Title	TRIAL CONSTRUCTION OF A ROAD BRIDGE USING ULTRA-HIGH PERFORMANCE CONCRETE RIBBED DECK
Author(s)	PARK, S. Y.; KIM, S. T.; CHO, J. R.; CHO, K.; KIM, B. S.
Citation	Proceedings of the Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13), September 11-13, 2013, Sapporo, Japan, G-3-5., G-3-5
Issue Date	2013-09-13
Doc URL	http://hdl.handle.net/2115/54422
Type	proceedings
Note	The Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13), September 11-13, 2013, Sapporo, Japan.
File Information	easec13-G-3-5.pdf

TRIAL CONSTRUCTION OF A ROAD BRIDGE USING ULTRA-HIGH PERFORMANCE CONCRETE RIBBED DECK

S.Y. PARK[1*], S.T. KIM[1], J.R. CHO[1], K. CHO[1] and B.S. KIM[1]

[1]*Structural Engineering Research Division, Korea Institute of Construction Technology, Korea*

ABSTRACT

Compared to conventional concrete, Ultra-High Performance Concrete (UHPC) develops higher strength and ductility as well as very high compressive strength. The Korea Institute of Construction Technology has succeeded in developing a 200 MPa-class UHPC and developed a corresponding lightweight and durable ribbed deck slab for cable-stayed bridges. This deck is characterized by a self-weight about half of that of a conventional concrete deck. This paper introduces briefly the development process of the deck system and the trial construction of a road bridge applying it to a steel U-girder. The simplicity of the construction process demonstrates the possibility to realize effective shortening of the construction period. In addition, the field loading test performed after the completion of the road bridge indicated satisfactory results proving its applicability for bridge structures.

Keywords: UHPC, ribbed deck, trial construction, cable-stayed bridge.

1. INTRODUCTION

Ultra-High Performance Concrete (UHPC) is today recognized as the construction material of the next generation featured by an ultra-high compressive strength of 150 MPa and high toughness and is the subject of numerous R&Ds (Schmidt et al. 2004; Fehling et al. 2008; Schmidt et al. 2012). In 2002, the Korea Institute of Construction Technology (KICT) started the development of a UHPC with target strength of 200 MPa, which resulted successfully in the realization of the K-UHPC exhibiting a design compressive strength of 180 MPa and design tensile strength of 9.5 MPa together with outstanding ductility and failure energy absorption capacity (KICT 2012a). In parallel, KICT also conducted research to improve significantly the economic efficiency and durability of K-UHPC by applying it to cable-stayed bridge structures, which provided results beyond our expectations. This paper summarizes the results of a research for the development of a cable-stayed bridge deck exploiting UHPC performed as part of this project and focuses on the trial construction process executed to verify the applicability of the developed deck on field.

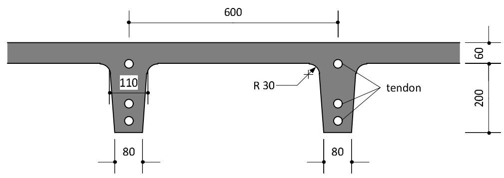
[*] Corresponding author and Presenter: Email: sypark@kict.re.kr

2. UHPC RIBBED DECK FOR CABLE-STAYED BRIDGES

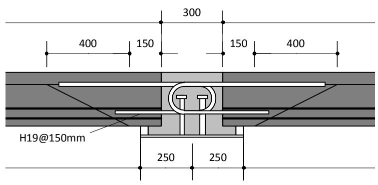
KICT conducted research to develop a cable-stayed bridge deck using the K-UHPC (KICT 2012b). In order to exploit the outstanding mechanical properties of K-UHPC arranged in Table 1, a slab structure with the thinnest possible thickness and strengthened by ribs was selected and its sectional efficiency was maximized by introducing prestress. The section was then optimized by considering a mean span length of 4 m, which resulted in a plate thickness of 60 mm strengthened with ribs disposed at spacing of 600 mm (Figure 1a). Series of 3 strands of 15.2 mm per rib were applied for the longitudinal strengthening and the conventional loop joints were used for the connection of the precast deck segments (Figure 1b). The weight of the resulting deck reached merely 1/3 of that of a conventional concrete deck and achieved a reduction by about 50% of the weight of the deck even when including the joints. Note that the content in steel fiber of K-UHPC used for the deck was 1.5% in volume ratio.

Table 1: Mechanical properties of K-UHPC

Design compressive strength	180 MPa
Design tensile strength	9.5 MPa
Elastic modulus	45 GPa
Poisson's ratio	0.2
Total shrinkage	600×10^{-6}
Creep coefficient	0.45



(a) Cross-sectional details



(b) Details of joint

Figure 1: **Designed UHPC ribbed deck.**

3. DESIGN OF TRIAL BRIDGE

After the successful completion of the performance verification tests conducted at the laboratory level on the deck of Figure 1, trial construction was envisaged and set up to verify its applicability on field. Since this deck was developed for applications to cable-stayed bridges, the road bridge was designed differently to agree with the objectives of the trial construction. In other words, the structural system was established so as to make the deck behave similarly to the deck in a cable-stayed bridge (Figure 2). The dimensions of the bridge were also planned to be minimized so as to realize the objectives of the trial construction (Figure 3). Considering that the longitudinal direction of the cable-stayed bridge deck is the transverse direction of the bridge and paying attention to the fact that the developed deck was designed to exhibit unidirectional behavior at the center of the bridge, the deck was conceived to present a structure supported only by the cross-beams as shown in Figure 2. Furthermore, in order to evaluate the behavioral characteristics in the positive moment zone at the central span of the cable-stayed bridge deck and in the negative moment zone above the cross-beams, the deck was fabricated by composing 3 precast deck segments with the cross-beams as illustrated in Figure 4. Finally, the girder of the bridge fulfills only the role of supporting the cross-beams without having particular influence on the behavior of the deck. Consequently the girder presented the U-shaped section shown in Figure 4.

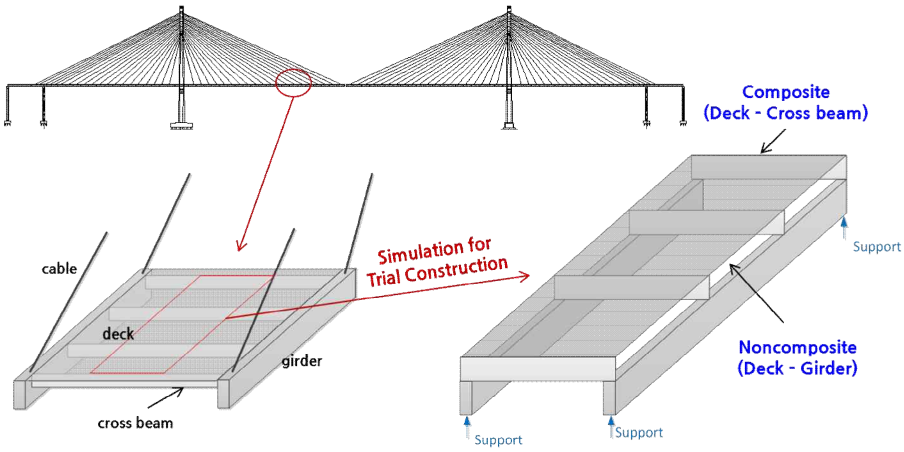


Figure 2: Design concept of the trial bridge.

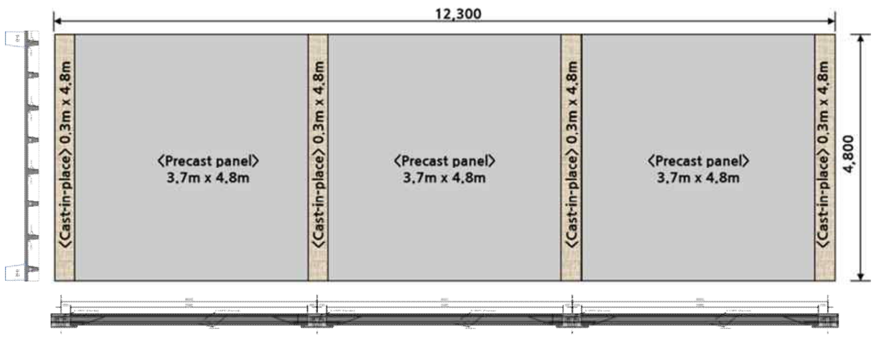


Figure 3: Composition of the trial bridge.

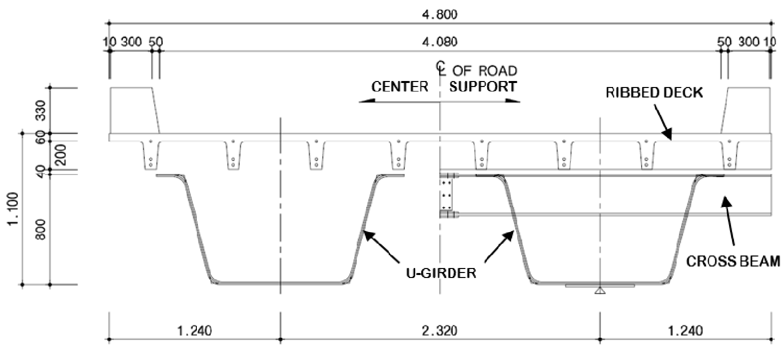


Figure 4: Cross-section of the trial bridge.

4. FABRICATION AND CONSTRUCTION OF THE DECK

The fabrication of the deck panels was executed in the purposed batch plant for UHPC located in the site of KICT. The prestressing table and form were firstly assembled (Figure 5) before applying prestressing (Figure 6) and placing UHPC (Figure 7). After the curing process, the forms were stripped and the forms were assembled to repeat this process. The fabrication of one panel took 8 days on the mean. One deck panel weighed merely 56 kN. The so-fabricated 3 panels were then transported to the trial construction site located approximately 300 km far away from KICT.

Figure 5: Assembling of prestressing table and deck form.

Figure 6: Prestressing.

Figure 7: Placing of UHPC.

Figure 8: Erection of U-girder.

Figure 9: Erection of deck panels.

Figure 10: Placing of UHPC joints.

The foundations and abutments were constructed on site during the fabrication of the precast deck panels. The girder was erected just before the transport of the panels on site (Figure 8). The deck panels were consecutively disposed on the girder using a crane (Figure 9). The deck joints were realized on field using a movable UHPC batch plant. The material used as cast-in-place filler was the mix-designed K-UHPC of which the fluidity was improved. The construction process of the deck described above took only one day and was achieved smoothly without any problem.

5. LOADING TEST

Two weeks after the completion of the bridge, field loading tests were executed to evaluate the serviceability and safety of the deck. Displacement sensors and strain gauges were installed to monitor the behavior of the deck (Figure 11) and the applied load combination cases were selected to generate as possible the maximum positive moment, negative moment and deflection at mid span of the deck (Figure 12). In Figure 12, LC1-1, LC2-1 and LC3-1 denote the positions of the wheels above the ribs of the deck disposed to be symmetric in the transverse direction at the centers of the three decks. LC1-2, LC2-2 and LC3-2 correspond to the cases where the wheels are disposed above the flanges of the deck asymmetrically in the transverse direction. The rear wheel load used in the test is 220 kN corresponding to 88.3% of DB-24, the load class 1 of the Korea Highway Bridge Design Code.

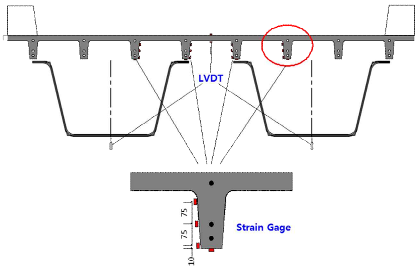
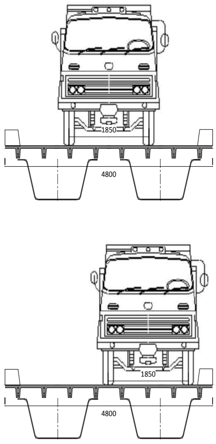


Figure 11: Sensor layout.



LC1-1
LC2-1
LC3-1

LC1-2
LC2-2
LC3-2

Figure 12: Loading cases.

Figure 13: Field loading test (LC1-1).

In Table 2, the real deflection of the deck is obtained by subtracting the displacement of the girder from the displacement measured at the bottom of the deck. This gives a deflection ranging between 0.49 mm and 0.93 mm. These values satisfy with large margin the allowable deflection of 4.625 mm (= L/800) specified by the Korea Highway Bridge Design Code. The values measured by the strain gages installed at the lower face of the flanges of the deck range between 55 με and 92 με which, converted in stress, provide a range of 2.48 to 4.14 MPa. This stress range is extremely small compared to the value of 9.5 MPa corresponding to the design tensile strength of the adopted UHPC. This indicates that the whole deck is in compression state even if the vehicle load is applied since sufficient prestress was introduced in the deck. These results demonstrate that the constructed UHPC ribbed deck secured sufficient serviceability and safety under the application of the design load DB-24.

Table 2: Measured deflection and strain converted to DB-24

Load case	Deflection of left girder (mm)	Deflection (mm)/strain (με) at bottom of deck	Deflection of right girder (mm)
LC1-1	1.62	2.11 / 70	1.63
LC1-2	1.14	2.31 / 62	2.21
LC1-3	0.67	1.25 / 92	0.57
LC1-2	0.36	1.40 / 55	0.83
LC2-2	0.66	1.33 / 82	0.63
LC3-2	0.42	1.54 / 62	0.80

6. CONCLUSIONS

The trial construction of a road bridge using the UHPC deck for cable-stayed bridge using the UHPC developed by KICT was conducted. No particular problem was reported during the fabrication and construction process of the deck. On the contrary, the lightweight deck eased significantly its erection. This process enabled to demonstrate that the developed deck secures sufficient applicability on field. The authors are awaiting for its first application to cable-stayed bridge.

ACKNOWLEDGMENTS

This research was supported by grant from Strategic Research Projects "Development of Smart Prestressing and Monitoring Technologies for Prestressed Concrete Bridges" and "Development of Deck Systems for Hybrid Cable Stayed" funded by the Korea Institute of Construction Technology. The authors express their gratitude for the support.

REFERENCES

Schmidt M., Fehling E. and Geisenhansluke C., (2004), Proceedings of the International Symposium on Ultra High Performance Concrete, Kassel, Germany.

Fehling E., Schmidt M. and Stürwald S., (2008), Proceedings of the 2nd International Symposium on Ultra High Performance Concrete, Kassel, Germany.

Schmidt M., Fehling E., Glotzbach C., Frohlich S. and Piotrowski S., (2012), Proceedings of the Hipermat 2012 3rd International Symposium on UHPC and Nanotechnology for High Performance Materials, Kassel, Germany.

KICT (2012a), SUPER Bridge 200/ Development of Economic and Durable Hybrid Cable Stayed Bridges, KICT 2012-075-1, Korea.

KICT (2012b), SUPER Bridge 200/ Development of Deck Systems for Hybrid Cable Stayed Bridges, KICT 2012-080, Korea.