The design technique of Chikugo River Bridge which will linger on The JSCE Civil Engineering Heritage site

Takayuki OMORI
Technical Designer
Oriental Consultants Co., Ltd. Fukuoka, JAPAN
ohmori@oriconsul.com

Shuji ONAMI
Aesthetic Designer
Oriental Consultants Co., Ltd. Tokyo, JAPAN
ohnami@oriconsul.com

Noboru ISHIKURA
Project Manager
Oriental Consultants Co., Ltd. Fukuoka, JAPAN
ishikura@oriconsul.com

Atsumi RYUEN
Technical Designer
Oriental Consultants Co., Ltd. Fukuoka, JAPAN
ryuen*@oriconsul.com*

Takuro KONNO
Aesthetic Designer
Oriental Consultants Co., Ltd. Tokyo, JAPAN
konno-tkr@oriconsul.com

Yuji HOSHINO
Associate Professor
Kumamoto University
Kumamoto, JAPAN
hoshino@kumamoto-u.ac.jp

1. Introduction

The Chikugo River Bridge will cross the largest river in Kyushu, surrounding by a large number of important designated historical heritages of the country.

Fig. 1: Chikugo River Bridge

On the other hand, The De Rijke Training Wall located in the center of the river was built for the purpose of securing ship courses in 1890 by Dutch engineer, Johannis de Rijke. It is an active civil engineering structure classified as “The JSCE Civil Engineering Heritage Site”.

Thus, this bridge design was aimed at protecting these landscapes and raising their value. In this paper, we demonstrate the design technique, including aesthetic and technical aspects of the continuous arches as a new form in Japan, in order to solve the above mentioned concerns.

2. Coexisting with historical heritage sites

The design concept should be able to harmonize with historical heritages and coexist with valuable sceneries, elevating the local symbol as a whole. Thus, the Chikugo River Bridge is aimed at the deuteragonist grade as a member to constitute the whole scenery.

We pay attention The De Rijke being an active engineering works heritage and a support of regional life. It was important to secure the function more than the figure. In other words, we place a pier at the De Rijke Training Wall to find a way of coexisting it with the historical heritage group to protect the landscape and the function of The De Rijke.

We arranged the value of The De Rijke’s one. Particularly, the historic value, not the figure form, is branded on the mind of people. We regarded this historic value as presence and pursued for a design to respect for the history of The De Rijke (*Fig. 2*). Our idea is to avoid concerning the texture of the surface, but to emphasize the training wall. We hope that the substructure succeeds in emphasizing the presence of The De Rijke.

Fig. 2: The design to respect for the history of The De Rijke Training Wall

3. Continuous Arches as the suitable form

The superstructure form is the steel 4-span continuous balanced arch bridge having 2 single chords. The trapezoid section is adopted as the arch rib without a knuckle line in a web to emphasize the arch. It will be shining with reflecting light equally. There is no other such superstructure form in Japan.

4. The design of the superstructure plate

The characteristic of this bridge is "The bearing part of continuous arches on the P6 substructure" and "The corner part where the arch rib is divided into two ways in the stiffening girder with the web plate twisted". It was necessary to research the characteristic of these structures, such as clearing the stress flow, method of fabrication and maintenance, etc.

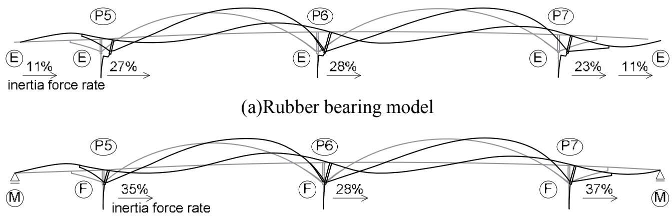
Planning of plate uses the FEM analysis for clarify stress flow, 3D-CAD simulated fabrication, considering the maintenance with the miniature. Reinforcement plates for the temporary support is adopted the staggered arrangement.

5. The evaluation of the seismic capacity against major earthquakes

The Chikugo River Bridge provides an important route for emergency transportation at time of disasters. Therefore, the design policy aims at "ability of quickly restoring bridges functions and limited damage" even in case of major earthquakes. Thus, there must be no damage at the pier on the De Rijke Training Wall, that is, this pier behaviour should be in the elastic region.

In the bridge axial direction, it was a problem that the substructures reached the ultimate state first. Therefore we adopted the fixed bearing model like Fig. 3 (b) to let P5 and P7 share a lot inertia force. At the major earthquakes, P5 and P7 absorb the inertia force and protect the P6 and The De Rijke Training Wall.

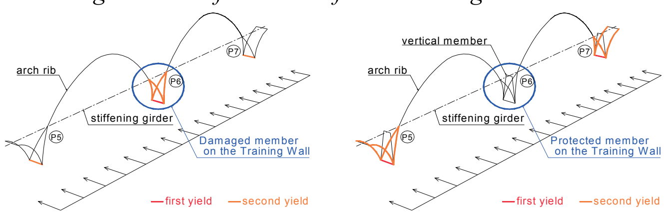
In the bridge axial-orthogonal direction, the sectional forces concentration occurs at Springing and horizontal members. This result shows the effect of improving superstructure stiffness by vertical members at P6 and the presence of vertical members can lead to differences in the limit state. Due to the importance of vertical members in seismic resistance, limit state is designed in order to have side spans (P5 and P7) damaged first.



(a)Rubber bearing model

(b)Fixed bearing model (adopted)

Fig 3: Inertia force rate of each bearing conditions



(a)Without vertical member model (b)With vertical member model (adopted)

Fig 4: Resistant performance by having vertical member or not

6. Study of the poor ground

The ground around the bridge is weak ground commonly in Japan. In this paper, the study policy is divided into 3 steps as following.

The first, it is confirmed that stress will not be larger than the yield stress even with new forces added. The safety factor in the over-consolidation amount is more than 1.5, with the lowest (around 2.0) at N1c layer right below the bearing layer. Consolidation is considered small.

The second, In case of long bridges, the effect of immediate and over-consolidated settlement cannot be neglected. The settlements are around 50mm to 90mm in the study. The safety side considered, the maximum settlement is set to be around 90mm when evaluating the superstructure sections.

The third, considering the worst scenario. The result suggests 100mm settlement at P6. However, the likelihood is extremely low, thus post-measures are adopted for this case, such as additional filler plate below under flange and so on.

7. Concluding remarks

This design would not be done without the cooperation from all involved parties. "Team building" and "respect other's ideas" are the most important keys in the ability to lead to the most suitable design. As in the study title, design technique is precisely "team building".