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Analytical Solutions for Flexural Stress of One-way UHPC-NC Hybrid Slab

Zhao LIU
Professor
Southeast University
Nanjing, China
mr.liuzhao@seu.edu.cn

Wei D. ZHUO
PhD Candidate
Southeast University
Nanjing, China
mr.zhuoweiding@seu.edu.cn

Si Q. YUAN
PhD Candidate
Southeast University
Nanjing, China
230179444@seu.edu.cn

Contact: mr.liuzhao@seu.edu.cn

1 Abstract

Ultra-high performance concrete (UHPC) is an advanced construction material that affords opportunities to innovate the structures made of conventional concrete (NC). The one-way UHPC-NC hybrid slab, designed to have the UHPC layer in tension and the NC layer in compression, can be an optimal use of UHPC for bridge deck. The analytical solutions for normal stress are essential under service limit state, but they cannot be found in the literature by now. Based on the elastic theory, analytical formulas for the neutral axis position and flexural stress are derived. The lowest neutral axis position is attained when the UHPC layer thickness ratio (UHPC layer thickness / hybrid slab thickness) approximates 0.4. The criteria to judge the position of neutral axis within UHPC or NC region are analytically established. To find out the ideal scenario to reach the allowable compressive stress in NC and allowable tensile stress in UHPC simultaneously, an inequality constraint with the elastic modulus ratio is proposed. Considering the UHPC tensile stress limitation and flexural moment capacity of the hybrid slab, the rational thickness ratio of UHPC layer of 0.4 is suggested, which can achieve better economy and efficiency of the hybrid slab.

Keywords: bridge deck; ultra-high performance concrete; UHPC-NC hybrid slab; flexural stress; slab design

2 Introduction

Since the 1990s, an increasing number of investigators have endeavored to alter and optimize the constituents of normal concrete (NC) in order to increase its strength, ductility and durability. As a result, some new products have been developed, such as engineered cementitious composite (ECC), reactive powder concrete (RPC), and ultra-high performance fiber-reinforced concrete (UHPFRC). In recent years, the ultra-high performance concrete (UHPC) has become more widely accepted as a general term to indicate these new variations [1].

Although UHPC is generally acknowledged as one of the most potential materials in the near future, it is still unrealistic to build the whole bridge structure with UHPC, allowing for its preparation conditions being strict and costly [2]. To this end, a new kind of hybrid slab or beam, consisting of precast UHPC bottom layer and cast-in-place normal concrete on the top, can be initiated for bridge decks (Figure 1). This alternative design for concrete slab has some remarkable advantages. Since UHPC can provide greater tensile capacity by mixing with high-priced steel fibers, such hybrid slab can make full use of tensile strength of UHPC and reduce construction cost compared with full depth UHPC slab. Besides, the precast UHPC bottom layer is to be easily shipped and installed because of its reduced size and weight, and it can also serve as gratis formwork when casting the rest part of concrete slab.

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