Extending the fatigue service life of a railway bridge by local approaches

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Summary

In this paper, fatigue assessment of a steel railway bridge is presented. The bridge is located in central Stockholm, Sweden, and is one of the most vital links for the railway network. The bridge service both freight trains and commuter trains with more than 500 passages per day. The main load bearing structure is designed as a steel grillage of welded I-beams. Fatigue critical sections have been identified at locations where secondary bracing systems are welded to the flanges of the I-beams. Both numerical simulations and extensive field measurements have shown a significant exceedance of the theoretical fatigue service life. Based on the analysis of local stress concentrations, improvement of fatigue critical details has been suggested. The decrease in stress concentration is demonstrated both by numerical simulations and in-situ field measurements and shows a significant improvement when estimating the remaining fatigue service life.

Keywords: cumulative fatigue damage; railway bridge; hotspot stress; finite element method.

1. Case study bridge

The case study bridge is designed as a six-span continuous steel grillage, carrying two railway tracks, *Fig. 1*. Secondary bracing systems connect between the lower flange of the cross beams and the main beams as well as to the upper flanges of the stringers. All flanges – to bracing connections consists of transverse gusset plates, welded to the flange without any noticeable radius. These connections are found at more than 450 positions on the stringers, 100 positions on the main beams and 50 positions on the cross beams. The main concern is the fatigue service life of the stringers due to these connections. A total of 54 strain gauges were instrumented on fatigue critical positions on the stringers, the cross beams and the main beams. Two sections along the bridge are instrumented, denoted I and II in *Fig. 1*.

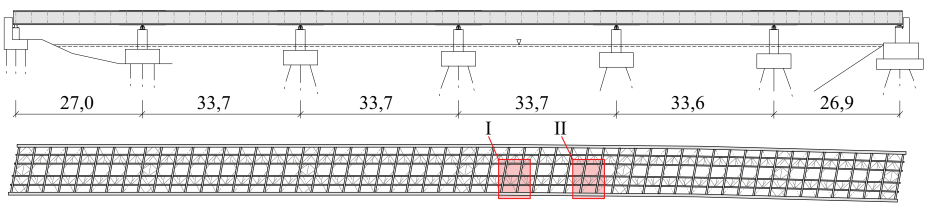

Fig. 1: Elevation and plan view of the Söderström railway bridge.

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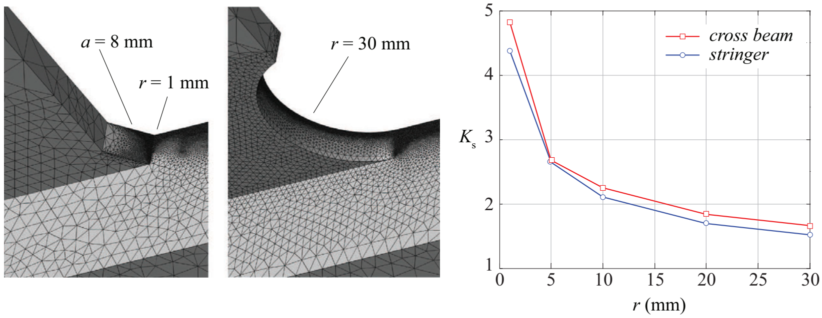
2. Fatigue assessment

A fatigue assessment is performed based on measured strain data. Long term continuous measurements have been performed, from which the response of passing trains are extracted. The stress collective is calculated based on Rainflow cycle counting. The fatigue service life is estimated based on Palmgren-Miners linear damage rule and available data on daily traffic intensity.

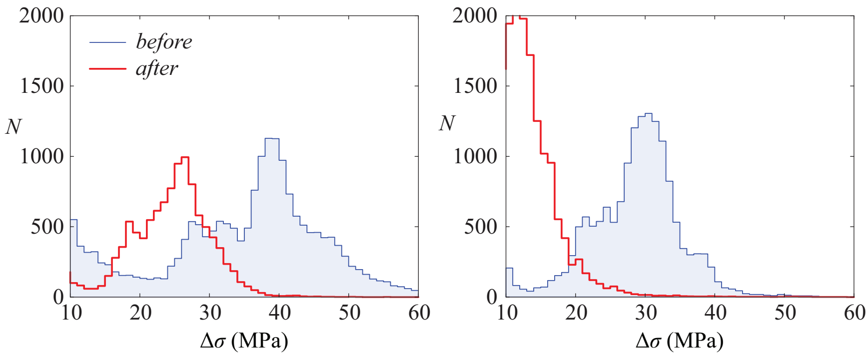
Geometrical improvement by a radius transition of the transverse gusset plate is proposed. The geometry of the gusset plate to cross beam flange is shown in *Fig. 2a*), the resulting notch stress concentration factor K_s as function of the radius r is presented in *Fig. 2b*).



a) b)

Fig. 2: Stress concentrations evaluated based on FE-analysis, a) detailed model of the transverse bracing on the cross beam lower flange, b) resulting stress concentration factors at the weld toe as function of the radius r.

A geometrical improvement by cutting a 20 mm radius was performed on two locations on the bridge. Additional field measurements were performed before and after the improvement. From the obtained stress collectives, *Fig. 3*, a large stress reduction was achieved, resulting in a significant improvement of the remaining fatigue service life.



a) b)

Fig. 3: Stress collective based on measured strain before and after geometrical improvement, a) stringer, b) cross beam.