Punching behavior of a novel steel-UHPFRC composite bridge deck slab

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Abstract

A novel steel-UHPFRC composite deck system, consisting of upper thin reinforced UHPFRC slab, hot rolled sections as longitudinal ribs, and steel strips as transversal reinforcement, is proposed originally in this paper. Considered as more economic and sustainable structure, the new composite deck is a promising alternative to traditional orthotropic steel deck (OSD) in long-span bridge. In this context, due to the relatively thin UHPFRC layer, the punching behavior of new composite deck becomes one of the dominant issues, which determines the spacing of steel trips. Hence, this paper presents the results of punching tests on 12 new composite deck slabs with various spacing of steel strips. All slabs failed in punching-flexure mode with a clearly delimited punching cone and significant flexural cracks on tensile surface. Moreover, the presence of steel strips can increase the punching shear resistance and flatten the inclination of critical shear cracks.

Keywords: long-span bridge; composite bridge deck; UHPFRC; steel strip; punching shear; DIC; critical shear crack; punching cone.

1 Introduction

The conventional orthotropic steel deck (OSD), widely applied in long-span bridges, has suffered awfully from vulnerability to fatigue cracking under cyclic traffic loads. This issue is mainly caused by large stress amplitude and stress concentration, resulting from: (1) insufficient stiffness at local steel deck; (2) initial welding defect and residual stress; (3) inappropriate details.

Nowadays, benefiting from the advantageous mechanical properties and fatigue resistance of Ultra High Performance cementitious Fiber Reinforced Composites (UHPFRC) [1–3], the combination of UHPFRC and steel as lightweight composite structures offer promising alternatives to traditional OSD in long-span bridges. Additionally, UHPFRC is a dense material of optimized compactness, thus providing robust protections as added values against water and chloride iron ingress.

The concept of adding a thin UHPFRC cover (with thickness ≤ 60mm generally), as external stiffener and protection layer to either improve existing OSD or combine with optimized OSD as new deck element (Figure 1), has been developed and implemented extensively over last 10 years [4–6]. Recent researches and applications have demonstrated large improvement of local stiffness of steel-UHPFRC composite deck, leading to considerable reduce (≥50%) of vehicle-induced stress ranges at most of fatigue details, and consequently extension of fatigue life (≥60%), compared with traditional OSD [7–9]. However, for some fatigue details, such as the cross beam

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