Numerical Fatigue Simulation of Access Hole Detail in Orthotropic Steel Bridge Deck

Chunsheng Wang, Yubo Mao, Puyu Li, Chenhui Zhu

Department of bridge Engineering, College of Highways, Chang'an University, Xi'an, CHINA

Contact: wcs2000wcs@163.com

Abstract

In order to investigate the fatigue crack mechanism of growth and propagation at access hole detail in the orthotropic steel bridge deck, welding numerical model and multi-scale whole bridge numerical fatigue model were established. Based on linear elastic fracture mechanics and eXtend finite element model (XFEM), numerical fatigue simulation and mechanism analysis were carried out under the multi-filed coupling effect. Welding residual stress analysis results show that the high residual tensile stress exists at welding hole edge, of which the maximum value located at the middle of the edge. The numerical simulation results show that stress intensity factor (SIF) range at access hole detail exceeded the fatigue crack propagation threshold under the multi-filed coupling effect. And fatigue cracks at access hole detail are mode I cracks.

Keywords: orthotropic steel bridge deck; access hole detail; numerical simulation; XFEM; welding residual stress; fatigue crack.

1 Introduction

The orthotropic steel bridge deck is wildly applied in modern steel bridges, especially in the long-span bridges and urban bridges, because of its convenient construction, excellent mechanical properties, and light weight [1]. However, the fatigue problem of the orthotropic steel bridge deck is serious, and the fatigue cracks will generate after using merely several years, which constraint the safety operation and health service of steel bridges. Since the 1960s, many fatigue cracks have been observed at daily detection in the orthotropic steel bridge deck [2]. Therefore, the fatigue problem has been the worldwide technical challenge [3], and it is necessary to investigate the fatigue problem of the orthotropic steel bridge deck.

With the development of fracture mechanics theory and finite element method, the fatigue crack numerical simulation is made excellently progress. Xiao et al. [4] carried out fatigue stress analysis under vehicle load based on linear elastic fracture mechanic theory, and estimated the life of joint details between deck and longitudinal rib. Wang et al. [5] found that the crack was grown in the weld joint toe between rib and diagram which was under pressure stress in the orthotropic steel bridge deck full scale fatigue test, because there existed high welding residual tensile stress. Zhao [6] and Berg [7] et al. calculated and tested the residual stress values of U-rib stiffener, and verified that there existed high welding residual tensile stress near weld joint at rib-deck detail of orthotropic steel bridge deck. Wang et al. [8] carried out welding numerical simulation of rib to deck weld joint and rib to diagram weld joint, then analysed the fatigue crack propagation mechanism and carried out numerical simulation of the fatigue crack propagation behaviour at typical fatigue details based on linear elastic fracture mechanic and XFEM. Wang et al. [9] made

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