Colorado River Bridge

The Colorado River Bridge is a concrete-steel composite arch bridge located 460 m downstream from the Hoover Dam, one of America's national historic landmarks. The total reservoir storage of the dam is about 40 billion tons, which greatly exceeds the reservoir storage of all dams in Japan. The bridge that now symbolizes the dam is the longest concrete arch bridge in North America.

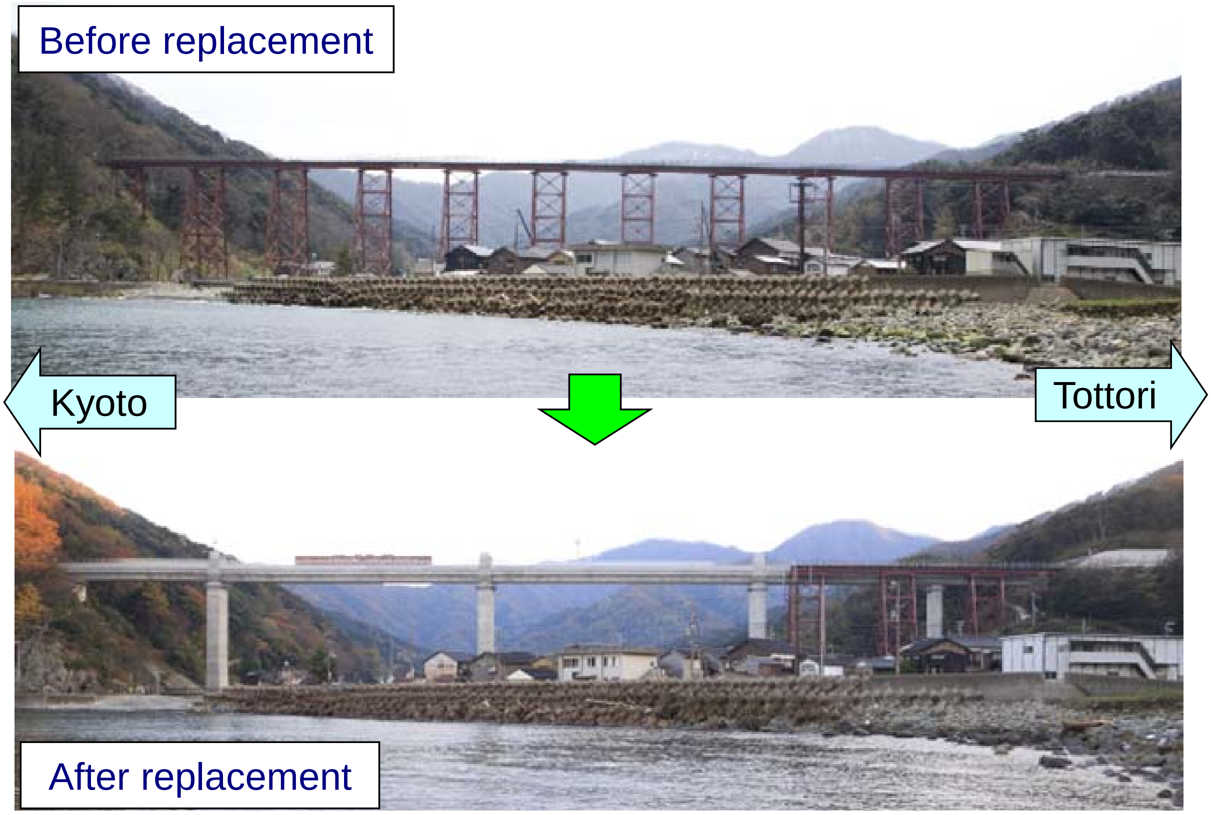
The 5.6 km long Hoover Dam Bypass Project, of which this bridge spanning the Colorado River is part, aims to alleviate congestion on United States Highway 93, a major highway linking the states of Utah, Nevada, and Arizona. Because the highway crosses over the dam, which also attracts many tourists, traffic jams and vehicular collisions with dam installations and accidents involving tourists had become issues. As a result, there was increased demand for a bypass route.

The first study of a possible bridge began in 1972. Various investigations, including selection of the actual bypass route, the assessment of environmental effects, and determination of bridge type, were completed in the years since.

The specific characteristics of the bridge, including its structural type and its location, many unique construction methods were brought to bear during its construction, utilizing highly advanced technology. There were many challenges to overcome, including the cantilever erection of long-span arch ribs by the pylon method, the construction of piers up to 87 m in height using precast segments, and the measures implemented to allow placement of mass concrete in the hot sun at temperatures over 40°C. Although construction work was extremely difficult, the arch section was finally closed in August 2009 and construction was completed in August 2010. The bypass opened to traffic in October 2010.

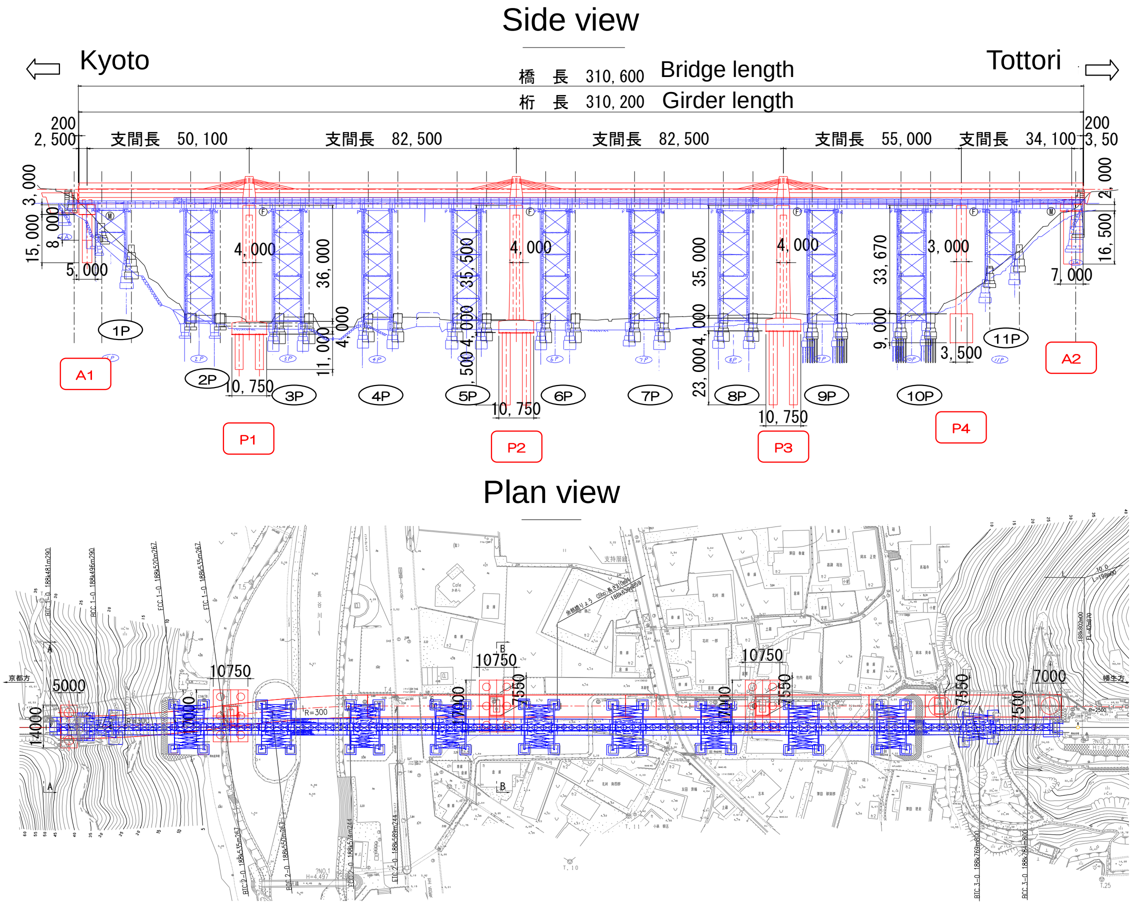
Amarube Bridge

○ **Overall view of the bridge**



○ **Overview of construction**

The Amarube Bridge is a 310 m long five-span continuous PC box girder extradosed bridge about 41.5 m high built as a replacement for the old Amarube Bridge about 7 m to its south. It is located between Amarube and Yoroi Stations on the Japan Railway San'in line. (See Figure 1.) The old bridge is a steel trestle completed in 1912, so is about 100 years old. After an accident in which a train overturned and fell from the bridge, wind speed restrictions on train services were tightened. As a result, there have been many more delays and cancellations due to strong winds. The Council for Countermeasures for the Amarube Bridge, tasked with finding solutions to these problems and improving train service punctuality and safety, had been carrying out studies and has also installed windbreak walls since 1991. These studies led to the decision to replace the bridge with a new concrete one, based on the need to ensure safe and reliable transportation and the requirement for realistic maintenance procedures. Construction of the new bridge began in 2007. In the summer of 2010, train services were suspended for 26 days while the new bridge was linked to the existing tracks, and the new bridge entered service on August 12.



Red line: New bridge, Blue line: Old bridge

Figure 1 Bridge structure

○ Features of the new bridge

(1) Designed to withstand the harsh natural environment (salt damage and strong winds)

To cope with the harsh coastal environment, a durability verification was performed in accordance with the JSCE Standard Specifications for Concrete Structures and the Design Standards for Railway Structures and associated Commentary. Based on an on-site survey of airborne salt content, suitable chloride ion concentrations were set for the verification for each part of the bridge. The water-cement ratio and the concrete cover were set at not less than 45% and 130-200 mm for the bridge piers and not less than 40% and 80 mm for the girders, respectively, to ensure a design service life of 100 years.

To investigate countermeasures against the strong winds at the bridge site, a wind tunnel test using a model (at 1:40 scale) was implemented. Considering the time taken by trains to cross the bridge, the percentage rise in maximum wind speed in this time (the rate of rise in peak wind velocity), and the relationship between windbreak height and critical overturning wind speed, windbreak walls with a height of 1.7 m were selected.

(2) Designed to take over the symbolism of the old bridge

To take over the symbolism of the old bridge, a design concept based on the ideas of "simple beauty in straight lines" and "a sense of transparency that blends in with the landscape" led to low-profile girders of equal depth (3.5 m). (See Figure 2.) These equal depth girders were realized by adopting a pin-joint structure where the girders meet the middle bridge piers.

(3) Earthquake-resistant design responding to special features of the ground and the structure

The new bridge crosses between mountains and the piers stand on irregularly bounded ground of greatly varying bearing capacity. To deal with this, a three-dimensional time-history response analysis was carried out using seismic waveforms developed to match the ground response.

(4) Traversing and rotation of girders with a total weight of 3,820 tons

The basic technique used to erect the girders was the cantilever method. (See Photo 1.) On the Kyoto side, however, the track immediately crosses the bridge after exiting a tunnel, so the following method of construction was adopted at this end (Figure 3 and Photo 2): (i) the superstructure of the end girder was erected by the cantilever method to the south of the old bridge; (ii) after train services were suspended and the old bridge girder, which interfered with the placement of this end girder of the new bridge, was removed, the new bridge girder was moved in a parallel direction by about 4 m; (iii) after completion of the parallel movement, the girder was rotated by 5.2 degrees to align it with the tunnel and the other girders; (iv) following concrete placement in the closing section, the track was laid.

The period of service suspension resulting from the track changeover was reduced by replacing the old bridge with the pre-fabricated new girder while realignment of the existing track was taking place (track changeover work) and eliminating the jacking-down and replacement of bearings by using permanent bearings and stoppers during the traversing and turning operation.

○ Effects of bridge replacement

Once the new bridge was opened to traffic, the wind speed at which train service restrictions came into force was increased from 20 m/s to 30 m/s. In the first six months of operation until the end of January, restrictions were imposed on six trains when wind speeds exceeded 30 m/s. The (estimated) number of train services that would have been affected if the wind speed restriction remained at 20 m/s was 112; that is, the number of affected train services was reduced by a factor of about 20, which indicates a substantial improvement in service punctuality. In this way, the new bridge contributes to safe and reliable transportation in the region.

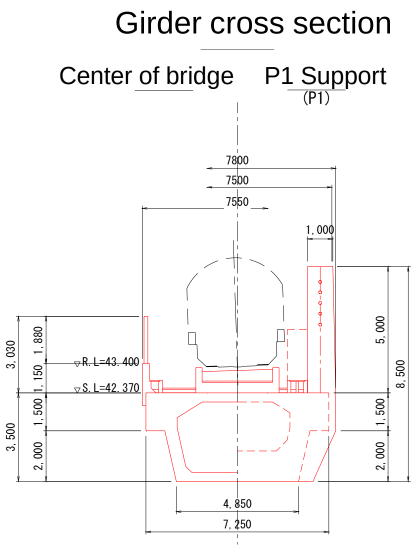


Figure 2 Cross-section of girder

Photo 1 cantilever method of girders erection

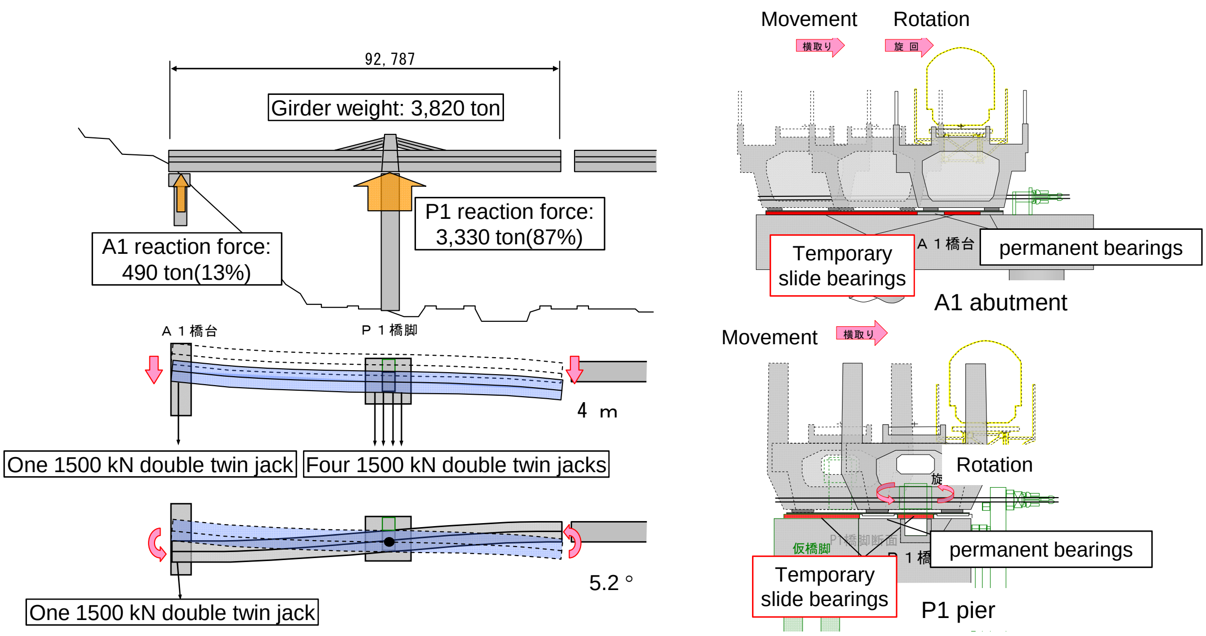


Figure 3 Schematic representations of girder traversing and rotation

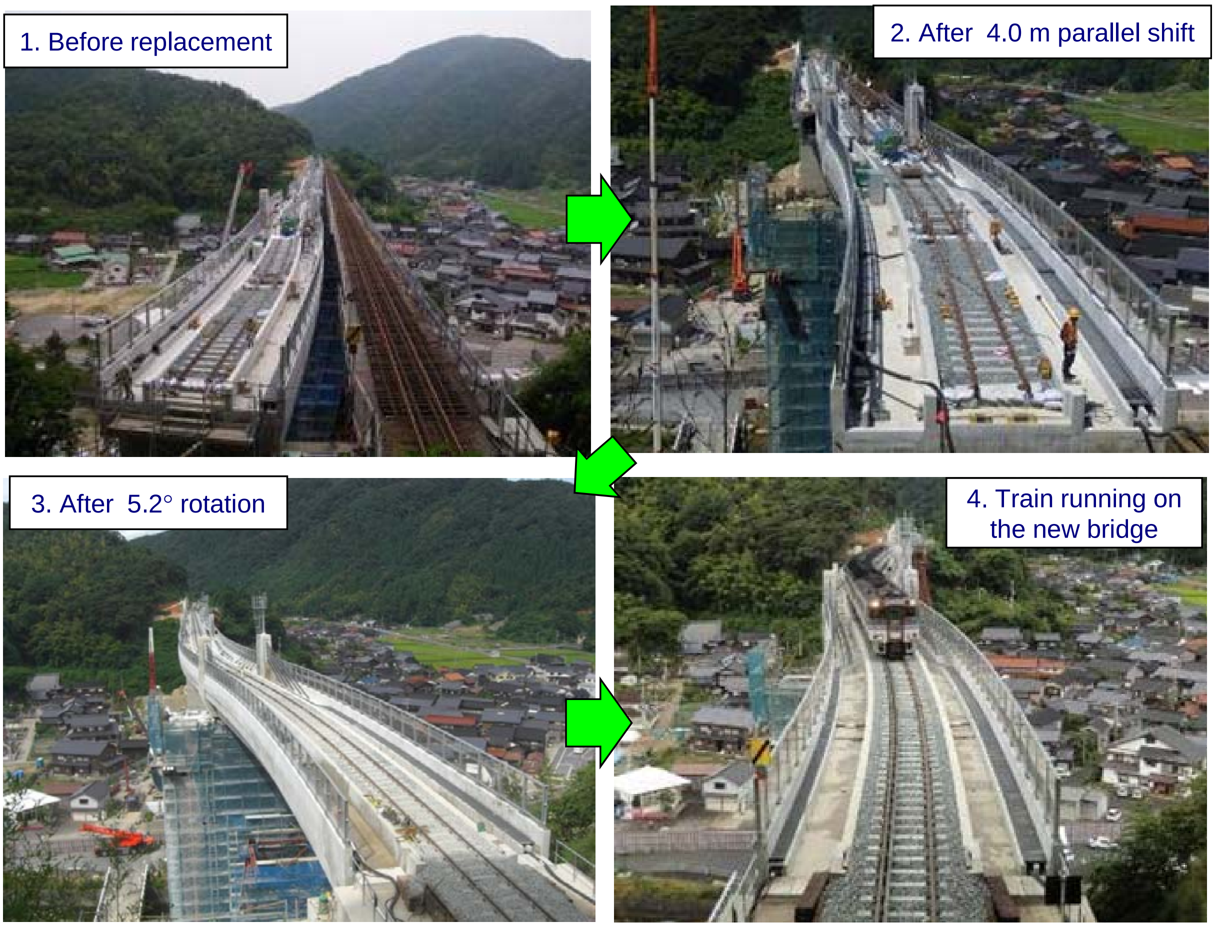


Photo 2 Connection with existing railway by girder traversing and rotation

Fudo Bridge (formerly 2nd Yanba Dam Bridge)

The Fudo Bridge was constructed as part of a replacement road needed for the Yanba Dam Project on the middle reaches of the Azuma River in Gunma Prefecture. The five-span continuous rigid-frame bridge with a length of 590 m is the world’s first PC composite truss extradosed bridge in which the technologies for PC composite truss and extradosing are combined. Of the PC composite truss bridges in Japan, this bridge has the smallest girder depth (6 m) and the greatest girder span (155 m).

A new structure was adopted for the panel points of the deck and truss, where a greater load-bearing capacity than that in a conventional structure was required. An FEM analysis was carried out and various loading tests were conducted to verify the safety of the completed structure.

The design takes preservation of the local landscape fully into consideration and the highly transparent superstructure, which is a particular feature of PC composite truss bridges, avoids all sense of spoiling the view.

Weather-resistant steel is used for the steel trusses to improve maintainability and durability. Semi-prefabricated cables of non-grouted heavy-duty structure were used for the diagonal members and external cables.