Construction of an Arch Bridge by Lowering Method

Kano River Crossing Bridge

The Kano River Crossing Bridge is a reinforced concrete deck, arch bridge under construction in Shizuoka Prefecture of Japan: a bridge with a length of 171 m and an arch span of 110 m. Since the Kano River is one of the best-known pristine rivers in Japan, environmental considerations required that piers should not be erected in the river. This type of structure was selected based on conditions of construction and seismic resistance considerations.

Developed in Italy in the 1950s, the lowering construction method has been used to build the arch bridges, with either concrete (photo 6) or steel members (photo 7) used for the arch members. In Japan, having many steep gorges, this method evolved as an effective method to construct arch bridges with spans of about 100 m. The method is not used for completely steel arch bridges. Also, for larger span, other construction methods such as the suspension support method may be adopted because of economic efficiency.

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1 Kano River Crossing Bridge after completing closure
2 General view of the whole bridge
3 Construction procedure
4 Comparison of lowering construction equipment
5 Lowering construction procedure

Because of the ground conditions at the site and in order to reduce the weight of equipment and subgrade reaction from the construction method, a lowering method with steel arch ribs was used for the erection of the Kano River Crossing Bridge (fig. 2). These temporary steel members for constructing an arch structure are called Melan's rigid reinforcement. By using lighter steel members (in comparison to concrete ones), the tension in the lowering cables is reduced. The steel member, with a total weight of about 360 tons, is manufactured in the factory and consists of elements with a length of about 6.0 m each. They were assembled by bolt joining at the construction site. After constructing partial arch rib members quasi-vertically at each abutment, the arch is formed by using cables to lower the members, rotating them to the specified position using the base footing as the center and closing the arch.

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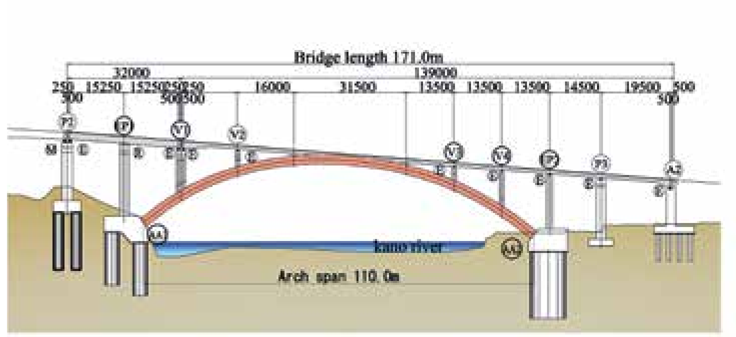

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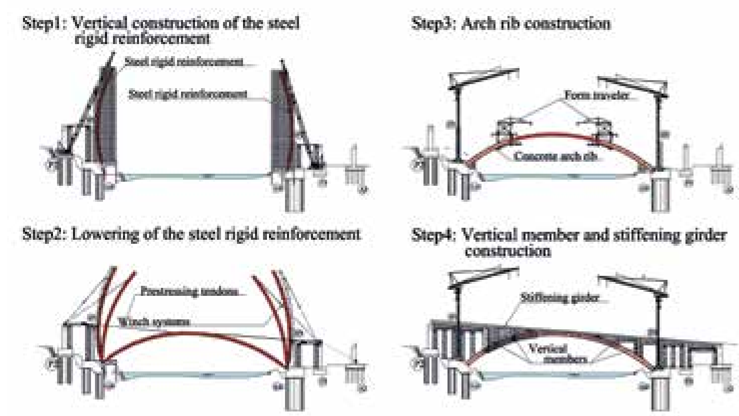

Construction Procedure

Figure 3 illustrates the entire construction procedure. The Melan's rigid reinforcement is erected using the lowering construction method to build the arch. The springing points, which are the base footings on both ends, are encased in concrete using falsework after closure of the arch. The form traveler is mounted above the springing point and the rigid reinforcement is encased in concrete, one step at a time on both sides, to complete the arch rib. Thereafter, vertical members and stiffening girders are constructed using scaffolding and falsework mounted on the arch rib to complete the bridge body.

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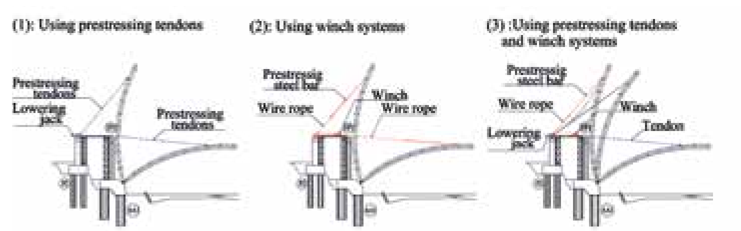

Lowering Construction method

There are three possible methods for lowering construction (fig. 4). When only a lowering jack is used on the prestressing tendons (fig. 4, option 1, and photo 11), safety issues arise concerning the wedge anchor of the strands because the tendon tensions are small at the initial stage of lowering. A method to pull in the rigid reinforcement with prestressing tendons from the opposite abutment is available, to ensure the minimum tension necessary to securely anchor the wedge. In this case, the equipment tends to be excessively large and construction time tends to be longer because of the difficulty of controlling tension during lowering. When only a winch system is used (fig. 4, option 2, and photo 8), several large winches are required, which makes it uneconomical because of the large-sized equipment, although construction time is shorter. Therefore, by conducting the lowering method with prestressing tendons using a winch system at the initial stage and a lowering jack at a later stage (fig. 4, option 3, and photo 10), both safety and economy can be attained.

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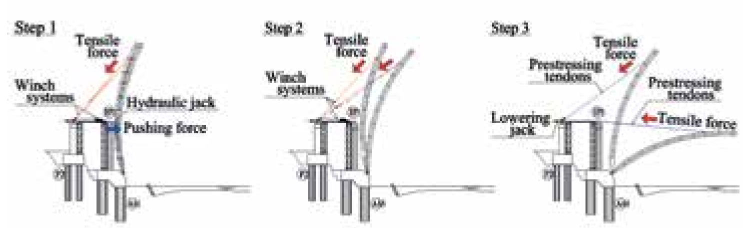

Figure 5 shows the lowering construction procedure adopted for this bridge, which uses different equipment according to the stage of lowering. In step 1, the rigid reinforcement is rotated forward by pushing with the jack since the center of gravity is at the end post side. During this time, the rigid reinforcement is being pulled by the winch system so that it does not fall suddenly while rotating. The procedure switches to step 2 when the center of gravity of the rigid reinforcement is in front of the

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center of rotation of the base. By loosening the winch cable in step 2, the rigid reinforcement is lowered by rotation under its own weight (photo 8 and 9).

When the angle of the rigid reinforcement is 18° and the tension is about 600 kN, the winch system is replaced with the jack system. Photo 10 shows step 3 of the lowering construc-

6 Lowering construction using concrete members
7 Lowering construction using steel members
8 Lowering construction procedure
9 Lowering with the winch
10 3 ton winch
11 Lowering jack system

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tion; Photo 11 shows the jack system. The jack system is composed of lowering jacks, prestressing tendons, hydraulic system and control panel. Two lowering jacks were installed at the rear of the concrete block set on top of the pier and were centrally controlled together from a control panel using two electric pumps. Prestressing tendons tension was at its maximum at 3040 kN immediately before closure. Two prestressing steel strands with 19 Ø15.2 mm strands were used for the prestressing tendons to obtain a factor of safety of more than 2.5 against rupture. Approximately 17 m of prestressing tendon was launched by the jack system during the lowering operation. A total of 110 strokes were used for launching, with 150 mm per stroke.

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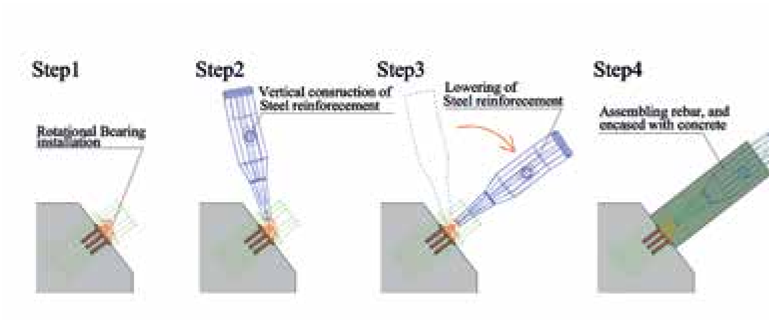
12 Construction procedure of the springing point
13 Rotational bearing installation
14 Rotational test



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Rotational bearings with through pin

Figure 12 shows the construction procedure of the springing point. At first, rotational bearings are installed. Next, steel rigid reinforcement is erected vertically and lowered by rotation. The rotational bearing and the steel rigid reinforcement are then encased in concrete.

Lowering the rigid reinforcement to its position accurately is important, since the form of the rigid reinforcement after lowering construction will affect the form of vertical members and stiffening girders and the form of this arch itself after the arch rib is completed. The accuracy of the rotational bearing installation is critical, since it serves as the center of rotation of the rigid reinforcement. The two bearings at each side were connected by a pin to reconcile their axis of rotation. Moreover, the bearings were joined at the plant, transported and erected together at the site to improve installation accuracy (photo 13).

After completing installation of the rotational bearings, temporary steel members were installed on the lowering bearings to perform a test for checking the installation accuracy of the rotational bearings. Photo 14 shows the confirmation test. By actually rotating the front while suspended with a crane, it was confirmed that there were no problems with the installation positions of the rotational bearings. This measure reduced the error in the level direction after completing the lowering to about 20 mm.

Central closure

Central closure was carried out after the rigid reinforcement members on both sides were rotated and lowered to the specified height. The central closure spacing was 50 mm. To handle the gap between bolt hole positions on both sides of the rigid reinforcement, splice plates were plant fabricated after measuring for the actual hole positions. Immediately after lowering was completed, the rigid reinforcement on both sides was connected by temporary splice plates and bolt hole positions were measured during the night, when temperatures are stable. Photo 15 shows the central closure; Photo 1 shows the panoramic view after lowering was completed.

Arch rib encasement work

Encasement work for the rigid reinforcement involved encasing the first block at both ends with concrete from the falsework, and then assembling the form traveler over the arch rib. Figure 16 shows the structural drawing of the form traveler. The form traveler weighs 1050 kN. It moves by tensioning a prestressing steel bar with a 500 kN jack installed in front and propelling itself forward on the rail installed over the arch rib.

To make the arch rib structure and construction more efficient, a new cross sectional structure was adopted where the rigid reinforcement is not filled with concrete and is placed outside the web.

15 Central closure
16 Construction procedure with the form traveler
17 Structural details of arch ribs
18 Comparison of cross section of arches
19 Conceptual rendering of the bridge

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Melan's rigid reinforcement is a temporary steel member, and the interaction between the steel member and the concrete member is not considered. The maximum thickness of the member is 25 mm for flanges and 17 mm for webs, and steel tensile strength is 490 MPa (fig. 17). Figure 18 shows a comparison of the cross section resulting from the old approach with that resulting from the new one. By baring the rigid reinforcement inside the box girder, web thickness could be freely set to its structurally required thickness and became unnecessary, thereby making construction work simpler and more efficient. This resulted in lower arch rib weight and improved seismic resistance.

Conclusion

Lowering construction was employed for the steel rigid reinforcement of the Kano River Crossing Bridge. Concrete encasement of the arch ribs is currently underway. Figure 19 shows the conceptual rendering of the completed bridge. Construction of this bridge is scheduled for completion in February 2018. ☒

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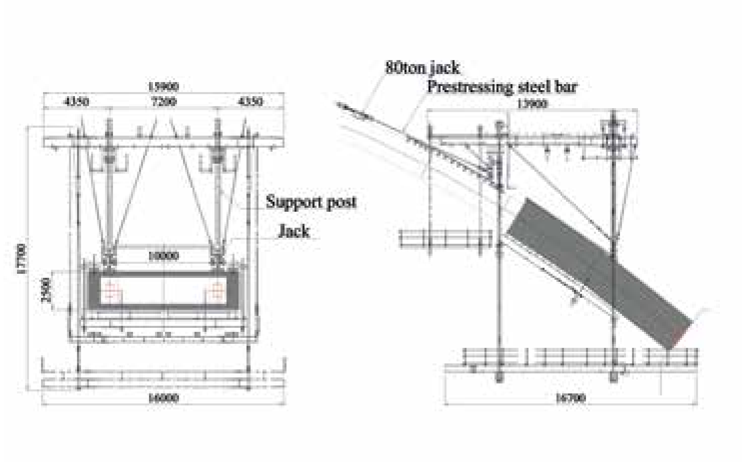

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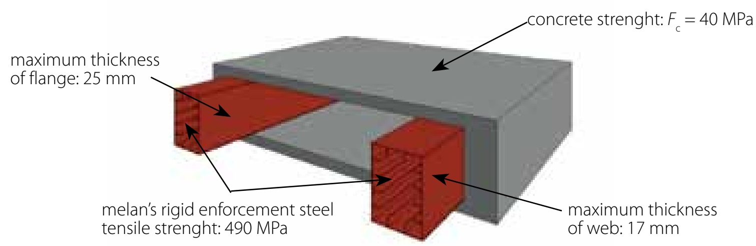

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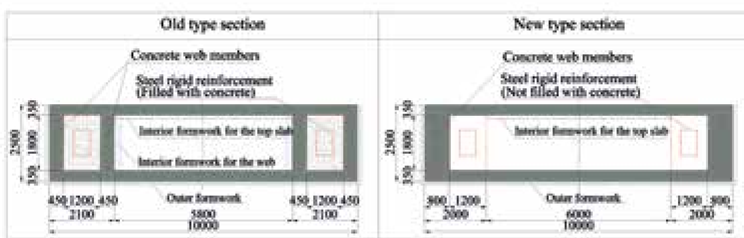

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