Journal of Constructional Steel Research 65 (2009) 1751–1762

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

journal homepage: www.elsevier.com/locate/jcsr

Steel–concrete composite bridge deck slab with profiled sheeting

Hyeong-Yeol Kim *, Youn-Ju Jeong

Structural Engineering Department, Korea Institute of Construction Technology, Gyeonggi-Do 411-712, Republic of Korea

A R T I C L E I N F O

Article history:
Received 22 September 2008
Accepted 20 April 2009

Keywords:
Steel–concrete composite
Bridge deck
Perfobond rib shear connector
Profiled sheeting
Experiment

A B S T R A C T

This paper presents an experimental study of a steel–concrete composite bridge deck slab with profiled sheeting and perfobond shear connectors. Two full-scale deck slab specimens cast onto three concrete blocks were fabricated and tested under static loading to examine the ultimate load-carrying capacity of the proposed deck slab system under sagging and hogging bending actions. The ultimate behaviour of the full-scale deck slab specimens is also compared with that of simply supported deck specimens under hogging bending only. In addition, the load–deflection behaviour of the proposed deck system is compared with that of a reinforced concrete (RC) deck slab. The test results indicate that the ultimate load-carrying capacity of the proposed deck system is at least 220% greater than that of the RC deck system and that the deck weighs about 23% less than the RC deck system. The paper summarizes the test results, findings, and recommendations for future study.

1. Introduction

Various types of deck slab systems have been developed and used for girder bridges, though a full-depth cast-in-place (CIP) reinforced concrete (RC) deck remains the most common system due to its economical advantages. Stay-in-place steel forms are often used for CIP RC decks because a full-depth CIP RC deck takes a relatively long time to erect. The use of steel forms saves a significant amount of time during the construction of an RC deck slab for girder bridges.

Steel forms are generally profiled and made of light-gauge steel sheets with indentations or embossments. If the composite action between the form and the concrete can be obtained, the forms can partially act as a tensile reinforcement and the cross-sectional area of the deck can be somewhat reduced. However, the composite action is generally neglected in the design of RC bridge deck slabs because the indentations or embossments in the forms fail to provide the desired level of horizontal shear resistance between the form and the concrete under a live load.

Jeong et al. [1] proposed a steel–concrete composite deck system with profiled steel sheeting for girder bridges. In such a system, the interaction between the sheeting and the concrete generally governs the strength and behaviour of the deck. Headed studs were used as shear connectors in the study of Jeong et al., and the studs were welded onto the profiled sheeting. However, the results of push-out and flexural tests indicate that a horizontal slip occurs between the sheeting and concrete under a service live load.

Although headed studs are the most common type of shear connector, they may be unsuitable for profiled sheeting because of need to weld the studs to a thin steel plate. If the studs have a large diameter, they may cause a welding problem during fabrication. On the other hand, if the studs have a small diameter, a greater number of studs must be used. Furthermore, the studs welded onto thin steel plate may cause a fatigue problem during the service life.

The perfobond rib shear connector may be an alternative shear connector that can be used with profiled sheeting. This type of shear connector consists of a steel plate with a number of uniformly spaced holes. If the holes are filled with concrete, concrete dowels are formed; and the dowels provide horizontal shear resistance between the sheeting and the hardened concrete. The perfobond rib shear connector has several potential advantages: they are easy to customize and fabricate; they help overcome the fatigue problem; and a single perfobond rib can replace a number of headed studs.

In 2006 Kim and Jeong [2] used perfobond rib shear connectors for a composite deck slab with profiled sheeting and experimentally investigated the behaviour of the deck slab. The type of composite deck slab that they proposed for girder bridges had a longer span but weighed less than a typical CIP RC deck slab.

More recently, 16 deck specimens were tested with different shear span lengths for the purpose of evaluating the horizontal shear capacity of the proposed deck system. The horizontal shear capacity of the proposed deck system was evaluated by means of the empirical design method described in [3], and the test results are briefly summarized in [4]. The estimated horizontal shear capacity of the proposed deck was identified as being at least two

* Corresponding author. Tel.: +82 31 910 0582; fax: +82 31 910 0578.
E-mail addresses: hykim1@kict.re.kr (H.-Y. Kim), yjjeong@kict.re.kr (Y.-J. Jeong).

0143-974X/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jcsr.2009.04.016

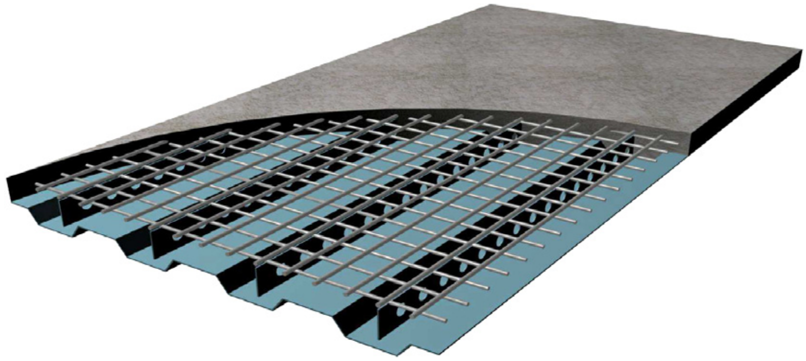

Fig. 1. Schematics for the proposed deck profile.

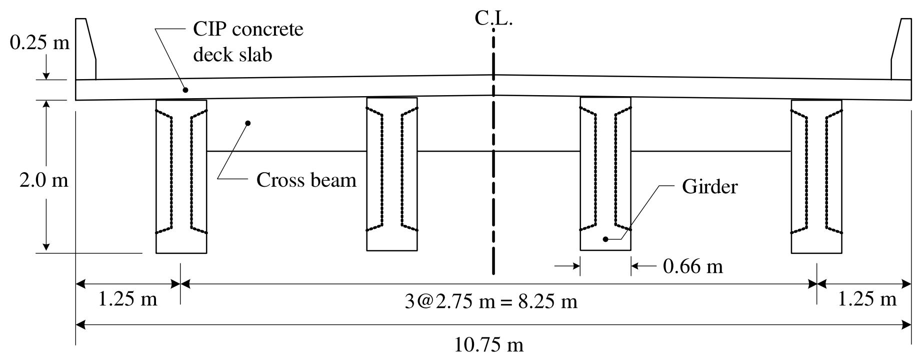

Fig. 2. Cross-section of a typical precast PSC I-girder bridge.

times greater than the required horizontal shear strength. The test results [2,4] indicate that the perfobond rib shear connection can be effectively used for the proposed deck system.

This study elaborates the work of [2] with a series of test programs. This paper presents the ultimate behaviour of a steel–concrete composite deck slab designed for a prototype of a precast prestressed concrete (PSC) I-girder bridge. The design is based on the deck profile proposed in [2].

The clear slab span length of the proposed deck slab was assumed to be 2.5 m, whereas that of a typical CIP RC deck slab for a PSC I-girder bridge is normally less than 2.2 m. Two full-scale deck slab specimens cast onto three concrete blocks were fabricated and tested under static loading to examine the ultimate load-carrying capacity of the proposed deck slab specimens under sagging and hogging bending actions. The test results are compared with the results of a finite element (FE) analysis of a full-length bridge. The ultimate behaviour of the full-scale deck slab specimens is also compared with that of the simply supported deck specimens tested in [4]. In addition, the load–deflection behaviour of the proposed deck system is compared with the behaviour of the RC deck slab specimens tested in this study. The test results and findings are summarized in this paper.

The use of the proposed deck system in bridge construction may be costly unless consideration is given to the savings in construction time and maintenance costs. The proposed deck system is roughly estimated to cost at least 1.6 times more than CIP RC decks but it may be competitive with CIP RC decks under certain circumstances. The user cost might be reduced, for example, when the proposed deck system is used in a deck replacement project for a high-traffic bridge. If the user cost is considered, the use of the proposed deck system in construction may be a less expensive choice because the expected erection time of the proposed system is about half that of RC deck system.

As discussed in [2], the proposed deck system has several advantages over conventional CIP RC decks but also a few disadvantages. During service, the condition of the deck, especially the concrete, cannot be inspected visually. In addition, the profiled sheeting must be protected from steel corrosion. For practical applications, there is also a need for a simple but effective sheet-to-sheet connection method to be developed because the size of the profiled sheeting is limited due to fabrication and transportation requirements.

2. Proposed deck system

2.1. Deck profile

Fig. 1 shows a schematic of the steel–concrete composite bridge deck system proposed in [2]. The deck consists of concrete, steel reinforcements, perfobond rib shear connectors, and profiled steel sheeting set perpendicular to the girders. Because the profiled sheeting serves as a tensile reinforcement in the design of the deck slab, no reinforcing bars are required at the bottom.

Fig. 2 shows a cross section of a prototype of a precast PSC I-girder bridge selected for the design of the proposed composite deck slab system. The clear slab span length (L) was assumed to be 2.5 m, which is approximately 1.2 times longer than a typical CIP RC deck slab for a precast PSC I-girder bridge.

The standard design truck load specified in the Korean Bridge Design Code [5] is used as the design live load. According to the code, the gross weight of the design truck is 43 200 kg. The self-weight of the deck slab together with the 50 mm-thick asphalt wearing surface is used for the dead load. The ultimate strength method was used for the deck design. Note also that the overall design process is driven by the strength limits because the horizontal shear capacity of the deck is obtained from test information.

Fig. 3 shows cross-sectional dimensions of the proposed composite deck profile. The dimensions of the profiled steel sheeting were determined on the basis of structural optimization. The design procedure for the deck profile is briefly summarized