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A STUDY ON THE DURABILITY OF UHPC RIB-TYPE DECK THROUGH WHEEL LOAD TEST

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ABSTRACT

A rib-type deck made of UHPC was developed and improved at the Korea Institute of Construction Technology to take full advantage of the outstanding properties of UHPC while reducing at the most the weight of the deck. A previous study already demonstrated that the UHPC rib-type deck satisfied the static performance requirements. In this paper, the durability of the UHPC rib-type deck is investigated through wheel load test. The fatigue test results show that the specimen satisfies the design criteria for deflection and crack even after 1 million loading cycles. Therefore, it is verified the UHPC rib-type deck of this study secures sufficient durability.

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A rib-type deck made of UHPC was developed and improved at the Korea Institute of Construction Technology to take full advantage of the outstanding properties of UHPC while reducing at the most the weight of the deck. A previous study already demonstrated that the UHPC rib-type deck satisfied the static performance requirements. In this paper, the durability of the UHPC rib-type deck is investigated through wheel load test. The fatigue test results show that the specimen satisfies the design criteria for deflection and crack even after 1 million loading cycles. Therefore, it is verified the UHPC rib-type deck of this study secures sufficient durability.

Introduction

Ultra High Performance Concrete (UHPC) is an outstanding material featured by a compressive strength higher than 150 MPa and high toughness. However, despite of its remarkable properties, UHPC is more expensive than normal concrete, which stresses the necessity to reduce as possible the amount of UHPC in order to increase its economic efficiency. Since the economy of the cable stayed bridge depends sensitively on the weight of its superstructure, reducing the weight of the deck becomes an important factor contributing to the economic efficiency of the whole bridge (Cho et al., 2009). Moreover, unlike medium to short span bridges, the deck of long span bridges like the cable stayed bridge is supported by cross beams. Need is thus for long span decks because a too small spacing between the cross beams, which corresponds to the length of the deck, results in the loss of constructability and economic efficiency.

Therefore, a deck structure composed of a thin slab and strengthening ribs made of UHPC, hereafter referred to as the UHPC rib-type deck, was derived by means of structural optimization in order to meet these requirements for lightweight and lengthening of the deck (KICT, 2009). And, its fundamental behavioral characteristics and performances were evaluated through beam tests (KICT, 2010). Figure 1(a) illustrates the derived cross-sectional shape of the rib-type deck. In the fatigue tests executed on this cross-section, cracking initiated at the interface between the ribs and the upper slab and showed continuous propagation. Accordingly, the cross-section shown in Figure 1(b) was improved to overcome

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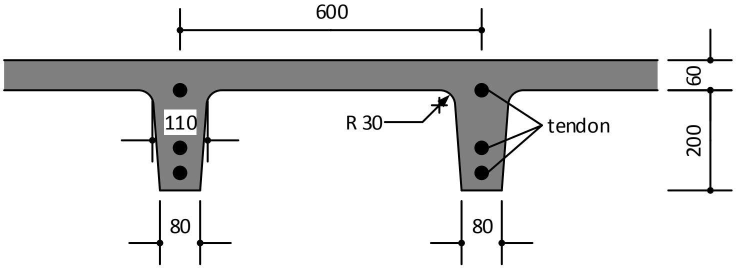
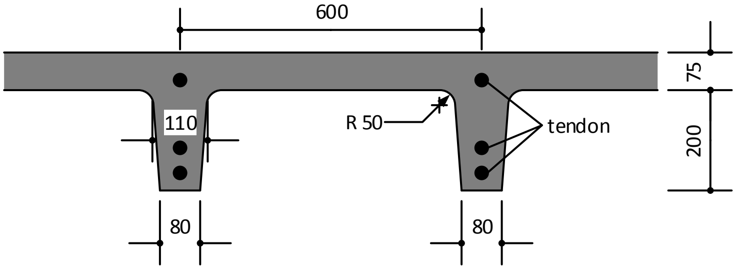
such problem by increasing the thickness of the upper slab from 60 mm to 75 mm and, by lengthening the radius of curvature at the interface between the ribs and the upper slab from 30 mm to 50 mm.



(a) Original cross-section



(b) Improved cross-section

Figure 1. Improvement of the cross-section of UHPC rib-type deck.

It is assumed that the improved cross-section depicted in Figure 1(b) satisfies the static performance requirements as much as the original cross-section shown in Figure 1(a). The present study focuses on the verification of the fatigue durability of the UHPC rib-type deck by means of wheel load test. The wheel load test is a fatigue test which rolls directly a wheel on the upper surface of the deck. This test is particularly appropriate for the evaluation of the fatigue durability since it reproduces more realistically the actual circumstances than the fixed point fatigue test which applies repeatedly the load on the same position.

Materials and Test Method

Details of Specimen

Full scale specimen of the UHPC rib-type deck was fabricated with span length of 4.0 m and width of 1.8 m as shown in Figure 2.

As shown in Figure 3, the specimen was constructed through a process similar to that of a real deck. The fabrication of the precast part was executed sequentially with the following process: (a) assemblage of form and arrangement of reinforcement; (b) tensioning of tendon; (c) placing of UHPC to complete the precast part; and (d) installation of the so-constructed precast part on H-beams followed by the welding of the studs and placing of the construction joints. The compressive strength of UHPC used for the precast part and cast-in-place construction joints is 180 MPa. Among the 9 tendons, a smart tendon was disposed at the top of the central rib so as to monitor the change in the prestress force. The prestress force introduced in each tendon was originally 180 kN, and reduced 160 kN after the loss generated by the removal of the hydraulic jacks. After completion of the curing of UHPC, the prestress force reduced additionally to 145 kN following the introduction of the compressive force of UHPC at separation from the prestressing platform.

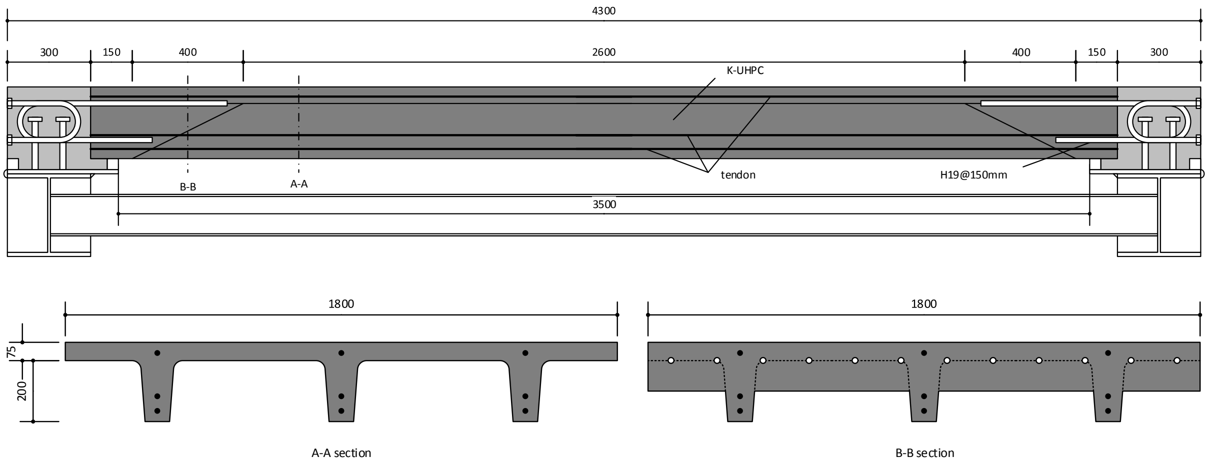


Figure 2. Shape and dimensions of specimen.

(a) Assembly of form and arrangement of reinforcement

(b) Tensioning of tendon

(c) Placing of UHPC of precast part

(d) Placing of UHPC in joints

Figure 3. Fabrication process of UHPC rib-type deck specimen.

The authors' institutional affiliations and addresses are to be given in single-line form at the bottom of the first page. Example illustrates format.

Test and Measurement

As shown in Figure 4, the specimen was installed by fixing completely the H-beams used as cross beams to the support blocks. The fatigue load was set to 124.8 kN to represent the rear wheel load of a truck considering the impact (Korean Bridge Design Code). The traveling distance of the wheel is 3.0 m. After a definite number of loading cycles, static loading test was conducted to evaluate the damage state of the specimen. The deflection was measured at the center of the central rib and, the crack width at the interface between the precast part and the cast-in-place joint was also measured.

Figure 2. View of wheel load test.

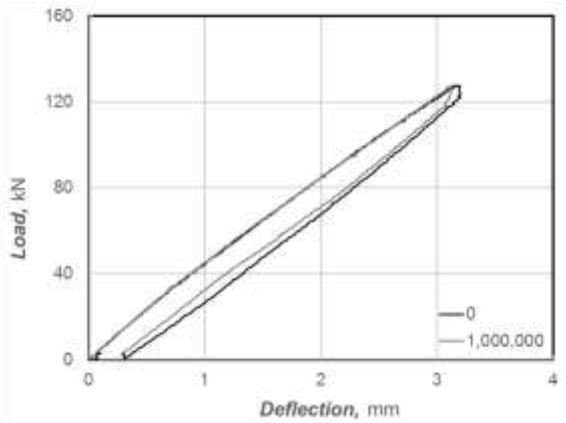
Test Results and Discussion

Fatigue Crack Pattern

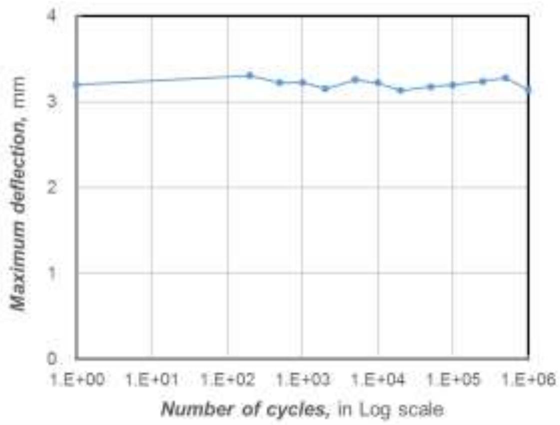
Cracking did not occur in the specimen even after 1 million fatigue loading cycles. This is different to the initiation and propagation of the cracks that occurred at the interface between the ribs and the upper slab during the fatigue loading of the previous specimen with slab thickness of 60 mm. Accordingly, the increase of the thickness of the upper slab from 60 mm to 75 mm can be seen to have sufficient strengthening effect in term of cracking.

Deflection Change Pattern

Figure 5 shows the deflection change pattern at the center of the deck according to the increase of the loading cycles. Figure 5(a) plots the load-deflection curves obtained from static loading tests performed at the beginning of the fatigue test and after 1 million loading cycles. Apart from the slight increase of the strain in the curve after 1 million cycles compared to the pre-loading stage, both curves are practically identical. Figure 5(b) plots the pattern in the change of the maximum deflection at the center of the deck according to the number of loading cycles. The deflection at initial stage reached 3.20 mm and reached to 3.14 mm after 1 million loading cycles. Such extent of the increase in the deflection can be sufficiently ignored and since the deflection change pattern does not exhibit clear trend of increase, it can be affirmed that the specimen remains sound against fatigue. Moreover, the width of the cracks occurring due to the negative moments developed at the interface between the precast part and the cast-in-place joint is also seen to remain extremely small with a maximum of 0.018 mm in view of the number of fatigue cycles.



(a) Comparison of load-deflection curves at initial stage and after 1 million cycles



(b) Pattern of change in deflection according to the number of loading cycles

Figure 5. Comparison of behavioral patterns according to fatigue loading.

The maximum deflection occurring after 1 million fatigue loading cycles ranged between 3.13 mm and 3.31 mm, which satisfies more than sufficiently the allowable deflection of 5.0 mm prescribed for the deflection of a girder (=L/800, where L = span length). Accordingly, in view of the results, it can be stated that the rib-type deck examined in this study secures sufficient durability to fatigue.

Conclusions

The durability of the precast rib-type deck made of UHPC was evaluated by means of wheel load test. A previous study revealed that the deck with rib depth of 200 mm and thickness of the upper plate of 60 mm experienced cracking that initiated and propagated from the interface between the ribs and the upper slab. Therefore, to overcome such problem, fatigue test was conducted on the deck in which the thickness of the upper plate was increased to 75 mm. Fatigue loading test was performed using a load of 124.8 kN up to 1 million cycles. The results showed that no particular crack occurred and that the maximum deflection did not increase during the test. Moreover, the deflection change pattern did not exhibit clear increase trend and the allowable deflection criterion was more than sufficiently satisfied. Consequently, it can be stated that the rib-type deck examined in this study secures sufficient durability to fatigue.

Acknowledgments

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