Fatigue safety examination of a riveted railway bridge using data from long term monitoring

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Summary

Long term monitoring of structural elements of a 115 years old riveted railway bridge structure of high value as cultural heritage has been conducted. Monitored values were exploited by Rainflow analysis and served as the basis for the fatigue safety verification. As the locations of measurements are generally not identical with the cross sections of verification, measured strains were translated to the relevant verification cross section by means of factors that were determined by structural analysis. Using these values, all fatigue relevant structural details were first verified with respect to the fatigue limit. Then, damage accumulation calculation according to the Palmgren-Miner Rule was performed for those elements where the fatigue limit check was not fulfilled. Sufficient fatigue safety could finally be verified for the entire riveted structure and additional service duration of at least 50 years for this riveted structure could be validated.

Keywords: Fatigue safety, service life, riveted steel bridge, structural health monitoring, examination.

1. Introduction

The main objective was to verify the structural and fatigue safety of the riveted structure in view of a long further utilisation period based on principles of the Swiss standards for existing structures. This paper outlines the methodology that explicitly considers monitored data and presents the main results of the examination of fatigue safety.

The railway bridge over the Rhine River at Eglisau in Switzerland was built from 1895 to 1897 for single lane railway traffic. The central part of the 457 m long bridge is a riveted steel truss structure made of early mild steel (Fig. 1).

Figure 1: Railway bridge across the River Rhine at Eglisau, Switzerland

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2. Monitoring

Strain gauges were mounted on structural elements relevant for the verification of the fatigue safety (Fig. 2a). These elements are essentially subjected to tensile stresses due to fatigue loading. An average of 159 trains per day was recorded during 12 months. Monitored raw data from every train passage were exploited by means of Rainflow analysis and presented as histograms as shown in Figure 2b.

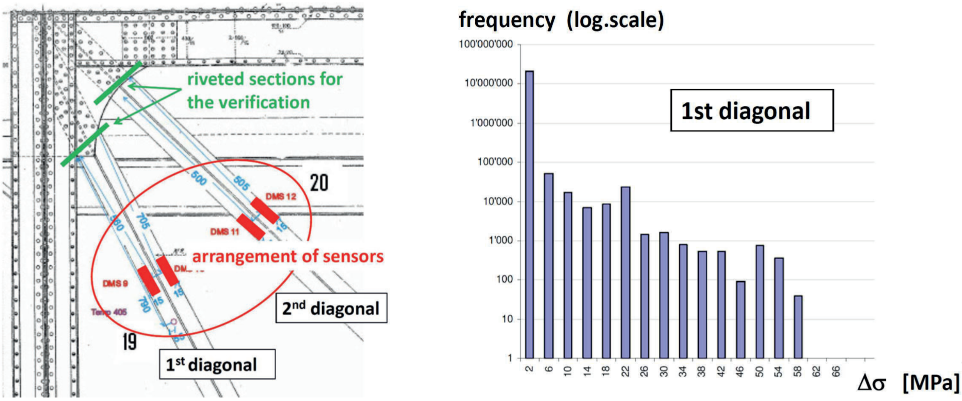

Figure 2: left: location of sensors and verification sections of diagonals of the main truss girder; right: histogram from 12 months of monitoring.

3. Fatigue safety verification

Fatigue safety is verified for determinant cross sections (details) with rivets. Since the location of the strain sensors were intentionally chosen to avoid measuring any stress concentration near rivets, monitored strain (stress) values need to be translated to the determinant rivet positions of the cross sections relevant for verification (Fig. 2 left). Consequently, conversion factors were determined for each verified cross section using the calibrated model for structural analysis and applied to the monitored values to obtain stress range values for the fatigue safety verification.

Verification followed a stepwise procedure: In a first step, the fatigue safety was checked with respect to the fatigue limit. Only when fatigue safety could not be verified on the first level, in a second step, fatigue damage accumulation calculation by applying the Palmgren-Miner approach was conducted. Fatigue loading due to past traffic was estimated due to information from statistical yearbooks of railway line traffic. A scenario of future traffic demand was considered to forecast fatigue damage in 50 years.

The fatigue safety verifications based on the monitored values show sufficient fatigue safety for the entire riveted structure for at least the next 50 years of service duration. Also, the structural elements having priority during inspections were identified.

4. Conclusions

- The suggested methodology to verify the fatigue safety allows for explicit consideration of data from long term monitoring.
- Monitored data allow for accurate determination of fatigue relevant stresses in fatigue prone bridge structures.
- The results show that applying this methodology, the fatigue safety of the riveted railway bridge was verified also after 115 years of service duration, and long future service duration may be expected taking into account the expected higher traffic loading.