Data-based asset management of a T-beam bridge with orthotropic deck exemplified by the motorway bridge at the Dortmund-Unna motorway intersection

Aim and motivation

For several years, the ailing state of bridges in Germany has been a subject of public debate and a growing socio-economic problem. The intermittent bridge inspection in accordance with the German standard DIN 1076 [1] may lead to delayed damage detection and consequently to increased repair costs. The financial burden is further increased by high labour costs and increased traffic obstructions. The prerequisites for a successful asset management could be optimised using continuous intelligent condition evaluation.

In a current research project, several bridges with similar structural properties, such as orthotropic deck plates, are clustered and compared with regard to their fatigue behaviour. In this thesis methods are being developed to determine key performance indicators that will provide bridge operators with information on current fatigue conditions, in particular on fatigue relevant details, and can be part of future asset management. For this purpose, data from 59 strain gauges and 9 temperature sensors, which are installed on the orthotropic deck plate of the A1/A44 Dortmund-Unna motorway interchange bridge are evaluated. In order to ensure the plausibility and resilience of the results, three cross girders (measuring cross section - MCS) are equipped.

Methodology and results

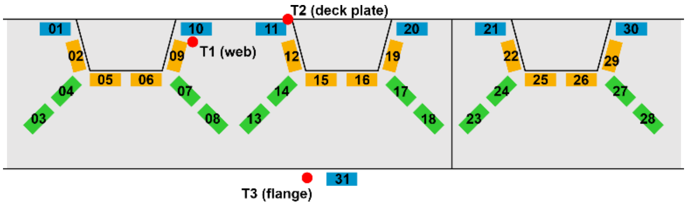

Figure 1: labelling and positioning of sensors on a cross girder

In order to analyse the load situation of the fatigue-relevant vehicles and to obtain further event-dependent information, a digital twin of the bridge is created by finite element modelling. This approach allows a holistic view of both, the impact and resistance of the structure. A simulation of a rolling wheel was carried out to determine the relevant load situation in the longitudinal direction at a wheel position of 80 cm in front of the cross beam. In addition, by correlating the measured data with the influence lines generated by the finite element analysis, it is possible to estimate the transverse position of the vehicle for each transition. A statistical analysis shows that most vehicles travel in the same axis which confirms the assumption of an increased risk of fatigue under the heavy goods vehicle lane.

The analysis of the weld joint stress provides the basis for the fatigue assessment of the orthotropic deck plate and is therefore fundamental for the evaluation in this work. As the sensors cannot be attached directly on the weld seam, the stresses are determined using the hot-spot stress concept [2] by extrapolation of the measured values of the strain gauges (green) (see Figure 1). As there is no suitable notch detail category in Table B.1 in DIN EN 1993-1-9 [3] for the fatigue resistance with regard to the hot spot stress concept, a structure-specific value for fatigue strength of 53 N/mm^2 is determined considering the time of occurrence of the first cracks.

Table 1: expected service lifetime for monitored welded joints

	MCS-1					
hot spot	3_4	8_7	13_14	18_17	23_24	28_27
total lifetime [a]	3549	419	348	51	290	
	MCS-2					
hot spot	34_33		36_37	40_39		43_42
total lifetime [a]	456897		85	23		462
	MCS-3					
hot spot	47_46		50_49	53_52		56_55
total lifetime [a]	33		100	13		492

Table 1 shows the theoretical lifetime expectancy as the reciprocal of the damage according to the Palmgren-Miner accumulation based on a data set of about one year. A comparison of the expected service life with the current age of the structure of approx. 50 years shows that a total of three weld joints have an expired calculated service life. Two welds have an unusually long life due to the fact that the welded joints at these details have already failed and therefore no stress redistribution is occurring. The redundancy of the measurement results can be confirmed, as the weld joints subjected to the highest loads are in the same position in direction of travel on the cross girders. These weld joints have a high probability of failure due to the direct impact of the truck wheels.

Conclusion and outlook

The service live expectations should be interpreted as theoretical values. They are significantly dependent on the fatigue notch class specified and are also influenced by visible and invisible cracks as well as the execution quality of the weld joint. For the development of key performance indicators, the damage of the details is compared and expressed as a probability of failure.

This work provides important information on the fatigue condition of the critical weld joints of the bridge, which allows an estimation of the service life and possible damage. Future developments could determine the damage gradients of weld joints in order to recognise anomalies that automatically indicate cracks.

References

[1] “DIN 1076:1999-11: Ingenieurbauwerke im Zuge von Straßen und Wegen - Überwachung und Prüfung,” Beuth Verlag GmbH, Berlin, 1999.

[2] A. F. Hobbacher, Recommendations for Fatigue Design of Welded Joints and Components, Paris: International Institute of Welding, 2008.

[3] “DIN EN 1993-1-9:2023-03-00, Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 1-9: Ermüdung; Deutsche und Englische Fassung prEN 1993-1-9:2023,” Beuth Verlag GmbH, Berlin, 2023.