Fatigue Assessment of Steel Bridge Superstructures, the Netherlands

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Summary

RWS has appointed the Managing Contractor (MC) in 2009 to manage the renovation of eight steel highway bridges in the Netherlands. Part of that project exists of fatigue assessment of the existing structures and strengthening works. The MC has used a fatigue analysis tool to assess the fatigue damage in the superstructures. The tool is used to automate the analysis process. Assessing the bridges with the detailed load model results in less fatigue damage compared to standard Eurocode fatigue load models and limits the magnitude of repairs on the bridges, but also results in large amounts of data to be processed. The automated fatigue analysis tool allows the structural engineer to conduct an extensive detailed fatigue analysis in a few hours time, and delivers ample results to give insight in the fatigue behaviour of the bridges.

Keywords: Steel bridges, fatigue, assessment, automation, refurbishment, strengthening, reservoir cycle counting, superstructure.

1. Introduction

In 2008 Rijkswaterstaat (Dutch Highway and Waterway Agency, RWS) began a program to renovate eight steel bridges in the Netherlands that carry major highways. These bridges were built in the late 1960's or early 1970's. All bridges have orthotropic decks, and seven of the eight bridges have longitudinal and transverse plate girders. The bridges suffer from fatigue damage, before the end of their design life. RWS has appointed the Managing Contractor (MC) in 2009 to manage the renovation of the bridges. The purpose of the renovation is to increase the lifetime of the bridges with 30 years. All bridges were designed to Dutch standards (NEN), but for their extended lifetime the MC assesses the bridges using Eurocodes and additional specifications developed by Rijkswaterstaat. A part of this assessment consists of fatigue analysis. This paper considers the global fatigue analysis process. For more details on the local fatigue analysis see [2].

2. Fatigue Load Model 5

2.1 Load Model based on Traffic Measurement Data

RWS has developed a fatigue load model to be used for fatigue assessments in the renovation project [3]. This fatigue load model is based on Fatigue Load Model 5 (FLM 5) of Eurocode 1, part 2 [1], appended with some additional specifications. The types and number of vehicles are based on measurements. The real traffic load of the bridge is modelled more accurately by using measurements and historic data. The calculated fatigue damage based on this load model is lower, which reduces the magnitude of repairs.

2.2 Parameter Sensitivity

The fatigue analysis is sensitive to the input stress. The value of the input stress (ranges) depends on the level of detail of the load model and the modelling of loads in the FE model. The fatigue damage calculation is logarithmic. A difference of 10% in the input values can result in 35% to 65 % higher or lower fatigue damage.

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2.2.1 Modelling of Vehicles

In the renovation project multiple axle modelling is used rather than a single point load to get a more realistic representation of the stresses in the structure and limit the magnitude of repairs of fatigue details. The height of peak stresses is lower for multi axle modelling and reduces the calculated fatigue damage.

2.2.2 Averaging of Factors and Vehicle Numbers

One could choose to average the trend factor to reduce the amount of analysis. However, averaging the load factor can result in higher or lower fatigue damage compared to an assessment with varying load factors. With averaged factors the value of the maximum stress range is underestimated, resulting in less predicted fatigue damage. In the global fatigue analysis for the steel bridges the factors and vehicle numbers are not averaged.

2.3 Large Data Sets

Per load case 123,480 influence lines are required for the assessment. This number illustrates that the complexity of the load model leads to a large amount of data that needs to be processed to perform a fatigue assessment of multiple types of details on various positions in a bridge.

3. Fatigue Assessment Tool

The fatigue tool consists of two parts: the Master Sheet and Detail Template Sheets. The Master Sheet is the main sheet that controls the analysis process. Detail Template Sheets are empty templates that are used by the Master Sheet to store the analysis results.

4. Conclusions

It can be concluded that a detailed approach for the global fatigue analysis of existing steel bridges limits the amount of required repairs of fatigue details in a steel bridge, and reduces the cost of renovation. By modelling the vehicles as sets of point loads rather than a single point load, and by not using average values for load factors and vehicle numbers, the calculated fatigue damage is more accurate. This can make the difference between repair and no repair.

The detailed approach requires large amounts of data to be processed. The fatigue tool is developed to automate the analysis and enables the structural engineer to perform extensive fatigue assessments in a relative short time.

5. Acknowledgements

The Managing Contractor is a joint venture that consists of Arup, Royal HaskoningDHV and Greisch. The fatigue tool is a development made by Arup and has developed further during the renovation projects.

6. References

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