Reconstruction of a Bridge Following Damage in the 2016 Kumamoto Earthquakes
— Aso Ohashi Bridge —

熊本地震で被災した旧橋の架替え工事
— 阿蘇大橋 —


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* Kenji NAGAO, P.E.Jp: Taisei Corporation
長尾　賢二，技術士（建設部門）：大成建設（株）
** Fumiaki SONOBE, Taisei Corporation
園部　文明：大成建設（株）
*** Yasuhiko UBAYASHI: Ministry of Land, Infrastructure, Transport and Tourism
鵜林　保彦：国土交通省
**** Shinichi FUJIKAWA: Ministry of Land, Infrastructure, Transport and Tourism
藤川　真一：国土交通省
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Synopsis
The Aso Ohashi Bridge is a 525 m road bridge built to replace an old bridge that collapsed due to damage incurred in the April 2016 Kumamoto Earthquakes. The river-crossing section of this prestressed concrete (PC) 3-span continuous rigid-frame girder bridge is designed to have a maximum pier height of 97 m and a maximum span length of 165 m, making it one of the largest bridges of this structural type in Japan.
For this section, the construction period was shortened by approximately 16 months compared with the standard period (66 months) by advanced construction technologies such as large incline system, a self-climbing system, and extra-large form travellers.

Structural Data
Structure: 3-span continuous PC rigid-frame box-girder bridge
Bridge Length: 345.0 m
Span: 80 m + 165 m + 100 m
Width: 10.5 m
Girder Height: 10.0 – 3.2 m
Owner: Ministry of Land, Infrastructure, Transport and Tourism
Designer: Chodai Co., Ltd.
Contractor: Taisei Corporation, IHI Construction Service Co., Ltd., Happo Corporation, JV

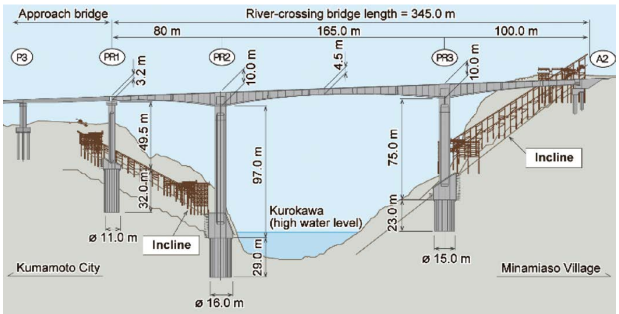

Fig. 1 General view of the Aso Ohashi Bridge (river-crossing section)

Construction Period: Mar. 2017 – Mar. 2021
Location: Kumamoto Prefecture, Japan

1. Introduction
This project involved the construction of superstructure and substructures for a new PC rigid-frame bridge, approximately 600 m downstream from where the old bridge collapsed. The Aso Bridge Route on Japan National Route 325, which includes this bridge, plays an important role in tourism and logistics. Thus, minimizing the construction period to allow an early opening was the primary goal. Furthermore, the bridge is built on a steep canyon with a height difference of about 100 m to cross over the river. The site, which is

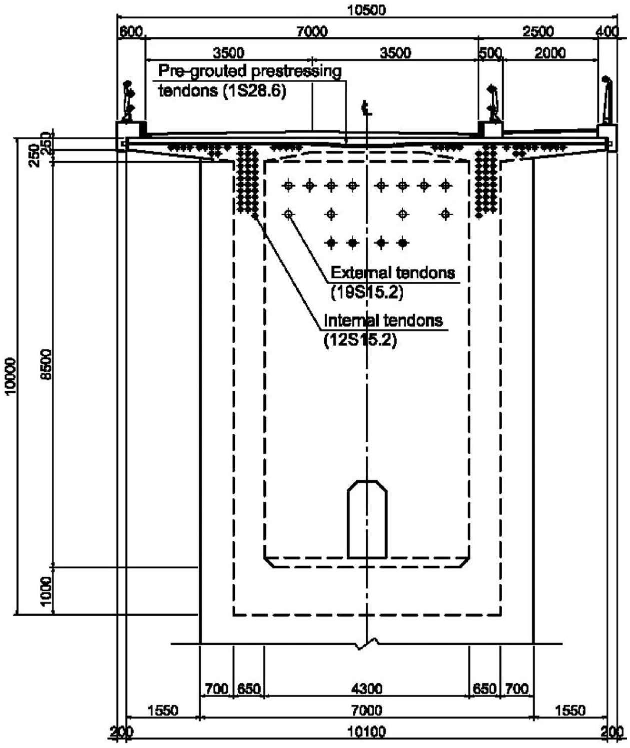

Fig. 2 Cross section at pier head

designated as a UNESCO Geopark, features an unusual type of bedrock with numerous cracks called columnar jointing throughout the area.

2. Overview of the Structure

All three piers, PR1–PR3, are reinforced concrete piers supported by large-diameter deep foundations, with the highest pier (PR2) reaching 97.0 m in height. The superstructure of the river-crossing section is a PC 3-span continuous rigid-frame girder bridge with a center span length of 165 m, making it one of the largest of its kind in Japan (**Fig. 1**). To reduce weight and ensure the required seismic performance, construction materials included high-strength concrete with a base design strength of 50 MPa, with SD490 high-strength reinforcing bars partially placed in the main reinforcement. The prestressing steels in the primary direction are a combination of internal tendons (12S15.2) and external tendons (19S15.2) (**Fig. 2**).

3. Introduction of the Incline System

The provisional construction plan for this project was originally to deploy the hoisting cranes on a stepped pier at the top and bottom of the steep slope to carry materials and equipment in and out. However, the construction site would likely be exposed to strong winds throughout the year, raising concerns that the initial plan, which involved the use of multiple cranes, would not stably supply materials and equipment or be able to remove the large amount of excavated earth and sand that would be generated during the deep foundation work. To solve this problem, two of Japan's largest incline system units, capable of loading up to

Fig. 3 Incline system

Fig. 4 Earth-retaining structure for PR2

60 tons, were installed on each of the right and left banks (**Figs. 1** and **3**). Each incline system, which uses a hoist to move a carriage up and down along rails, has a carriage size of 14.0 × 9.0 m to accommodate up to two dump trucks or concrete mixer trucks, allowing steady transport of materials and equipment during the entire construction period.

4. Substructure Construction

(1) Construction of Large-diameter Deep Foundations

This bridge has large-diameter deep foundations, ranging from 11.0 to 16.0 m in diameter and up to 32.0 m in depth. To construct such deep foundations, a circular and vertical excavation technique (the angle cut cylinder earth-retaining method) was applied to reduce construction areas as much as possible, thereby reducing the amount of excavated earth and the burden on the natural environment. PR2, which is adjacent to the river, is situated on a steep slope containing columnar jointing, preventing the application of the conventional earth-retaining method with closed ring. Thus, a new semicircular earth-retaining method was developed based on a design and construction method[1] that considers the characteristics of columnar jointing, which features numerous cracks and poses a high risk of collapse due to vibration and other factors, while still preserving the Geopark landscape and ensuring

Fig. 5 Rebar assembly of foundation

Fig. 6 Pier construction with a self-climbing system

construction safety (**Fig. 4**).

Considering that fractured bedrock is widely distributed throughout the construction area, all excavation of the deep foundation was performed by mechanical excavation using large heavy machinery to avoid loosening the natural ground. Deformations of the ground and retaining wall were constantly monitored using insertion-type multistage inclinometers and axial force gauges, and excavation work was carried out with the utmost care. When constructing the framework, the work efficiency of creating the rebar assembly was improved by prefabricating the peripheral rebar and using an elevating work platform (**Fig. 5**). Since the maximum amount of concrete placement at one time was 1500 m^3, concrete was pumped to placement sites from a pump truck installed on the upper work platform to the placement point through two pipelines (approximately 200 m long and with a height difference of approximately 100 m) installed along the incline system rails.

(2) Pier Construction

Construction of the high piers PR1–PR3 utilized a self-climbing system comprising working scaffolds and formworks, absorbed reaction forces from the existing framework, and used hydraulic jacks to climb up piers along rails (**Fig. 6**). This method lowered the

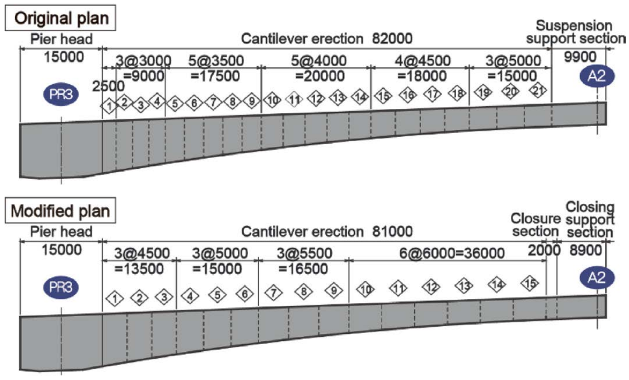

Fig. 7 Comparison of main girder blocks (PR3 side)

number of construction days by reducing the need to install scaffolding on all four sides of the perimeter and interior walls and reducing the need for the lifting and lowering of formwork materials by crane for each lift, as is required in standard construction methods. The system formwork uses large, rigid panels with a thickness of 18 mm. This extends the separator spacing to about 900 mm, reducing the number of separators by about half compared with the use of ordinary plywood. These innovations made application possible up to the final lift, eliminating the need for replacements during construction and saving labor in formwork-related tasks. For rebar assembly tasks, in addition to the batch erection of prefabricated and intermediate rebars and the adoption of a system for rebar assembly, work efficiency was also improved by adjusting rebar lengths such that the joint positions of the main rebars would always be at a certain height from lift joints.

5. Superstructure Construction

As another method for shortening the construction period, the number of construction blocks was reduced by introducing extra-large form travellers with a capacity about three times that of the standard type in Japan (6,000 vs 2,000 kN m). Based on the results of framework analysis that reflected the actual construction steps and erection plans, the number of construction blocks was reduced from 17 to 12 on the PR2 side and from 21 to 15 on the PR3 side. In the side-span sections of PR1 and A2, the suspension supports in the original design were replaced with pre-constructions using bracket supports, and a 2.0 m closure was provided between the pre-constructions and the final block of cantilever erection (**Fig. 7**).

Balanced cantilever erection using extra-large form travellers was carried out in day and night shifts, and each block was erected in approximately 7 days (**Fig. 8**). Because of the high piers and long overhang length, concrete quality control and camber control during construction were considered to be primary issues. Laboratory tests were conducted under the assumption of a high-temperature environment to examine the change in slump over time and pump-feeding properties and to determine the specifications

Fig. 8 Balanced cantilever erection with extra-large form travellers

Fig. 9 The completed bridge

for the high-strength concrete[2]. To manage concrete placement, the entire series of processes, including shipping, transportation, placing, and quality control of ready-mixed concrete, was digitized using information technology, and a system that allows cloud-based data sharing was introduced to enable a smoother and higher-quality supply of mixed concrete than was previously possible.

In camber control, formwork heights were determined based on planned values calculated by considering the rigidity of the pier's main reinforcement bars, and by using a proprietary system to assess behaviors due to temperature changes. While tip deflection of the cantilever block showed daily fluctuations of about 30 mm, the block tip was connected to the previously constructed end span with H-shaped steel and prestressing steel rods on the same day of casting, and closure was completed within allowable construction tolerances[3].

6. Conclusion

Steep terrain and strong winds imposed severe construction conditions on the river-crossing section construction of this bridge. However, efficiency through the various construction techniques described above and around-the-clock construction scheduling enabled this project to be completed in approximately 16 months less than the standard construction period. The Aso Ohashi Route on Japan National Route 325 opened to traffic on March 7, 2021, approximately 5 years after the 2016 Kumamoto Earthquake, restoring the main road network connecting the urban areas of Kumamoto City and Minamiaso Village, which the earthquake had divided (**Fig. 9**).

References

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概　要

阿蘇大橋は，2016年４月の熊本地震により落橋した旧橋の約600m 下流側に架け替えられた全長525m の道路橋である。対象の PC3径間連続ラーメン箱桁橋は最大橋脚高97m，最大支間長165m であり，この構造形式の橋としては国内有数の規模である。

本橋を含む国道325号阿蘇大橋ルートは観光や物流の面で重要な役割を担っており，工期短縮による早期開通が最大の課題であった。一方で，年間を通じて強風が吹き，柱状節理と呼ばれる亀裂が多い岩盤が広く分布した急峻な渓谷上での施工が求められた難易度の高い工事であった。

こうした課題を克服するため，大型インクライン，ACS セルフクライミングシステム工法や超大型移動作業車などの高度な施工技術を導入し，標準工期（５年半）に対して約１年４カ月の工期短縮を実現し，地震で分断された交通ネットワークの早期復旧に大きく貢献した。