An alternative approach of fatigue life predictions in orthotropic steel bridge decks

Wim NAGY

PhD Student, Researcher
Ghent University
Ghent, BELGIUM

Wim.Nagy@UGent.be

Wim Nagy, born 1986, received his civil engineering degree from Ghent University in 2010. He is currently working as a researcher with the civil engineering department of Ghent University and preparing his doctorate.

Hans DE BACKER

Professor
Ghent University
Ghent, BELGIUM

Hans.DeBacker@UGent.be

Hans De Backer, born 1978, received his civil engineering degree from Ghent University in 2002, and obtained his doctorate in 2006. He is currently working as professor with the civil engineering department of Ghent University.

Philippe VAN BOGAERT

Full Professor
Ghent University
Ghent, BELGIUM

Philippe.VanBogaert@UGent.be

Philippe Van Bogaert, born 1951, received his civil engineering degree from Ghent University in 1974, obtained his doctorate in 1988 and is currently working with the civil engineering department of Ghent University and with Tuck Rail Ltd.

Summary

Orthotropic plated decks are widely used in long span steel bridges since they are extremely light weighted and very efficient for resisting localized traffic loads. As this bridge deck consists of a complex network of longitudinal and transverse stiffeners, it is very sensitive to fatigue. Traditionally fatigue predictions result in a conservative design for the bridge deck since these techniques have reached their limits. Therefore, other techniques are necessary to improve the fatigue life. A possible solution can be the use of fracture mechanics. If these techniques are used for the case study of the Temse bridge in Belgium, approximately $38{,}5.10^6$ load cycles are needed for a crack length of 600 mm. This is more than the traditional calculations would predict because the FEM-model does not take residual stresses and other welding defects into account. This could be a possible improvement in future research.

Keywords: orthotropic bridge deck; fatigue; fracture mechanics; XFEM; Temse bridge.

1. Introduction

Orthotropic steel decks are an indispensable structural element in long span steel bridges. This type of bridge deck consists out of a complex network of longitudinal stiffeners, transverse stiffeners and is extremely lightweight, durable and efficient for carrying large traffic loads. Nevertheless, in the past, fatigue effects have sometimes been overlooked during design. Due to the important number of welding details, it is obvious that these bridges are very sensitive to fatigue damage.

Nowadays fatigue behaviour of steel bridges is mainly analysed by applying SN-curves as well as through the Palmgen-Miner hypothesis. However, there is a need for relevant test data for the used geometrical conditions and welding configurations. In addition, the background tests for the SN-curves do not exclusively use present construction technology, resulting in a conservative approach and thus leading to an overestimation of the necessary dimensions. Furthermore, classical fatigue calculations assume damage accumulation to be a strictly linear phenomenon, which implies that the load sequence has no effect. Questions have been raised in recent research about the validity of classical fatigue philosophy. A possible design improvement could be the use of fracture mechanics since this is a more in-depth analysis.

This fatigue design method is well known in the automobile, marine and aeronautics industries. Unfortunately it is not frequently used in civil engineering since it is a more complex and labour-intensive method. Fracture mechanics can deal with fatigue crack initiation, crack propagation and subsequent failure of the structure. Therefore, the method could be used for the lifetime prediction of orthotropic decks and the remaining strength of existing steel bridges.

In this research project, the focus is on the fatigue problems of the stiffener-to-deck plate connection mid-span between two crossbeams. This was also the location of a fatigue problem in the Temse bridge across the river Scheldt in Belgium. To verify the problem, a comparison is made between the classical fatigue analysis and the fracture mechanics method.

https://doi.org/10.2749/222137912805111438