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Digital Simulation and Evaluation of Cold Reinforcement using UHPFRC for Distortion-induced Fatigue in Steel Bridges

Chunsheng Wang, Peng Wang, Yuzhu Wang

School of Highway, Chang'an University, Xi'an, China

Contact: wcs2000wcs@163.com

Abstract

With the increase of traffic volume and vehicle load, more and more steel bridges are prone to suffer the fatigue problems. Fatigue cracks seriously affect the safety and service life of steel bridges, probably leading to structural failure. In this paper, digital fatigue test was conducted to investigate cold reinforcement method of casting UHPFRC at horizontal gusset plate web gaps in steel bridges. Digital tests were built based on fracture mechanics theory and extended finite element method (XFEM), combining with the full-scale physical fatigue tests data. Parametric analysis was carried out on the dimensions of strengthening elements, so as to determine the optimum reinforcement plan. In addition, the effectiveness of cold strengthening technique was evaluated by comparing the stress intensity factors, and the out-of-plane distortion as well as the fatigue stress of web gap details before and after reinforcement.

Keywords: Steel girder bridges; Distortion-induced fatigue; Cold reinforcement method; UHPFRC; Digital simulation and evaluation; Fracture mechanics; Extended finite element method.

1 Introduction

The fatigue problems in existing steel bridges are accumulated continuously in service stage, which can be divided into two categories, including distortion-induced fatigue and load-induced fatigue. About 90% of initiation and propagation of fatigue cracks in steel bridges were caused by out-of-plane deformation [1], and out-of-plane deformation usually leaded to the fatigue damage at the horizontal gusset plate web gaps in steel bridges. In the steel plate girder bridges, when the lateral bracings intersects with the vertical stiffener in space, the stiffeners are usually not cut off. The method of cutting the part of the horizontal gusset plate near the position of the vertical stiffener were often taken to avoid fatigue problems caused by the intersection of multiple welds and facilitate processing as well as installation. Meanwhile, the web gap region is created between the stiffeners and the horizontal gusset plates, as shown in Figure 1.

When the horizontal gusset plates are subjected to loads transferred from lateral bracings, large out-of-plane distortion will appear at the web gaps. Large out-of-plane distortion-induced fatigue stress occurs at the stiffener-to-web weld

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