Proceedings of the Belgian-Dutch IABSE

Young Engineers Colloquium 2019 - YEC2019

Bridge Herentals-Lier on the Albert Canal, Belgium

Eindhoven, The Netherlands
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Parametric analysis of rib distortion induced stress concentration at rib-to-crossbeam joint

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Abstract

The closed rib with trapezoidal section is broadly adopted all over the world. However, when applying higher and more slender ribs, the tire load which is eccentric from the axis of the rib causes rib distortions. At the rib-to-crossbeam joint, the rib distortion is impeded by the crossbeam which creates high stress concentrations at the web of the rib leading to fatigue damage. In this paper, the influence of 4 conventional design parameters on distortional behavior is investigated. A refined finite element model of an orthotropic steel deck specimen is built. Research results indicate that the distortional stress rises with the increment of the spacing of crossbeam or the weld length of rib-to-crossbeam joint. The thickness of rib is negatively correlated with the distortional stress. The influence of the spacing of rib on distortional stress depends on the relative size between the width of load area and the spacing of rib.

Keywords: Steel bridge; Orthotropic steel deck; Rib distortion; Numerical simulation

1 Introduction

The orthotropic steel deck is widely adopted in the world especially in long-span bridges. Nevertheless, due to the complex structure and the existence of numerous welds, fatigue damage caused by stress concentrations is the primary problem required to be concerned. With reference to previous research, there are four positions where fatigue cracks typically appear: rib-to-deck joint, splice joint of the longitudinal rib, deck plate at the position of crossbeam and rib-to-crossbeam joint. This paper focuses on the rib-to-crossbeam joint.

The tire load which is eccentric from the axis of rib causes rib distortions. Rib distortions are impeded by the crossbeam at the rib-to-crossbeam joint, which creates high stress concentrations at the web of the rib leading to fatigue damage. This paper presents the influence of several classical design parameters on the distortional behaviour. The finite element model of an orthotropic steel deck specimen was developed adopting the hot spot stress approach and the sub-model analysis. The influence of the considered parameters was calculated and analysed by getting influence lines of different parameters.

2 Parametric analyses

2.1 Finite element model

The parametric analyses are performed by ANSYS. Initially, a standard orthotropic steel deck is designed, which is composed of 6 ribs, 3 crossbeams and 2 main girders. The dimensions of the longitudinal ribs are 300 mm high, 300 mm wide at the top and 125 mm wide at the lower soffit. Based on the geometries of the base design, a global model was first built using shell element with relatively coarse mesh, as shown in Figure 1. Then, a sub-model was developed using solid element with the same parameters as the global model. The sub-model was composed of segmental deck, crossbeam, rib and relevant welds. The position of the sub-model is at the intersection of the third rib and the middle crossbeam (Figure 1). The numerical simulation is based on linear elastic properties of the material. Meanwhile, the linear extrapolation method is adopted for the structural hot spot stress. The boundary conditions of the global model are based on the real support conditions of the orthotropic steel deck specimen. As for the sub-model, it comes from the calculation result of the corresponding global model. Displacements and rotations of nodes along the cutting boundary between two models are places on the sub-model as external loads. The unit pressure of 1 MPa is adopted with the load area of
100×100 mm and a load of 10kN. The loading path is at the central line between rib 2 and rib 3 (Figure 1). The interval distance between two loading points is 200 mm.

![Figure 1. FEA model and load path](image)

### 2.2 Results and discussion

In total 4 conventional design parameters are considered, namely the thickness of rib, the transversal spacing of rib, the weld length of rib-to-crossbeam joint and the longitudinal spacing of crossbeam. Based on the standard design, only one parameter will change each time. Due to the limitation of pages, only the influence lines of different weld lengths of rib-to-crossbeam joint is presented (Figure 2). Rest results are presented in reference 1.

![Figure 2. Influence lines of weld length of rib-to-crossbeam joint](image)

On both the tension side and the compression side, the maximum distortional stress increases while the weld length of rib-to-crossbeam joint increases. The most unfavorable load position is not affected by this parameter which is about 1600 mm away from the middle crossbeam.

### 3 Static load experiment

The corresponding experiments of the parametric analysis were performed recently, as shown in Figure 3. The tested specimen has the same geometries with the standard design in part 1. The weld length of rib-to-crossbeam joint varies from 127 mm to 252 mm. Experiment results are in processing.

![Figure 3. Static load experiment](image)

### 4 Conclusions

Among these 4 parameters, the spacing of crossbeam and the weld length of rib-to-crossbeam joint have positive correlations with the distortional stress. The rib thickness has a negative correlation with the distortional stress. The influence of the rib spacing on distortional stress depends on the relative size between the width of load area and the rib spacing which requires further research. The most unfavourable load position of distortional stress is determined by the geometries of ribs, whereas rest three considered parameters of this paper do not show obvious influence. Possible alternatives to reduce the distortional behaviour and simplified calculation method of distortional stress will be the main objective for further research.

### References