Outline of Development of Lightweight and High Durability Highway Bridge Deck using UHPFRC

鋼床版と同等の軽量かつ耐久性の高い UFC 道路橋床版の開発の概要




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Keywords: UHPFRC, bridge deck, wheel running fatigue test, durability
DOI: 10.11474/JPCI.NR.2018.153

1. Introduction

When constructing an urban expressway, the locations of piers, the sizes of foundation elements, and the allotted construction time may be constrained in many cases, and therefore lightweight orthotropic steel deck slab has been widely used. However, fatigue cracks on the orthotropic steel deck slab of existing bridges has raised concerns about durability.
To address this problem, the authors have developed a lightweight highway-bridge deck with high durability using ultra-high-performance fiber-reinforced concrete (UHPFRC)[1]. Very thin components were proposed to construct the UHPFRC deck, which has the same weight as an orthotropic steel deck. Three-dimensional finite element analysis was conducted to examine the deck behavior. Moreover, the fatigue durability of the deck was verified by a wheel running fatigue test.

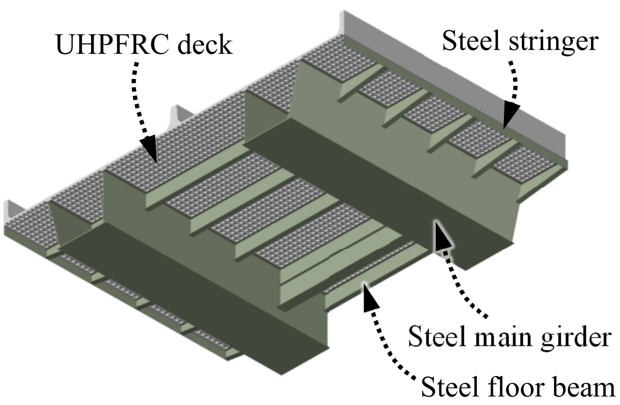

Fig.1 Composite girder bridge

2. Scope of the Study

(1) Outline of a UHPFRC Deck

In this study, ettringite-generating-type UHPFRC[2] was used with compressive strength of 180MPa. Schematics of the UHPFRC deck are shown in **Fig.1**. The UHPFRC deck was assumed to be a deck structure supported by four sides, a steel main girder, a steel stringer, and a steel floor beam. The UHPFRC deck is joined to a steel main girder by studs. Therefore, the behavior of the deck was designed as a composite girder.
The UHPFRC deck was designed with a waffle configuration having ribs in two orientations, as shown in **Figs.2** and **3**. The UHPFRC deck consists of a slab on which wheel loads act and ribs in which prestressing strands are arranged. Based on the minimum requirements of concrete cover and clearance of prestressing strands, the slab thickness was set at 40mm, the rib height at 83mm and the rib width at 70mm.

(2) Analytical Study of Serviceability

Three-dimensional finite element analysis of the UHPFRC deck was performed to examine the deck behavior by calculating stresses and displacement behaviors. The maximum tensile stress on the top of the deck was 6.6MPa, which is 83% of the limit value of 8.0MPa (**Fig.4**). The maximum compressive stress on the bottom side of the rib was 80.2MPa, giving a ratio

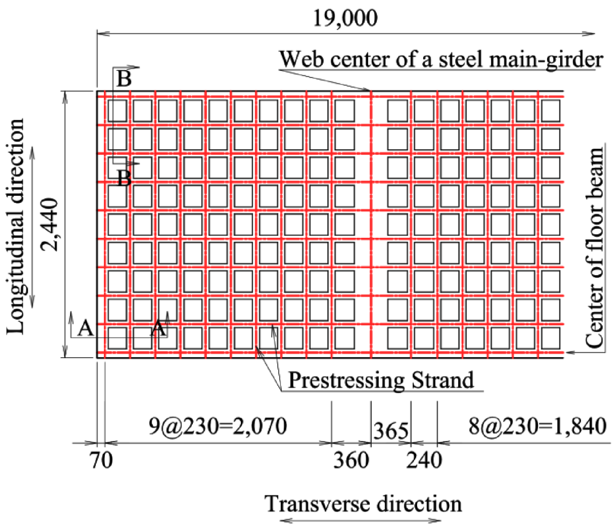

Fig.2 Top view of a deck (units: mm)

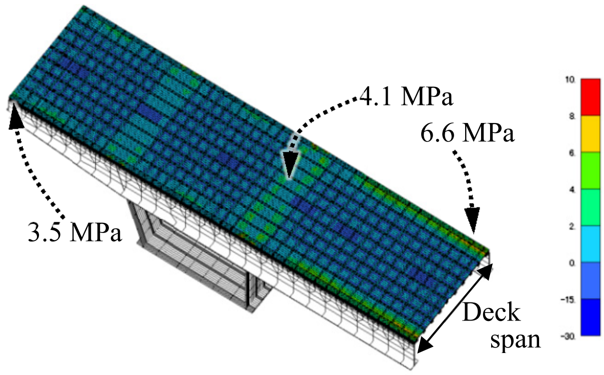

Fig.4 Maximum principal stress of the deck

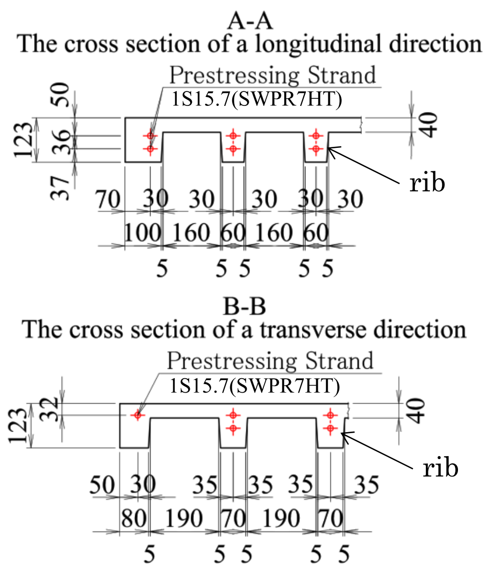

Fig.3 Sectional drawing of a deck (units: mm)

Fig.5 Wheel loading machine

of 74% against the limit value (108MPa).

The results showed that the maximum tensile and compressive stresses of the slab were at about 80% of the limit values.

(3) Wheel Running Fatigue Test

Since the structure of a UHPFRC deck consists of ribs in two orientations, local stress may arise near the intersection where the ribs cross. By conducting loading test using an actual wheel loading machine, the variations in local stress were verified to confirm the safety of this thin deck. The wheel load was applied 200,000 times (100,000 cycles), and the magnitude was varied from 100kN to 220kN. An overview of the test is shown in **Fig.5**.

3. Conclusions

(1) A UHPFRC deck was proposed, using a slab with thickness of 40mm and ribs with height of 83mm, width of 70mm, and rib spacing of 250mm. Finite element analysis of this deck showed the static stresses to be about 80% of the limit values.

(2) A wheel running fatigue test was conducted to evaluate the fatigue durability of the deck, in which the wheel load was applied 200,000 times (100,000 cycles). The result showed no damage under the design load.

(3) When a load roughly twice the design load was applied, minor cracks were detected on the side faces of the ribs. However, there was no reduction of stiffness. It was thus confirmed that the fatigue durability of the UHPFRC deck is sufficiently high.

References

[1] Kosaka, T., Kanaji, H., Ichinomiya, T., Saito, K.: *Development of a Highway Bridge Deck Using Ultra-High Performance Fiber-Reinforced Concrete*, IABSE Conference, NARA, pp. 326-327, May 2015.

[2] Matsubara, N., Ohno, T., Sakai, G., Yanai, S., Ashida, M.: *Properties of New Ultra High Performance Fiber Reinforced Concrete*, Engineering Conferences International, pp. 78-82, Jul. 2006.