Designs of Bridges in the Hirose-Gawa Area Determined by Competition

設計競技で形式を決定した広瀬川地区橋梁

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Synopsis

The bridges (the Hirose-gawa Bridge and Nishikoen Viaduct) are the structures of the Sendai Subway Tozai Line cross over the Hirose-gawa River and Nishikoen Park. These structures are passes through the scenic Sendai area that is called “Forest city”. Sendai City required the two bridges an excellent aesthetic design constructed for such an important area. In 2006, the city held a design competition to select the design. It was the first design competition as railway bridges in Japan. The winners of the competition were consigned the design of the bridges [1], [2]. Construction works, which have been conducted since 2008, are planned to be completed in 2013, and will be followed by installation of rail tracks. The outline of the fully worked-out plan for realization of a very exceptional bridge design and construction will be reported in this paper.

Structural Data

Structure: (1) 3-span continuous partially prestressed concrete(PPC) rigid frame box-girder bridge
(2) reinforced concrete(RC) slab concrete filled steel tube (CFT) column rigid frame viaduct
Bridge Length: (1) 172m
(2) 118m
Span: (1) 53.0 + 70.0 + 47.0m
(2) 5.0m
Width: (1) 13.976 - 7.881m
(2) 7.885 - 10.706m
Owner: Sendai City Transportation Bureau
Designer: Docon Co., Ltd.
(Winner of the competition)
Contractor: JV of P.S. Mitsubishi Construction Co., Ltd.,Fuji P.S. Co., Ltd., and Higashinihon Concrete Co., Ltd.
Construction Period: Dec. 2008 – Sep. 2013
Location: Aobayama, Aobaku of Sendai City, Miyagi prf.

1. Outline of the design competition

The site of two bridges in the Hirose-gawa area is in an important scenic area called Aobayama Area, which is a hilly area in Sendai City and its beautiful hills and forests have been considered as the symbol of the city.
To realize bridges with excellent design that fully take the beautiful scenery of the area into consideration, Sendai city established the Examination Committee for Bridges in the Hirose-gawa Area of the Sendai Subway Tozai Line. The committee determined the direction in designing bridges for a space which is surrounded by Aobayama Park and Nishikoen Park with abundant greenery[1] as “the design of the bridge should complement the surrounding beautiful scenery, and the bridges should provide comfortable space for the users of the parks.” At the same time the Committee proposed a design competition.
To achieve what the committee determined, the Design Competition for the Bridges in the Hirose-gawa Area of the Sendai Subway Tozai Line was planned, and the Selection Committee for the competition was

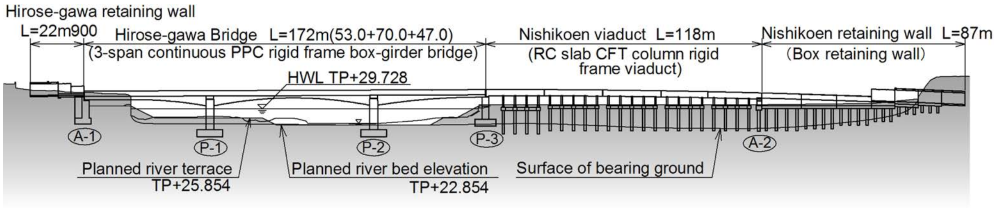

Fig.1 Cross-sectional view of the plan

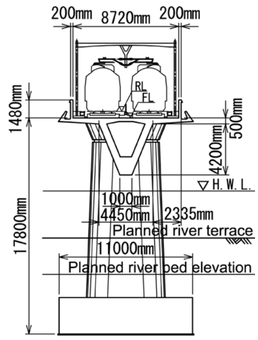

Fig.3 Typical cross-section of the Hirose-gawa Bridge

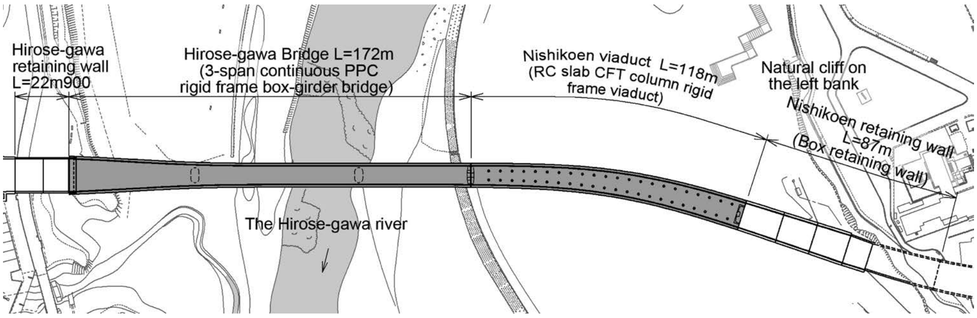

Fig.2 Plan view of the plan

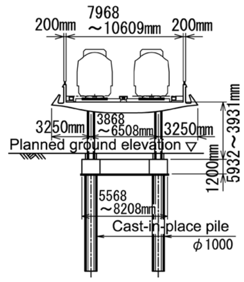

Fig.4 Typical cross-section of the Nishikoen viaduct

established [2].

2. Outline of the design that was selected in the competition

These bridges in the Hirose-gawa area were planned by the method of dividing sections of abundant natural environment. There are concrete arch bridge (Ohashi bridge) completed in 1938, double deck bridge (Nakanose bridge) of the national road 48th, and municipal roads in the area. Redevelopment of Aobayama Park on the right bank and Nishikoen Park on the left bank of the Hirose-gawa river was planned at the time of construction works of the subway line; however, the new bridges were clearly a nuisance for the users of the parks. In the proposal, it was stated that the design and planning for the bridges aimed at creating new all weather “park devices” that would be useful for the park users. Realization of this proposal was possible by converting the “annoying bridges that cut through the parks” into a “stage for new activities”. The required design was to create bridges with unimposing subtle forms. The bridges should blend with the surrounding natural scenery when seen from a distance, but their elegantly designed parts gradually appearing when the viewers come closer to the bridges. The plan for 1) the river bridge and 2) the viaduct are as follows:

1) 3-span continuous PPC rigid frame box-girder bridge with inverted triangle cross-section, that results in a wide deck overhang, and creates a distinct nuance in the space under the girders (**Fig. 1,2,3,5**).

2) RC slab CFT column rigid frame bridge with only 5m of span length creates an attractive colonnaded arcade with a widely overhang ceiling and columns under the girders. It was expected that the bridges with subtle forms would be accepted as urban facilities that contribute to cultivating the Sendai way of enjoying the beauty of nature through the citizens’ activities held in the space created by the new bridges (**Fig. 1,2,4,6**).

3. Outline of the structures

Fig.1-4 show the outline of the bridge structures. The notable feature of the bridges is that even though the structures of the river bridge and the viaduct differ clearly, they have continuity and unity in their appearances by the open channels along the outer sides of the both structures. The open channels, working as drainage devices, soften the heavy impression of wall railings (**Fig.7**).

4. The Hirose-gawa Bridge

(1) Bridge plan

In designing the Hirose-gawa Bridge the arches of the Ohashi Bridge which is located about 200m downstream of the Hirose-gawa Bridge were taken into consideration. The Ohashi Bridge had created the image of the space around it since the early years of the Showa era. The new bridge that was decided to a 3-span continuous concrete bridge with variable section was designed to create a double silhouette with the Ohashi Bridge (*i.e.,* the two bridges with arches simultaneously come into view of the park user). By providing the new bridge the similar rhythm as that of the Ohashi Bridge, it was expected that the new shape of structure constructed using current technology would further enhance visual effects of the old and new

Fig.5 The shape of the Hirose-gawa Bridge

Fig.6 The shape of the Nishikoen viaduct

Fig.7 Wide overhang for the open channel

bridges. A cross-sectional shape of the main girder was determined as a large inverted triangle. It was expected that the main girder with wide overhang create a space with nuance under it.

(2) Structural design

This bridge has a PPC structure. The height of pier is 10m, which is low for the maximum span length of 70m. High earthquake resistance, and maintenance and economical efficiencies were provided by the rigid frame structure, which was determined after considering the possibility of decrease in stiffness when cracking occurs in the piers.
The cross-section of the main girder was designed in the similar way for those of box-girders with diagonal webs. The followings are the specially investigated and verified points in using the inverted triangle cross-sectional main girder.
1) At the location of pier, where compressive stress concentrates, the width of 1.00m and thickness of 1.50m were secured for the lower deck slab.
2) Sufficient strength against biaxial flexural stress was secured based on the dynamic response analysis of seismic motion perpendicular to the railway tracks.
3) By conducting 3-D frame analysis with eccentric train load, it was verified that the effects of twisting moment were very small.

5. The Nishikoen Viaduct

(1) The RC slab CFT column rigid frame structure

The structural features of this bridge is as follows (**Fig. 4**).
1) CFT column was used for the pier.
2) The superstructure of RC slab and the CFT columns were directly connected.
3) The CFT columns were directly connected with the underground beams (Two-layered rigid frame structure including the superstructure).
4) The span length was 5.0m and the CFT columns were placed at the location of the tracks.
The structure of this bridge is a special rigid frame structure, in which multiple CFT columns connected with the RC underground beams directly support the RC slab. The structural design was achieved by using a frame model that showed the rigid frame structure made up of the slab, column, and beam. In the modeling, generally used beam members were used for CFT columns and underground beams. The effective width of the slab was determined based on the distribution characteristics of normal stress obtained from a 3-D elastic FEM analysis. A beam member that had the resultant effective width replaced the slab.

(2) Structure of the connection

1) Slab-column connection (steel beam, reinforcing bar inserting connection)
For connection of the CFT column and the slab, well established, widely used design method of the steel beam, reinforcing bar inserting connection was used (**Fig.8, top half**).
2) Column, underground beam, and pile connection (Socket connection)
The connection of the CFT column, underground beam, and pile was done by the socket connection whose uses have been well established (**Fig. 8, bottom half**).

(3) Securing the quality at each connection

Shrinkage compensating mortar was filled into the connection of the steel pipe socket and CFT column. Concrete was filled in the connection of the inner part of the CFT column and box-shaped steel beam. To establish a construction method for realizing high quality filling, a full-scale filling experiment using a CFT column was conducted before actual construction. To verify the quality of filling, a concrete filling sensing system (Jutendar) with a vibration device was used. For the connection of the CFT column and the box-shaped steel beam, where securing the quality of filling was thought to be challenging, the subject part was cut for visual inspection after the filled concrete was solidified (**Fig.9**).

(4) Finishing the deck slab

The bottom mold frames of the viaduct are left in place for relatively long period, which often leave stains on the surface. The bottom of the bridge deck was designed to serve as the ceiling of the promenade. Sand blasting was carried out to create a special texture for concrete surface. It is a technique to create a rough texture by blasting granular abrasive on the subject surface using pressurized air (**Fig.10**).

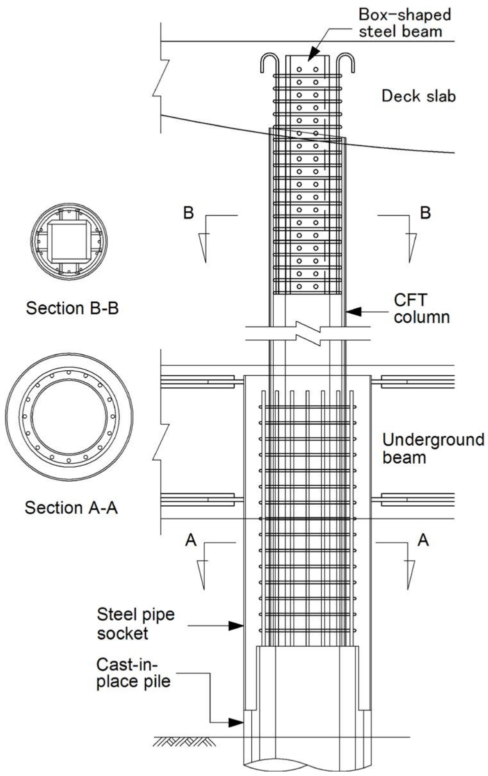

Fig.8 Cast-in-place pile-deck slab connection

Fig.9 Cross-sectional view of the box-shaped steel beam in the CFT column

Fig.10 Polishing by sandblasting

Conclusion

At the time of the Great East Japan Earthquake of March 11, 2011, the Hirose-gawa Bridge was under the cantilever processes. Only minor cracks were founded (max. width of 0.3 mm) in the proximities of the heads of P1 and P2 piers in the detailed inspection after the earthquake. They were considered to be caused by the earthquake and repaired in due course.

The construction work was launched after detailed inspection in July 2011. The construction of the bridges will be completed in September 2013. Before the completion of the civil engineering works, rail track installation works will start. After a test operation, the Tozai Line is planned to open in 2015 fiscal year.

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概　要

広瀬川地区橋梁（広瀬川橋りょう及び西公園高架橋）は仙台市高速鉄道東西線が広瀬川を渡河する低地部に計画された。この２橋は杜の都を代表する景観形成地区を分断しており，仙台市はデザイン的に優れた橋梁の計画が必要と考え，平成18年に鉄道橋ではわが国初となる設計競技を開催した。

選定案は「公園を貫く迷惑な橋」を「新たな活動を生む舞台」に変換しようというもので，渡河橋は200m下流の大橋との同時展望性から３径間連続PPCラーメン箱桁橋に，高架橋は公園内のプロムナードとしての用途から支間わずか5mのRCスラブ式CFT柱ラーメン橋にしている。派手さはないが，いずれも類を見ない構造デザインであり，この空間で生まれる多彩な活動と美しい自然が主役となって，やがては仙台流儀を育む都市施設に成長してくれることを期待したのである。

設計競技方式で橋梁形式を選定後，平成19年２月に当選者へ実施設計を委託し，土木工事は平成20年12月に工事が開始され平成25年９月で終了した。それに先立ち平成25年８月からは軌道工事が始まり，試験運転を経て東西線の開業は平成27年度の予定である。