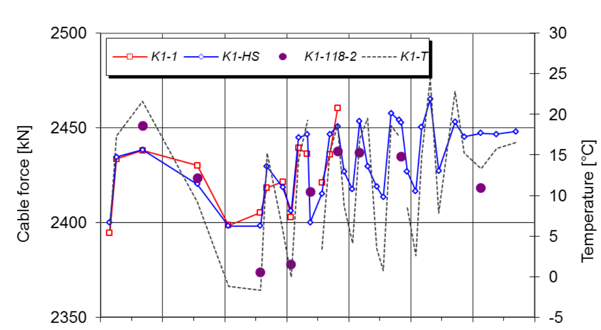
One year-graph of a typical RSG-measurement on cable K43. Temperature induced load variation of the CFRP-is about 25% since the axial thermal expansion of the CFRP-cables is negligible compared to the steel cables.

Bridge Kleine Emme, Lucerne (Switzerland)

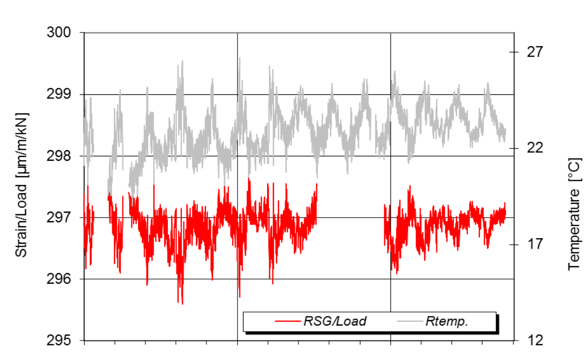
This bridge is a 47 m long steel-concrete-composite bridge constructed in 1998 and monitored since then. Two CFRP-cables with 91 wires were installed under the bridge deck for pretensioning. Each cable was prestressed with 2400 kN – corresponding to a high strain level of about 8500µm/m on the CFRP-wires.



Longitudinal section of the CFRP cable anchorage with RSG and FBG sensors on the steel sleeves and the CFRP-wires – inside and outside of the anchor head



Cable force obtained from measurements with FBGs (K1-118-2) and RSGs (K1-1) and the sleeve (K1-HS) on the CFRP- wires

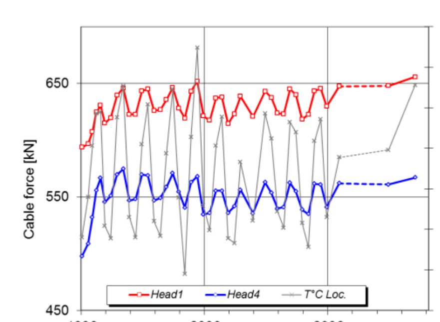


Strain to load ratio of the reference measurement on the CFRP-wire with a constant load of 32 kN

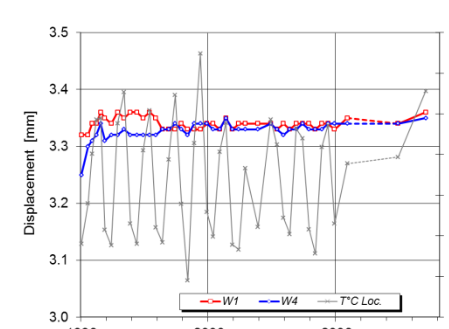
Bridge sul Ri die Verdasio, Centovalli (Switzerland)

During operation of this 70 m long bridge the steel post-tensioning cables partially corroded. Therefore, the bridge was retrofitted in 1998 with four additional CFRP-cables. Each cable is pre-stressed with 600kN, which induces very high strains in each of the 19 CFRP-wires of up to 9500µm/m.

Anchorage of the four CFRP-cables where the forces and the pull-in of the CFRP-wires are measured



Typical data of the force measurement on both anchor heads of one CFRP-cable



Typical data of the displacement measurement on both anchor heads of one CFRP-cable

Conclusions

On three bridges with CFRP-cables, tensioning forces and displacements were measured with different measuring techniques. Well established RSGs and LVDTs as well as newly developed FBG-sensors have been in service for up to 17 years. To obtain information regarding the long-term reliability, reference sensors and redundant sensing systems have been installed, allowing one to differentiate between sensor drift and changes in the performance of the CFRP-cables. Additional long-term laboratory experiments have helped to validate sensing systems. That usually some parts, e.g. RSGs, cannot be replaced without losing baseline information is a major difficulty. Approaches to solve this problem are to include means to set the sensing system in a well-defined state to regain the baseline or to include adequate redundancy. Still, well-planned sensing systems, verified methods and careful installation result already now in suitable long-term monitoring systems for infrastructure.

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