Prestressed Reinforced Concrete Continuous Rigid-frame Bridge with Unequal Pier Heights
— Gunkaigawa Bridge —

不等橋脚高を有する PRC 長大連続ラーメン橋
— 郡界川橋 —


*

**

***

* Kenichi NAKATSUMI, P.E.Jp: Sumitomo Mitsui Construction Co., Ltd.
中積　健一，技術士（建設部門）：三井住友建設（株）
** Yoshino MASAMICHI, P.E.Jp: Sumitomo Mitsui Construction Co., Ltd.
吉野　正道，技術士（建設部門）：三井住友建設（株）
*** Mitsutaka MIYABE: Central Nippon Expressway Co., Ltd.
宮部　光貴：中日本高速道路（株）
Contact: nakatsumik@smcon.co.jp
Keywords: design-build, lighter superstructure, excavated pier, horizontal loading erection
DOI: 10.11474/JPCI.NR.2018.83

Synopsis
Located about 3km east of the Toyota-higashi junction on the Shin-tomei Expressway, the 740m-long Gunkaigawa Bridge comprises two separate inbound and outbound bridges that are continuous seven-span prestressed reinforced concrete rigid-frame box girders with an effective width of 14.75m and a maximum span length of 124m (**Figs. 1** and **2**).

The 800-m construction section was procured as a design-build project. Taking economy, maintainability, and durability into consideration, all bridge members are made of concrete whereas the bridge piers and main girders are all rigidly connected structures. To make this structure feasible, the superstructure weight was reduced and the pier heights were adjusted by adopting excavated pier construction on some bridge piers, together with displacement adjustment work with horizontal loading performed during girder closure.

Structural Data
Structure: 7-span prestressed reinforced concrete continuous rigid-frame box-girder bridge
Bridge Length: 740.0m
Span: 92.8 + 124.0 + 104.0 + 2@100.0 + 124.0 + 92.8m
Owner: Central Nippon Expressway Co., Ltd.
Designer: Sumitomo Mitsui Construction Co., Ltd.
Contractor: Sumitomo Mitsui Construction Co., Ltd.
Construction Period: Jul. 2008 – Jul. 2014
Location: Aichi Prefecture, Japan

Fig.1 Gunkaigawa Bridge

1. Introduction
For the Gunkaigawa Bridge, the locations of the piers were restricted by the Gunkai River, the two prefectural roads on either side of the river, and an erosion-control dam. Moreover, the central part of the construction section is located in a mountainous area with gentle contours and for which the bridge piers could not be too high. Under these constraints, the locations of the bridge piers and abutments were set with the goals of balancing the span lengths and reducing the construction costs, leading to the choice of seven spans. Furthermore, to increase durability and reduce maintenance costs along with construction costs, all bridge members are made of concrete whereas the bridge piers and main girders are all rigidly connected rigid-frame structures. Although it is generally difficult

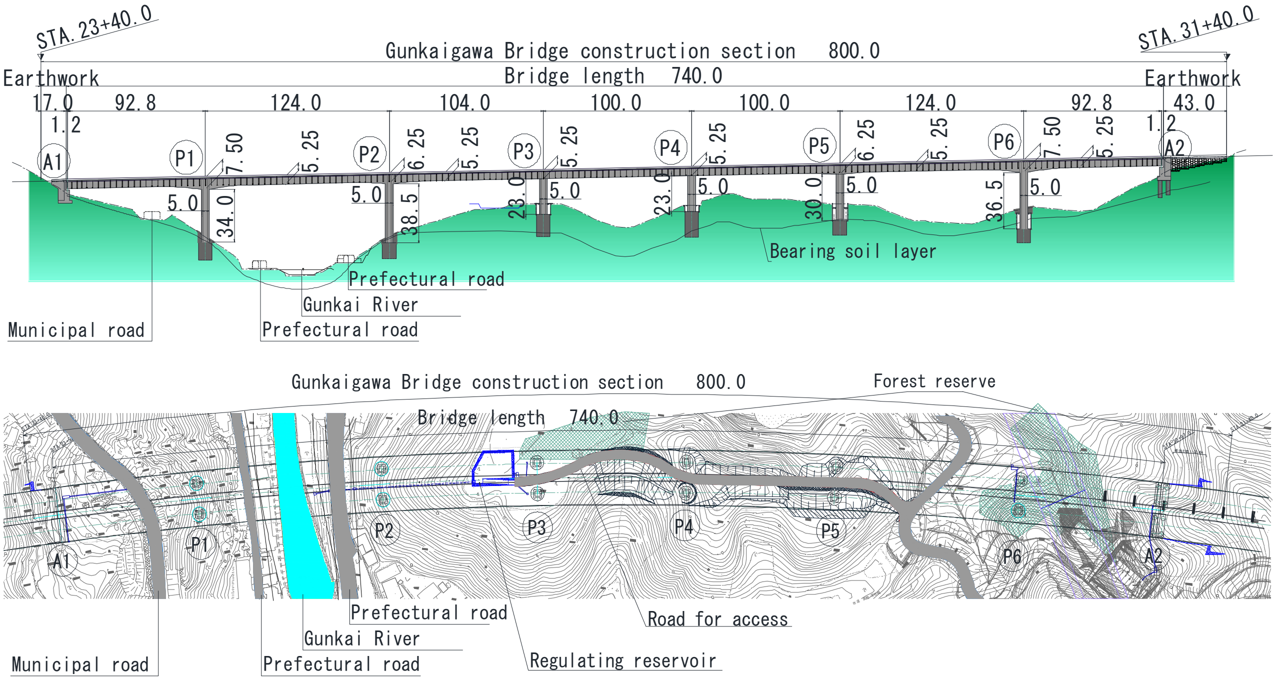

Fig.2 General view of Gunkaigawa Bridge

to achieve a continuous rigid-frame bridge under the topographic conditions and bridge length dimensions of this bridge, this structure was made possible by adopting three strategies, namely using (i) a lighter superstructure, (ii) excavated pier construction with below-grade footings, and (iii) a horizontal-loading erection method.

To facilitate future maintenance of the bridge, consideration was given to making inspections easier on detailed parts of the superstructure and substructure. Because the bridge is situated in a mountainous region with a rich natural terrain, consideration was also given to the surrounding environment by minimizing the area of topographic modification.

2. Design

(1) Main Girder

When considering a rigid-frame structure over the entire bridge length under the prevailing topographical conditions, high pier stiffness is expected because there is less height available for the bridge piers at the central part of the bridge around piers P3 and P4, which concentrates sectional forces during an earthquake and makes it difficult to maintain strength. Moreover, it is generally difficult to achieve a rigid-frame structure because the effects of temperature change on the superstructure and deformation from creep and drying shrinkage are larger at the end piers P1 and P6 of the bridge, because the pier heights are less than the fixed span lengths.

Therefore, for the short piers at the central part of the bridge, inertial forces were reduced by using a lighter superstructure together with excavated pier construction providing below-grade footings (**Fig.4**) to

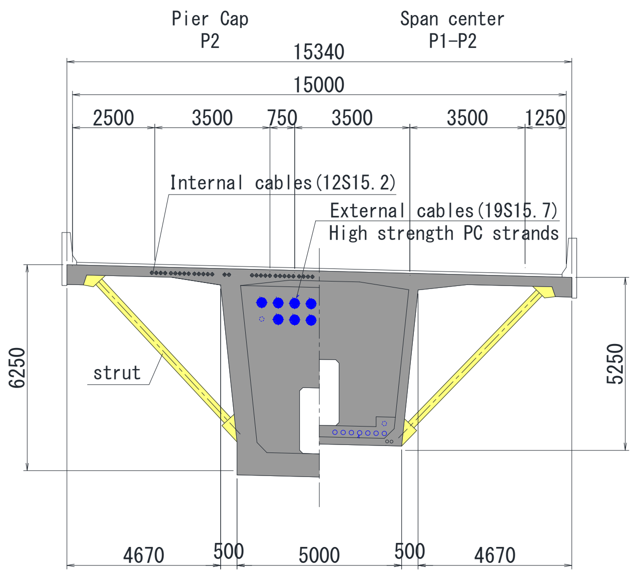

Fig.3 Main-girder cross section

increase the pier heights and make the structure flexible for seismic resistance. For these bridge piers, part of the excavated shaft was not backfilled, thereby eliminating ground resistance during an earthquake. Shaft covers were provided at ground level to prevent third-party accidents.

For the end piers, horizontal-loading erection method (**Figs.5** and **6**) was adopted to apply loads horizontally to the main girders before central closure of the cantilever construction and to provide displacements to the end piers, thereby reducing the pier bending moments at normal loading. Taken together, this combination of approaches allowed the bridge to be built with rigid- frame structures for all the piers.

(2) Shape of Main-girder Section

To reduce the weight of the main girders, a single-cell box-girder section with struts stiffening the deck overhang was used to provide an overall width of 16m (**Fig.3**). This reduced the main-girder weight by 18% compared with conventional single-cell box-girder sections. The strut spacing was 4m, with one strut placed at each block of the cantilever construction. Moreover, stretches of bridge sections with the same girder depth were extended to keep the strut angle constant, thereby improving constructability (**Fig.3**). The strut members used fiber-reinforced concrete to prevent spalling with 70mm cover for high durability.
The use of struts reduced the box-girder width, thereby reducing the girder weight, but also restricting the number of external cables inside the girder. Therefore, high-strength prestressed concrete (PC) steel strands with 28% higher strength compared to conventional PC steel strands were used to reduce the number of cables required.

(3) Detailed Structure for Maintainability

To prevent rainwater penetrating from the expansion joints to the supports at the girder ends, a structure with the expansion joints shifted toward the abutment side and with a drainage channel underneath, called a setback joint structure, was adopted (**Fig.7**). In a conventional structure, rainwater leakage due to deterioration of the expansion joints penetrates the surfaces of the end wall and bridge seat, causing the bearing support to corrode. With the setback joint structure, rainwater leaks are caught by the drainage channel, improving maintainability of the end bearing support. Inspection ladders and access hatches were installed to allow the drainage channels to be cleaned and their conditon checked.
Also, CCD cameras were installed to facilitate inspection of the base of struts from within the girders. Furthermore, vertical access systems were installed in the excavated pier shafts to enable examination of the pier base after an earthquake (**Figs.4** and **8**).

3. Construction

(1) Excavated Pier Construction

During the large-diameter deep foundation excavation conducted for the foundations of the excavated piers, the shaft was shored with steel-ring falsework and shotcrete until reaching the bearing ground.

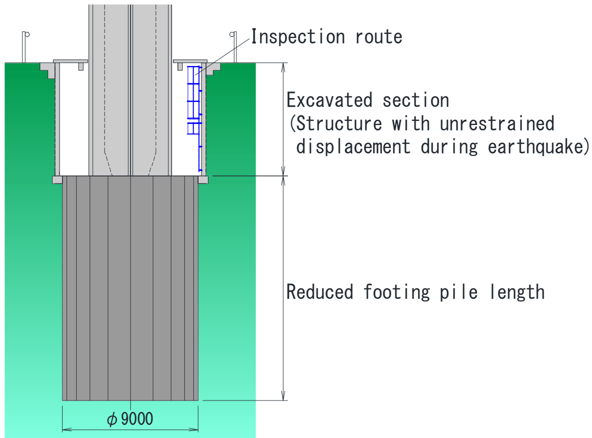

Fig.4 Excavatedb pier

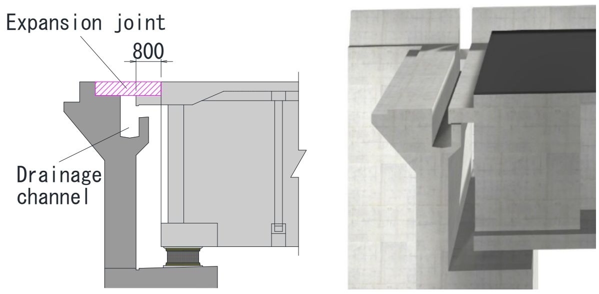

Fig.7 Setback joint structure

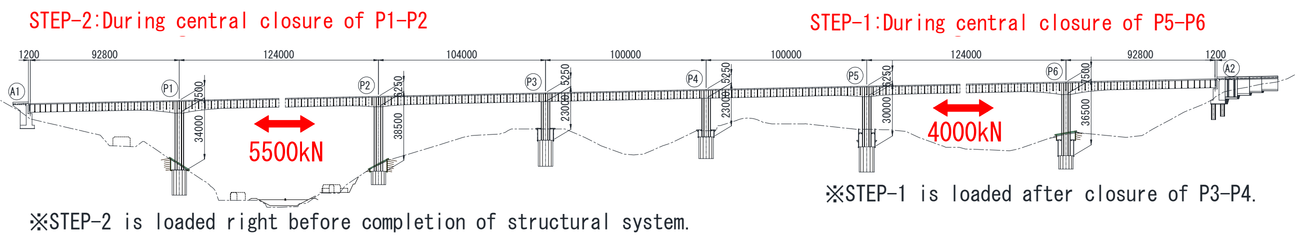

Fig.5 Horizontal-loading location and order

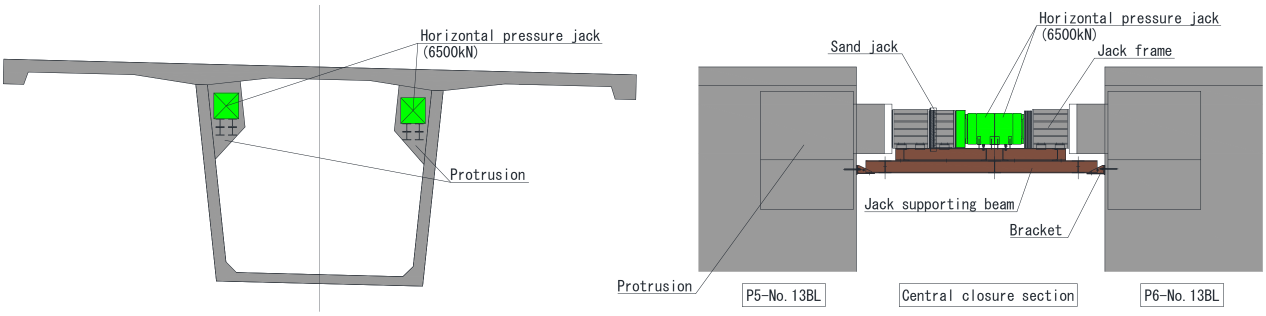

Fig.6 Detailed diagram of horizontal-loading device

(a) Before installing cover

(b) After installing cover (access hatch)

Fig.8 Excavated pier construction

Fig.9 Erection of struts

The shaft construction work was then carried out using full scaffolding, with one lift at 5.4m high. **Fig.8** shows the excavated pier shaft after cover installation. Backfilling was not performed inside the excavated section. To prevent third-party accidents such as falls, a fence was installed around the periphery and a concrete cover was installed, securing a gap so that pier displacement is not restrained at the top of the shaft.

(2) Cantilever Construction

In the cantilever construction, 12 large form travelers were used simultaneously for the six piers. Each cantilever block was 4m long, equal to the strut spacing, to make the work schedule more efficient and enable a construction cycle of ten days. Struts were installed using two electric chain blocks on the form traveler (**Fig.9**).

(3) Horizontal-loading Erection

The horizontal-loading process applied the curvature assumed in the design to the bridge piers, using displacement instead of load to control the loading to attain the predetermined amount. Because the bridge piers contain D51 bars distributed on three layers, the load-displacement relationship was obtained from the converted stiffness which takes the reinforcing bars into account. Actual loading produced values that are mostly in agreement with the calculated values.

4. Conclusion

In this bridge, the piers at the central part were extremely short while end piers were also not so tall due to the constraints of the mountainous area location. All bridge members were made of concrete, and bridge piers and main girders were all rigidly connected rigid frame structures. This approach enabled the design to balance span lengths and reduce construction costs, as well as to reduce maintenance costs and increase durability. Although it is generally difficult to attain a continuous rigid frame bridge with constraints such as those applying in this case, we were able to build it with a newly conceived excavated pier construction method in combination with technologies for a lighter superstructure and horizontal loading. Furthermore, we made inspections easier to conduct, to take into account future bridge maintenance, and minimized the area of topographic modification to take the surrounding environment into account.

Reference

[1] Takeda, H.: *Design and Construction of the Gunkaigawa Bridge on New Tomei Expressway*, Bridge and Foundation Engineering, Vol.48, No.3, Japan, pp. 5-10, Mar. 2014. (in Japanese)

概　要

郡界川橋は，新東名高速道路の豊田東 JCT の東方約3km に位置する橋長740m，有効幅員14.75m，最大支間長124m の PC7 径間連続ラーメン箱桁橋であり，上下線分離の 2 橋から構成される。

本工事は，工事区間800m を設計施工一括発注（デザインビルド）方式で発注された。本橋は維持管理性や経済性，耐久性に配慮して全部材をコンクリートとし，橋脚と主桁をすべて剛結構造とした。本構造を成立させるために上部工を軽量化し，一部の橋脚に掘込み式橋脚を採用して橋脚高さを調整するとともに，主桁閉合時に水平加力方式変位調整工法を併用した。