THE LATEST TECHNOLOGIES OF PRESTRESSED CONCRETE BRIDGES IN JAPAN

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SUMMARY

For more than 50 years prestressed concrete is one of the most important construction materials in not only Japan but also all over the world especially in the field of bridge construction. Since the first prestressed concrete bridge was constructed in 1952, tremendous prestressed concrete bridges have been constructed in Japan. In this paper the latest technologies, an extradosed bridge, a cable stayed bridge, a stress-ribbon bridge and truss bridges of the prestressed concrete and steel-concrete composite structure in Japan are introduced.

Keywords*: Prestressed concrete bridge; extradosed bridge; cable stayed bridge, stress-ribbon bridge; composite bridge; truss bridge*

A STEEL-CONCRETE COMPOSITE EXTRADOSED BRIDGE
KISO & IBI RIVER BRIDGE

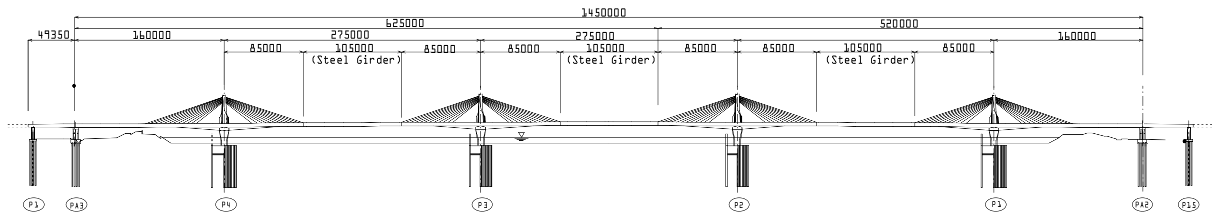

Fig.1 Side view of KISO River Bridge

Location : KISO & IBI River Bridges are located near NAGOYA city, 370 km west of Tokyo. These are a part of the New MEISHIN Expressway between NAGOYA and KOBE city.

Outline of the bridge : The KISO and IBI River Bridge are 1,145m (=160+3@275+160m) and 1,397m (=154+4@271.5+157m) long respectively. Both bridges are 33m wide with six traffic lanes. The depth of the concrete girder varies from 7m at the supports to 4m at the standard section. The depth of the steel girder is uniformly 4m. The height of the pylon is 30m.

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The external tendons (stay cables) are longitudinally arranged at the center of the section as a single-plane suspension system.

Structural characteristics : The KISO and IBI River Bridges are prestressed concrete-steel composite, five and six span continuous, extradosed box girder bridges respectively. In the extradosed bridge the tendons are placed externally with very large eccentricity and they are anchored at the pylon and post-tensioned from the girder side. Regarding the differences between the extradosed and cable stayed bridge the height of the pylon and the depth of the girder of this new type of bridge are shorter and higher than those of the counter one respectively. Very costly post-tensioning is executed once as external tendons in the extradosed bridge, while the post-tensioning stay cables (adjustment of deflection) must be done many times in the cable stayed bridge.
In order to reduce the self weight of bridge the steel girders of around 100m long are employed at the central section of middle spans. This renders the span much longer.

Construction : For the concrete sections the segmental free cantilever construction was adopted. Precast concrete box segments were pre-fabricated in casting yards, 10-15km away from the construction site, and transported to the bridge position with a barge. The column capital segment, whose weight is approximately 400 tons, was erected from a floating crane barge. Cantilever erection of precast concrete box girders excepting the column capital segments is executed with erection noses. The strength of concrete is 60 N/mm^2. The short-line-match-cast technology was employed, in which the side surface of a already cast concrete is used as a formwork for a next segment. The number of all segments is 360.
After the completion of concrete sections the steel girder, which was manufactured in a factory (approximately 2,000 tons), were transported with a barge and lifted into the final position from the reaction girders installed at the end of main concrete girders already in place. The steel girder was fixed tightly to the concrete girders to close the span.

Photos : Photo 1-1 and 1-2 show the completed bridge and the bridge under construction after the completion of the concrete sections respectively. The erection noses for the concrete segmental girders are seen at the end of the girder in Photo 1-2. In photo 1-3 the central steel girder is under erection. Photo 1-4 shows the short-line-match-casting and photo 1-5 the view of the prefabrication casting yards.

Photo 1-1 Completed KISO River Bridge

Photo 1-2 After the completion of concrete

Photo 1-3 Erection of the central steel girder

Photo 1-4 Short-line-match-casting

Photo 1-5 Prefabrication casting yard

A HYBRID CABLE STAYED BRIDGE
YAHAGI-GAWA BRIDGE

Location : The YAHAGI-GAWA bridge, a part of the New TOMEI Expressway, crosses YAHAGI-GAWA River at 50km east of NAGOYA city. This bridge is located near the place of EXPO 2005 AICHI.

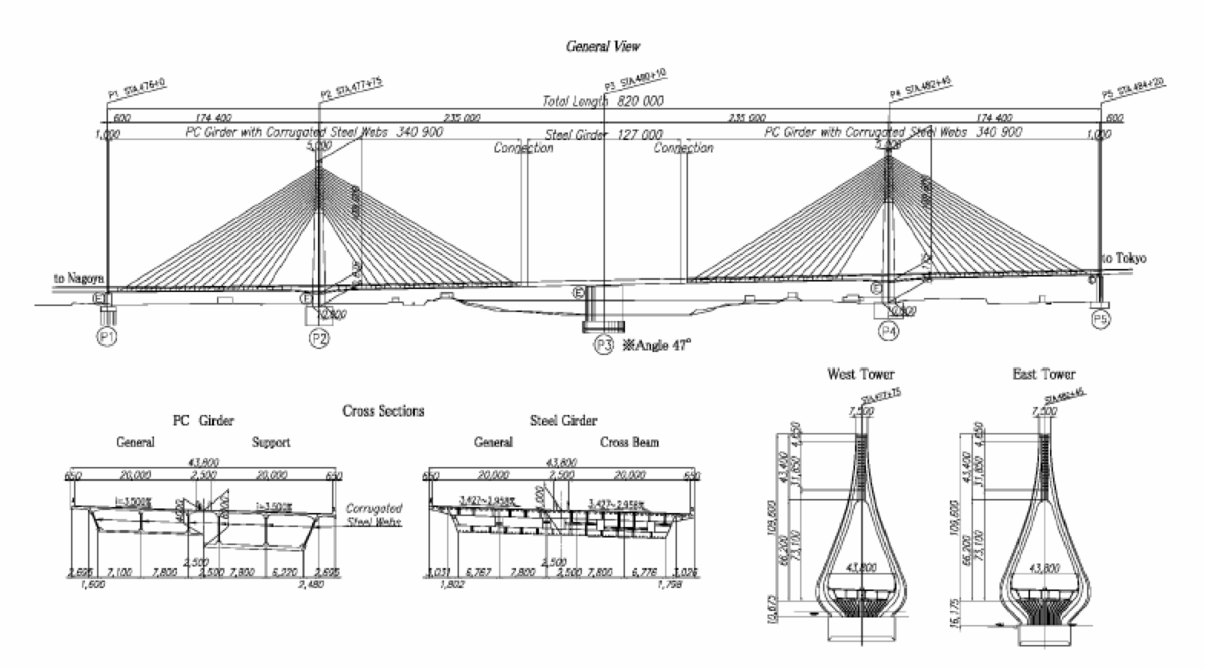

Fig.2 Side view and sections of YAHAGI-GAWA Bridge

Outline of the bridge : The bridge length is 820m (=175+2@235+175m) and the width is 43.8m with eight traffic lanes. The height of pylon is 109.6m from the bearing level. The depth of girder varies from 6m at the pylon to 4m at the standard section.

Structural characteristics : YAHAGI-GAWA bridge is a hybrid cable stayed bridge composed of prestressed concrete girders with corrugated steel webs and a steel girder of 127m long, which is mounted at the center support. This is the first application of corrugated steel web to the prestressed concrete cable stayed bridge in the world. The single plane stay cables suspend the bridge composed of five-cell box girders of 43.8m wide. In order to avoid very complicated reinforcing around the anchorages of stay cables at the girder ends prefabricated steel plate anchor beams, which are embedded in the upper and lower decks, are employed.
Because of aesthetic reason the pylon has a curved shape, simulating a drop of water. Since this complicated shape causes large forces in the pylon, steel shell structures are embedded in the concrete pylon as reinforcements instead of conventional re-bars. Against large shear forces set up at the connection between the pylon and column horizontal prestressing tendons, which are curved downward at the end of tendons, are placed to counteract the shear forces.

Construction : The pylon was divided in four sections and the each section was executed in different scaffolding systems suitable to the section. For instance at the middle part, where the pylon has two columns, a climbing scaffolding system was adapted.
The superstructure was constructed in free cantilever method using a traveler. All steel members of corrugated webs, diaphragms and anchor beams, significant re-bars and the formworks for the upper deck were prefabricated as a unit on the ground under the side span and transported to the traveler. The rest of reinforcement of re-bars, external longitudinal prestressing tendons inside the box girder and transverse tendons embedded in the upper deck were placed in the position and concreting the lower and upper decks were followed. This prefabrication allowed the very rapid construction to take place and the bridge was completed within the planned term of construction.
The steel girder of 127m long and 4,250 tons mounted at the center support was erected with the free cantilever method, balancing the weight of girders of both sides and closed to the concrete sections.

Photos : Photo 2-1 shows the completed bridge. The climbing scaffolding system for the pylon can be seen in Photo 2-2. Photo 2-3 show the free cantilever erection with the traveler.

Photo 2-1 the completed YAHAGI-GAWA Bridge

Photo 2-2 Climbing scaffolding for the pylon

Photo 2-3 Free cantilever erection with the traveler

A COMPOSITE STEEL TRUSS BRIDGE WITH CONCRETE SLABS
SHITSUMI-OHASHI BRIDGE

Location : SHITSUMI-OHASHI Bridge is located in a mountain area, 300km west of OSAKA city. It crosses a artificial lake of SHITSUMI dam.

Outline of the bridge : The bridge length is 280m (=65+75+60+45+35m) long and 10.75m wide. Girder depth varies from 6.5m to 2.5m.

Structural characteristics : The bridge is a 5-span continuous composite truss bridge with concrete upper and lower slabs and steel pipe webs. It consists of a composite truss structure from abutment A1 to pier P3 and a conventional prestressed concrete box girder structure for the remaining part to abutment A2. As shown in Fig.3-2, the joint has a shear key and the whole junction is embedded in the concrete slab. The performance was verified by full-size

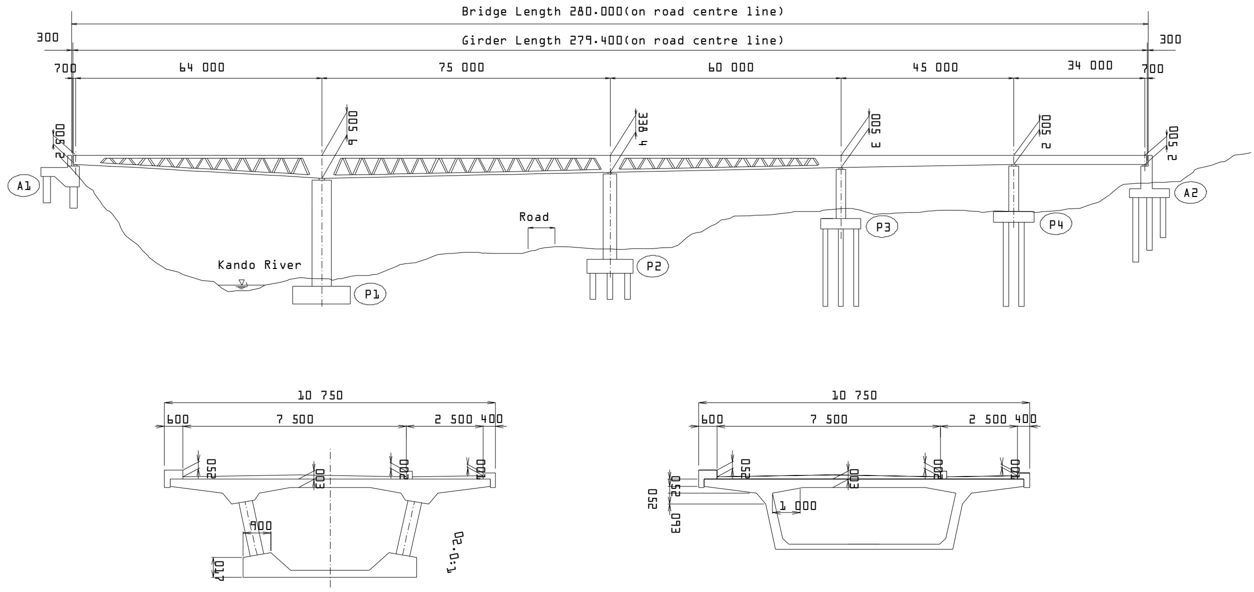

Fig.3-1 Side view and sections

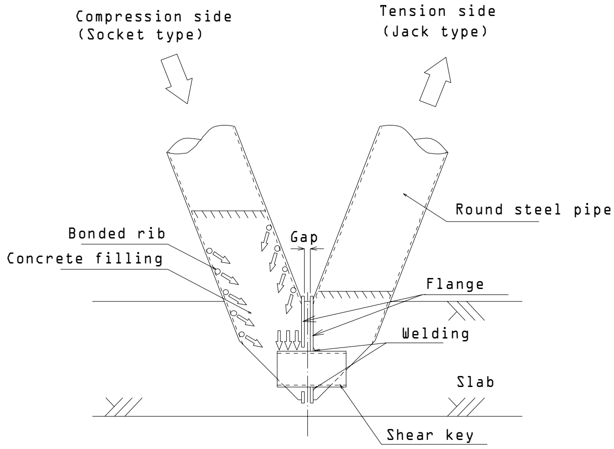

Fig.3-2 The joint structure

load bearing test and fatigue test. The compressive force to be transmitted to the steel pipe is transmitted to the concrete filling inside the compression pipe through the round steel ribs welded to the inside of the steel pipe, and the force is transmitted to the tension diagonal member through the shear key welded only on the tension diagonal member side. The structure is the same on the upper and lower slab sides.

Half of the steel truss member (steel pipe) is embedded at the both ends of the column head concrete web. In order to transmit the force from the truss member to the concrete web dowels, studs and steel bars are welded at the embedded surface of the steel pipe. The steel pipe is filled with concrete to reduce not only stress concentration at the bottom of the truss member but also the influence of temperature change between the steel pipe and concrete web.

Construction : A pylon was placed at the pier P1 to suspend the girders temporally and free cantilever construction was executed from pier P1 to abutment A1 and pier P2 using a traveler of the capacity of 3,500kNm. The segment length was 5m and 10 segments were erected on each side. The other spans were in-situ concreted on the shoring.

Photos : Photo 3-1 shows the completed bridge. Photo 3-2 and 3-3 show the joint and the bridge under erection respectively.

Photo 3-1 the completed bridge SHITSUMI-OHASHU Bridge

Photo 3-2 joint

Photo 3-3 the bridge under erection

A HYBRID STRUCTURE OF STRESS-RIBBON DECK AND TRUSS
NOZOMI BRIDGE

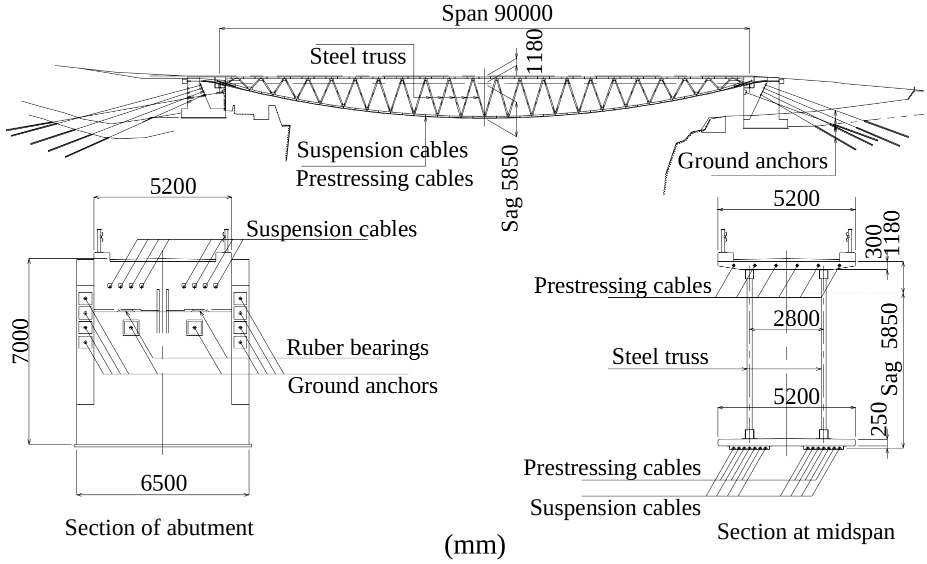

Fig. 4-1 Side view and sections

Location : NOZOMI Bridge is located in front of MARUYAMA Dam over KISO River, 50km north-northeast from NAGOYA city.

Outline of the bridge : The bridge is 90m long and 5.2m wide. Unlike a stress-ribbon bridge, which is generally used as a pedestrian bridge, this is a roadway bridge, although this looks like a stress-ribbon bridge. Since the bridge was planed to provide a access road to the dam construction site, very heavy traffics were expected to pass frequently through the bridge.

Structural characteristics : The bridge is a hybrid structure consisting of a stress-ribbon deck and truss chords consisting of diagonal steel pipes and concrete lower deck. This hybrid bridge has advantages over the stress-ribbon deck bridge since the former exerts much less horizontal force in suspension cables and has higher flexural stiffness than those in the latter. Studies show that the maximum horizontal reactions at the abutment and the deflection at the mid-span due to live load are significantly reduced to approximately the half of those in the stress-ribbon bridge. Therefore this new type of hybrid bridge is applicable to a roadway bridge. Nozomi Bridge is not only a hybrid structure combining stress-ribbon deck and truss, but also a composite structure combining precast concrete panel and steel pipe. The self-weight of truss girder is supported by suspension cables and does not set up any stresses in members of the truss chords. And the surface and the traffic loads are supported by the truss girder and do not increase any stresses in the suspension cable since the flexural stiffness of the truss girder is much higher than that of the suspension cable.

Construction : This bridge has advantages over the truss bridge because the hybrid bridge can be constructed in a similar way of the stress-ribbon bridge without costly false works and erection equipments. Fig.4-2 shows the construction procedure of this bridge.

Photos : Photo 4-1 and 4-2 show the completed bridge and the erection of truss chords.

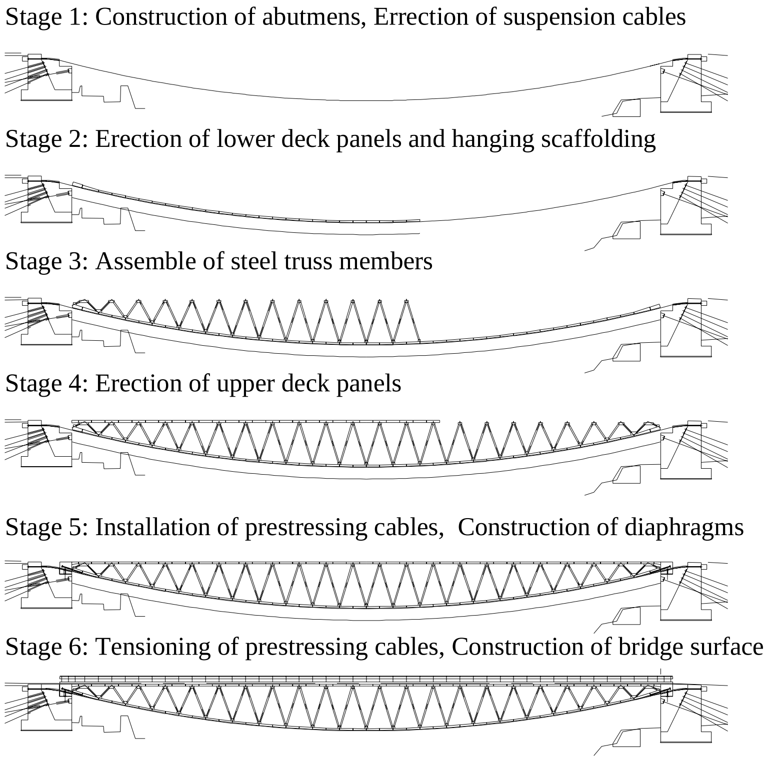

Fig. 4-2 Construction procedure

Photo 4-1 Completed NOZOMI Bridge

Fig.4-2 Erection of truss chords

A STRESS-RIBBON BRIDGE WITH EXTERNAL TENDONS
MORINO-WAKUWAKU BRIDGE

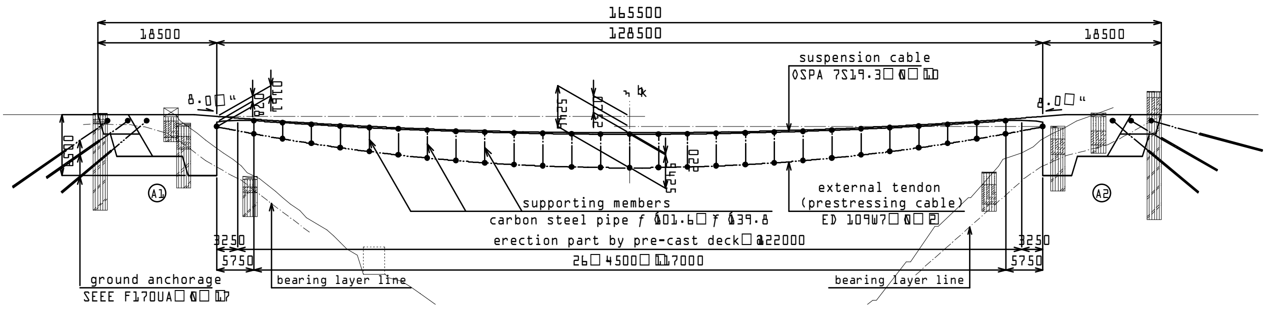

Fig.5-1 Side view

Location : MORINO-WAKUWAKU Bridge is located in a park, 200km north of TOKYO.

Outline of the bridge : This bridge is a pedestrian bridge and the first stress-ribbon bridge with external tendons in the world. The bridge is 128.5m long in span and 4.4m wide. The depth of the deck is 22cm.

Structural characteristics : The bridge consists of the conventional stress-ribbon deck and external tendons which are connected to the concrete deck with supporting members (carbon steel pipe). The horizontal force acting on substructures, which is a very troublesome problem for the stress-ribbon bridge, decreases to

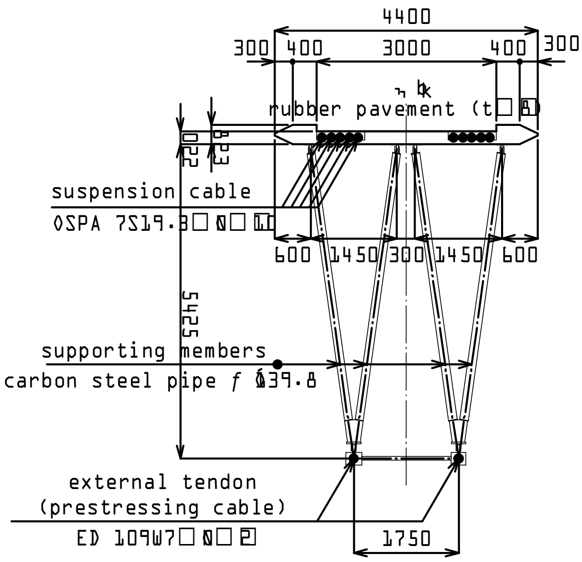

Fig.5-2 Section

about 70% by setting larger sag of external cables than that of the concrete deck. The flutter vibration in this bridge is generated with higher wing velocity than that in the conventional stress-ribbon bridge.

Construction : A prefabricated unit consisting of a pre-cast concrete deck, supporting members and a hanging scaffolding was erected with a crane and it was slid on the suspension cable embedded in the concrete deck. After the external tendons were placed in the position they were tensioned to the desired force.

Photos : Photo 5-1 shows the completed bridge and photo 5-2 during sliding erection.

Photo 5-1 Completed MORINO-WAKUWAKU Bridge

Photo 5-2 Sliding erection

A PRESTRESSED CONCRETE TRUSS BRIDGE
KAMAN-TANI BRIDGE

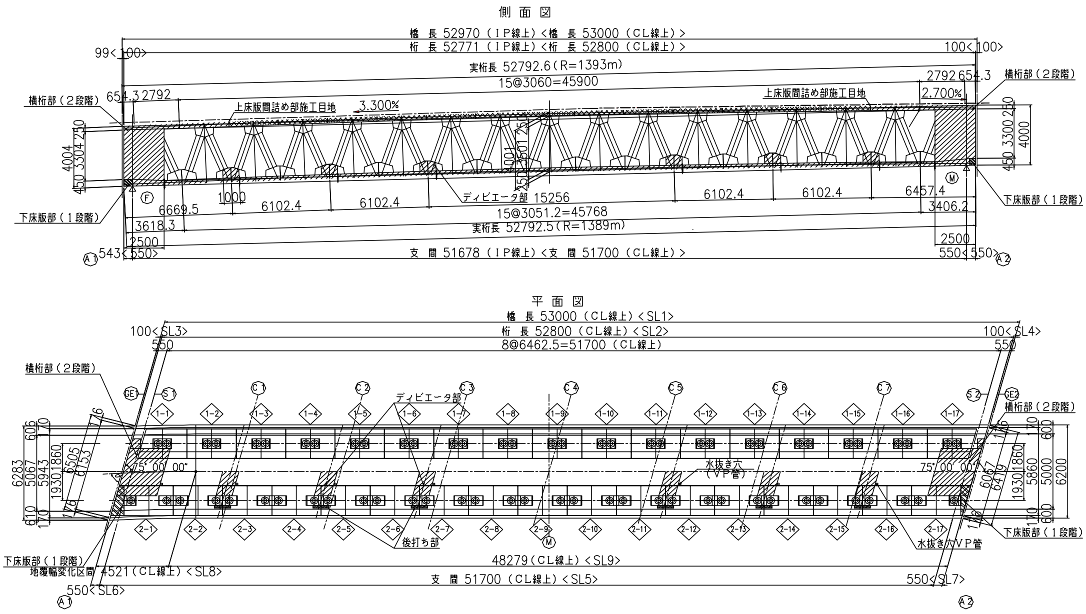

Fig.6-1 Side view and plan

Location : The bridge is located in SHIKOKU Island, 150km southwest of OSAKA city.

Outline of the bridge : KAMAN-TANI Bridge is a prestressed concrete truss bridge, 53m long and 6.2m wide. There are four prestressed concrete railway truss bridges in Japan, while this is the first roadway prestressed concrete truss bridge.

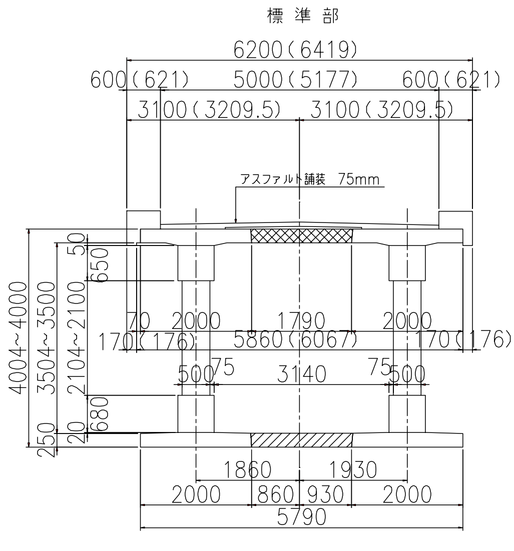

Fig.6-2 Section

Structural characteristics : Both the diagonal concrete members and the lower concrete deck and the whole structure are internally and externally post-tensioned to counteract tensile stresses set up mainly due to the dead load and live load respectively. Furthermore the joints, diaphragms and deviators are in part prestressed to counteract tensile stresses set up due to stress concentration. The design interests are in the principal tensile stress at the serviceability limit state and the shear resistance at the ultimate limit state in the joint.

Construction : The bridge was constructed in the segmental construction strategy, in which the bridge was divided into two main girders. Fig.6-3 shows a precast segment composed of both the upper and lower deck, two diagonal members and joints. The concrete strength of both the deck and joint and the diagonal member are 50 and 60N/mm^2 respectively. The diagonal members were manufactured in a concrete pile factory for the centrifugal compaction. Five segments were match-cast in a line sequentially. After separating the segments the last one was moved to the first position and the same way was repeated.

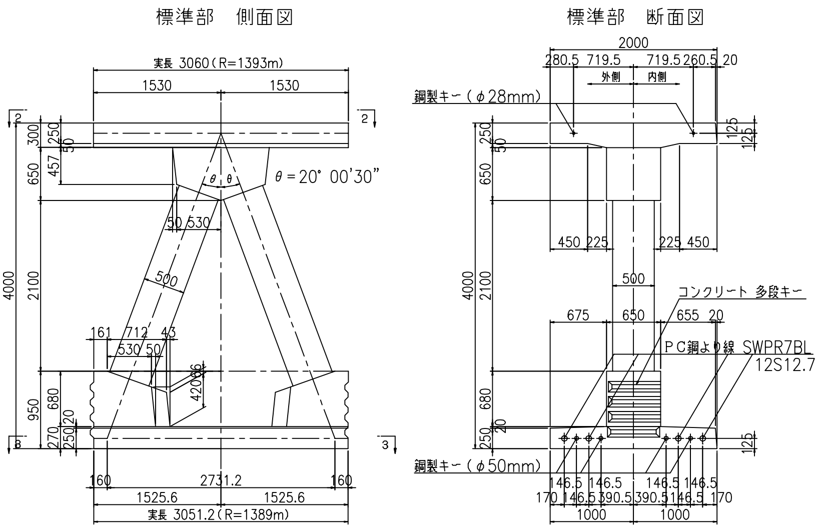

Fig.6-3 Precast segment

Segments were transported to the site, assembled and post-tensioned to put segments together. Two main girders were erected with a launching girder, joints between two main girders were in-situ concreted and the bridge was externally post-tensioned.

Photos : Photo 6-1, 6-2 and 6-3 show the completed bridge, segment prefabrication and erection of a main girder.

Photo 6-1 Completed KAMAN-TANI Bridge

Photo 6-2 Segment fabrication

Photo 6-3 Under erection

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