Ootagawa Bridge

1. Overview

The Ootagawa Bridge is a six-span continuous steel and concrete composite arch bridge that is located in the lowest reaches of the Ootagawa discharge channel running through the west area of Hiroshima city. The bridge started operations as part of the city's Hiroshima-minami Road on March 26, 2014 (Photo 1).

The basic design of the bridge was selected as the best in the international competition hosted by the Hiroshima Municipal Government (13 entries from Japan, 2 from overseas). Viewing the bridge from upstream, the design creates a harmonious blend of the two low-rising steel arches and the landscape around the Seto Inland Sea, including Itsukushima Island (Photo 2). The sidewalk is completely separated from the dedicated roadway and is linear with varying sections, each of which has supporting structures according to their positional relationships with the roadway.

The superstructure of the bridge was constructed by extending the girders in sequence, making use of the arches' main structures. The main girders were extended while being suspended by using vertical members from the arches' main structures, which were constructed simultaneously in the middle of the extension construction. This resulted in a low girder height-to-span ratio.

Photo 1. Ootagawa Bridge after completion

Photo 2. Double arches with Itsukushima Island in the background

Structural overview

Structural system:	Six-span continuous steel and concrete composite bridge
Foundation system:	Steel-pipe sheet pile foundation, steel-pipe piles, and cast-in-place piles
Bridge length:	412 m; maximum span 116 m
Span:	40.0 m + 46.5 m + 47.0 m + 2 x 116.0 m + 46.5 m
Main girder system:	One-segment and two-segment PC box girder; girder height 2.7 m
Total width:	Inbound lane: 9.75-16.235 m Outbound lane: 9.75-12.585 m
Client:	Hiroshima Municipal Government (Streetscape Section of Road Department of Road Traffic Bureau)
Designer:	Eight-Japan Engineering Consultants Inc.
Contractor:	Shimizu Corporation
Work period:	September 28, 2011, to December 27, 2013

2. Characteristics of the bridge

(1) Special structure of steel arch PC composite bridge

Generally, a bridge with a continuous arch structure and traffic lanes under the arch is not easy to design. The continuous arch structure of this bridge was achieved by balancing the horizontal reaction generated in each arch's main structure with the tensile force of the external cables installed in the PC (prestressed concrete) box girders. Moreover, the rigidity of the main girders at the fulcrums was increased by means of a finback structure with internal cables installed at the attachment areas in the arches' main structures, which mitigated the negative moment generated at the rigidly connected fulcrums.

The PC continuous-moment-frame box-girder bridge is reinforced by the arches' steel main structures. The loads are sustained by both the main girders and the arches' main structures, which creates a slender girder shape (girder height-to-span ratio: 1/43) with a limited girder height. The arches' main structures are located in the median strip area between the inbound and outbound lanes. The arches' main structures were constructed simultaneously in the middle stage of the extension construction of the main girders. Then, while the suspension cables from the main structures supported the main girders, the main girders were extended in sequence and constructed. The suspension cables were tensioned and fixed to the vertical suspension cross girders that connected the inbound and outbound lanes (Figures 1 and 2).

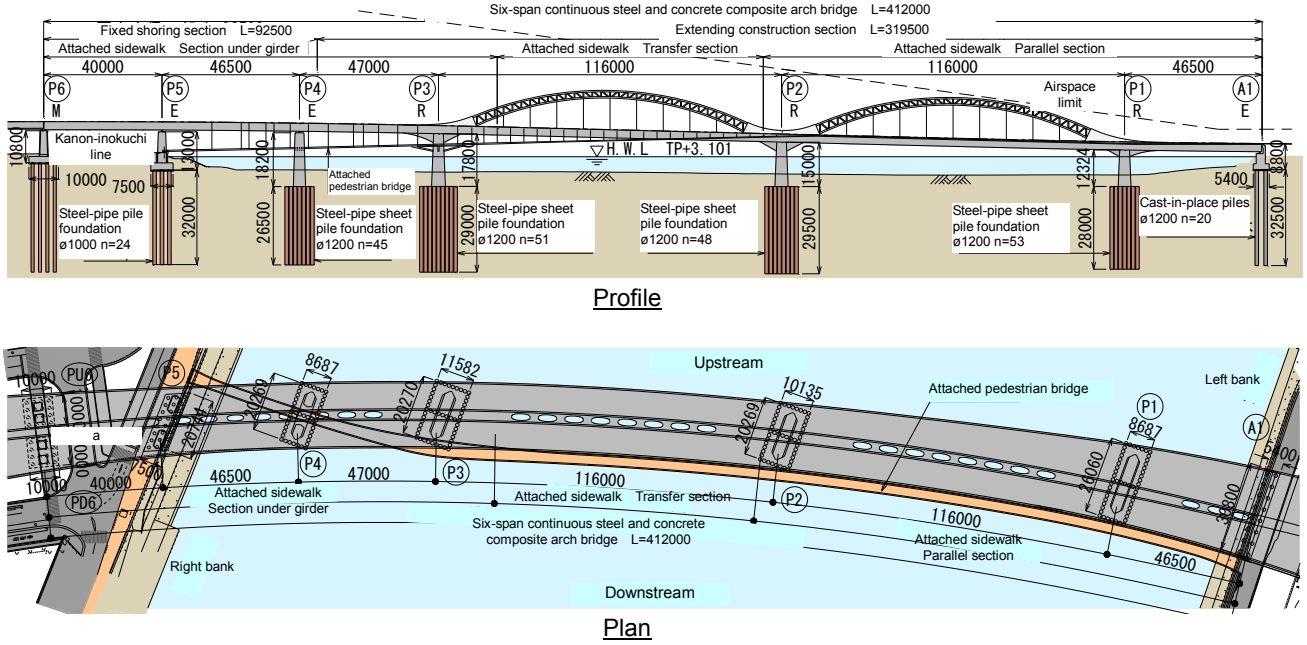

Figure 1. General view of the bridge

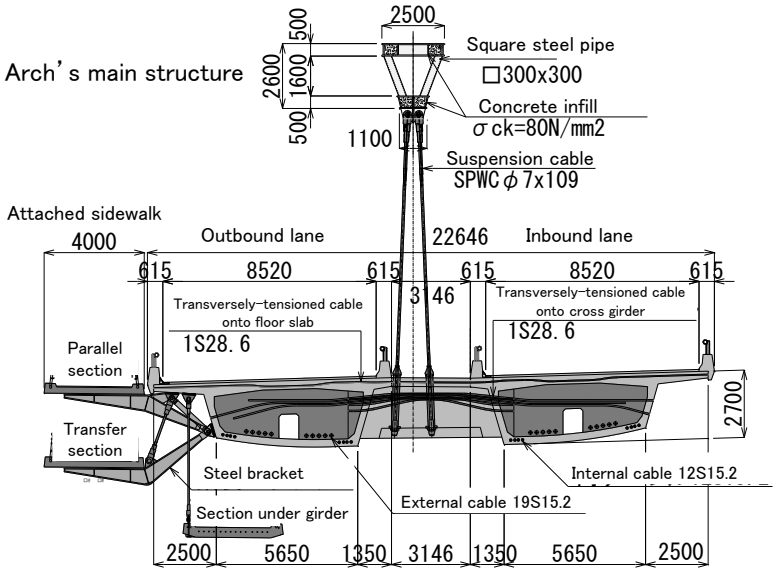

Figure 2. Typical section

(2) Sidewalk designed for user convenience and to provide a view of the Seto Inland Sea

Completely separated from the roadway dedicated to vehicle traffic, the sidewalk is connected to the bank road on both banks to provide easier accessibility and a view of the Seto Inland Sea. The sidewalk has a planar linear shape that allows pedestrians to travel from the connection point on the right bank (upstream side of the girder adjacent to the residential area), walk through the space under the girder in the roadway section, and exit on the downstream side and view a splendid panorama of the sea. The longitudinal gradient is a gentle 2.5% or less. Moreover, the sidewalk's supporting structures are designed to correspond to its varying sections: Steel brackets support the parallel section with the roadway, while suspension brackets support the transfer section. The section under the girder is supported by suspension (Photo 3).

Photo 3. Layout of the sidewalk and sequence of sidewalk sections from the right bank to the left bank

(3) Construction of brackish water area

The non-flooding period of the Ootagawa discharge channel falls between October 26 and June 10. The work generally was carried out within this period, with temporary facilities installed on the river banks. All six substructures A1 to P5 were constructed on the river banks. The bridge construction site was 200 m from the estuary, and the work proceeded by taking into consideration the maximum tidal difference of 3 m in the Seto Island Sea, which is noted for its great tidal variations.

(4) Simultaneous construction of the arch's two main structures on a barge

The water at the construction point was up to 5 m deep, which made it difficult to use large crane ships to construct the main structures of the two arches. Instead, both structures were constructed simultaneously on barges equipped with lifting jacks to accommodate the ebb and flow of the tide. The work schedule for the main girder extension construction was coordinated with the work schedules for the arches' main structures, main girders, and construction equipment. The sea tide conditions restricted

the days and times of work, which necessitated an elaborately developed construction plans (Photo 4).

(5) Concrete infill for arch's main structure

The main structure of each arch is a truss frame (braced rib arch main structure) composed of upper and lower cord members with a steel box section and square steel-pipe diagonal members arranged in a V shape. The interior of the box section (cell) needed to be filled with self-compacting high-strength and high-durability concrete (80 N/mm^2) to improve the buckling resistance and fatigue characteristics; however, due to constraints on the on-site operations and the site conditions, the filling operation required the concrete to be transported pneumatically over a distance of 300 m. Because of this, before the work started, a test using a life-size mockup was conducted to find a concrete composition that could be pneumatically transported and could provide the necessary infilling performance.

Photo 4. Simultaneous construction of the arch's main structures using a barge

(6) Super-short work schedule

The 412 m bridge was constructed in a very short period of 27 months, including the superstructure and substructure and the inbound and outbound lanes. In addition to the constraints imposed by the river and the special structure of the main girders, the project involved many special construction methods, such as installing bracket materials in the attached sidewalk, using barges to simultaneously construct the two arches, filling the arches' main structures with concrete, connecting the inbound and outbound lanes, and supporting the main girders from the arches' main structures. Thus, the schedule was very challenging.

3. Conclusion

The project, including additional bridge surfacing work, was completed in March 2014 and the bridge started operations on March 23. We hope that the bridge will contribute to

further economic growth in the Hiroshima costal area and mitigate traffic congestion in the surrounding area. We also hope that the bridge will be loved by the local residents and visitors for a long time.

Lastly, we would like to express our deep gratitude to those concerned in the local area and inside and outside the companies for their cooperation and assistance.

Photo 5. Ootagawa Bridge after completion