Using Steel Arches to Construct Large Concrete Arch Bridges: Kashirajima Bridge on a Town Roadway, Hinase Kashirajima Route

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The Enlargement of Concrete Bridges

Currently, the largest span of domestic large concrete bridges, whether a girder bridge or a cable-stayed bridge, stalled at around the latter half of the 200m range and the breaking of the record of length has hit a plateau in recent times. Arch bridges are in a similar situation and currently the longest domestic arch bridge is the Second Tomei Expressway's Fujikawa Bridge with a central span of 265m.

The lengthening of concrete bridges which carry large dead load require a wide variety of advanced technology such as data analysis, material technology, and construction technology. What kind of new bridge technology is currently needed to increase the span length?

There are only 4 concrete arch bridges with spans over 200m in length constructed in Japan (6 if you include bridges currently under construction), but with the boom in cable-stayed bridges over and girder bridges leveling off, currently, a silent boom in arch bridges has arrived. It is said that arch bridges take twice the work of regular bridges due to the difficulty of construction and curve profile of the formwork but the superior structural beauty after completion enhances the surrounding environment and becomes a multifaceted symbol of the region. According to the report by the Large-span Concrete Arch Bridge Design Method Research Sub-committee, JSCE Structural Engineering Committee, concrete arch bridges as a complete structure can not only be 600m but provide a stable structure for even greater spans.

The issue is how to implement the construction. Regarding this issue, the construction technology used in the recently visited Kashirajima Bridge gives us a hint. An arch bridge is being constructed on Seto Inland Sea's Kashirajima Island, located in Wake County of Okayama Prefecture. We visited the site upon hearing that a new measure is being implemented in the arch bridge's construction method to find out more.

A Large-span Concrete Arch Bridge Connecting Islands

The Kashirajima Bridge is being constructed in Hinase Town, in Okayama Prefecture's Wake Country.

Hinase Town is in the southeastern edge of Okayama Prefecture and includes the "National Park-Hinase Islands," a group of 13 islands of various sizes in the Seto Inland Sea and the most heavily populated of the Hinase islands is the Kashirajima Island. This island's history begins when it was first populated by people from Hinase Town around 200 years ago. The island has various public facilities with an active tourist industry revolving around private hotels and tourist fishing, making it a center of activity among the islands. Hinase-Kashirajima Route, a town road, connects Kashirajima and Kakuijima Islands and plans to cross the strait to connect to Banshu Akaho (Figure 1).

Photo 1　Construction of the Kashirajima Bridge

Figure 1　Location of the Kashirajima Bridge

Kashirajima Bridge connects Kashirajima Island to the neighboring Kakuijima Island and is a composite arch bridge with a central span of 218m (Photo 1, Chart 1).The following explains the structural characteristics of the bridge and the many new methods implemented from the construction perspective.

Chart 1 Construction Overview

構造規格	第3種第4級，A活荷重，設計速度40km/h
橋　長	300.000 m（アーチ支間長218.000 m）
有効幅員	6.500 m
構造形式	【上部工】複合アーチ橋 【下部工】直接基礎
架設工法	メラン併用斜吊り張出し工法
工　期	2000（平成12）年3月8日 ～2004（平成16）年10月30日
橋梁事業費	約29.9億円

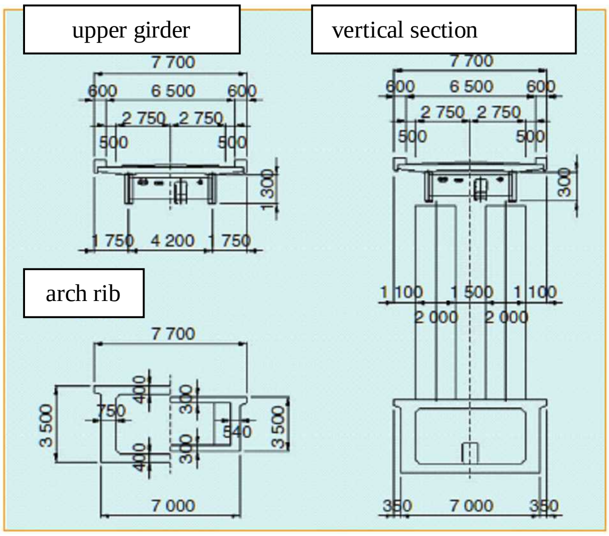

Figure 2　General Drawing (Cross-section)

Structural Characteristics

The structural characteristic of the Kashirajima Bridge is that the arch rib and vertical members are composed of RC while the upper girder adopts two steel main girders.　As a result, the axial force that influences the arch rib size is greatly reduced. For a large-span arch bridge with an arch central span exceeding 200m, the span to rise ratio is 8.0 (=arch span length/arch rise, generally 3.0-8.0), making an extremely flat arch bridge (the dead load of the arch rib is reduced by roughly 30%). It goes without saying that this leads to a reduction in the construction costs. Also, maintenance and management measures for the steel upper girder include new technology such as lead-aluminum spraying. This anti-rusting technology increases initial costs by 20% compared to traditional heavy corrosion proofing but makes re-coating after opening unnecessary, so it reduces lifecycle costs to under 50%.

Another structural characteristic is the use of high-strength concrete with a σ_{ck}=50 N/mm^2. The effect compared to using σ_{ck}=40 N/mm^2 makes it possible to reduce the arch rib thickness from 4.5m to 3.5m in the springing section and from 3.0m to 2.5m in the crown section making it possible to reduce the thickness of various components for a more slender arch rib (Figure 2 and 3).

Construction Method Characteristics

1. The Use of Melan Material that Occupies 60% of the Arch Span

The construction of large-span arch bridge involves an extremely unstable structure until the arch structure is completed and requires numerous construction equipments such as diagonal stay cables and ground anchors. Accordingly, the selection of the construction method is an extremely important issue from the viewpoint of safety and economy. The arch rib construction method for Kashirajima Bridge utilized the Melan element and diagonally supported cantilever election, taking into consideration the site location spanning the Seto Inland Sea and the need to swiftly achieve stability against the influence of wind and typhoons. Melan element is an arch-shaped steel reinforcing material used to rapidly create an arch structure during construction. The Melan element for Kashirajima Bridge is a 130.4m long, two steel main girder structure weighing 383t and is the largest scale in terms of the proportion of Melan span length to over all span (=Melan span length/overall span length) for the combined Melan element. Although there are various discussions regarding the optimal Melan length, there is no precedent for using Melan material in close to 60% of the total span. However, after various considerations, this long Melan material was adopted to quickly achieve arch structure stability and successfully reduce the anchoring strength of the backstay needed to join the arch significantly.

The overall construction process is illustrated in Figure 4. The arch rib construction began in January 2002. First, end posts were constructed on both sides of the strait and along with diagonal stay cables, nine 4.5m long blocks were constructed with moving arch construction equipment (Photo 2, Figure 4-1 Diagonally Supported Cantilever Construction). In September 2002, Melan material assembled at an Ehime Prefecture factory was transported by sea using a 16,000t barge to the construction site. The Melan element was hoisted with a 1300t floating crane boat and fixed to the Gelber hinge bearing support installed

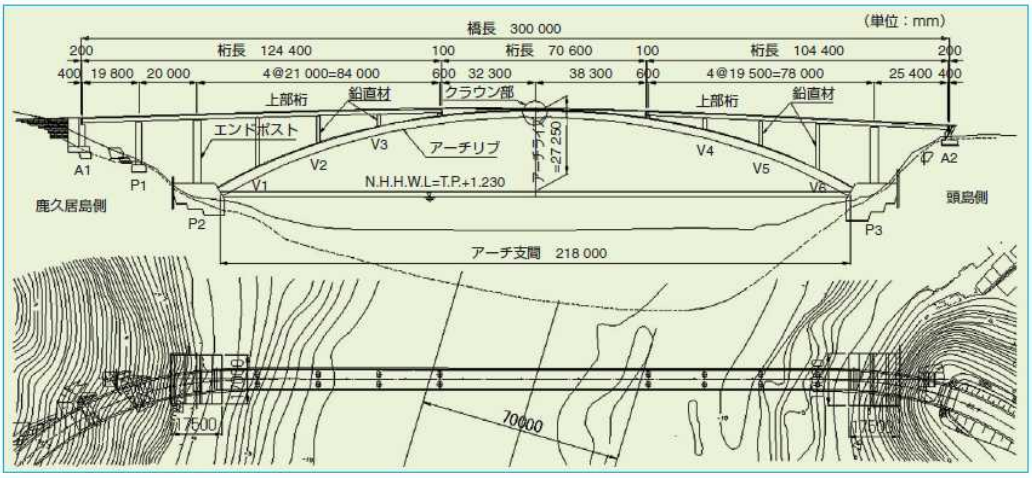

Figure 3 General Drawing (Side Drawing)

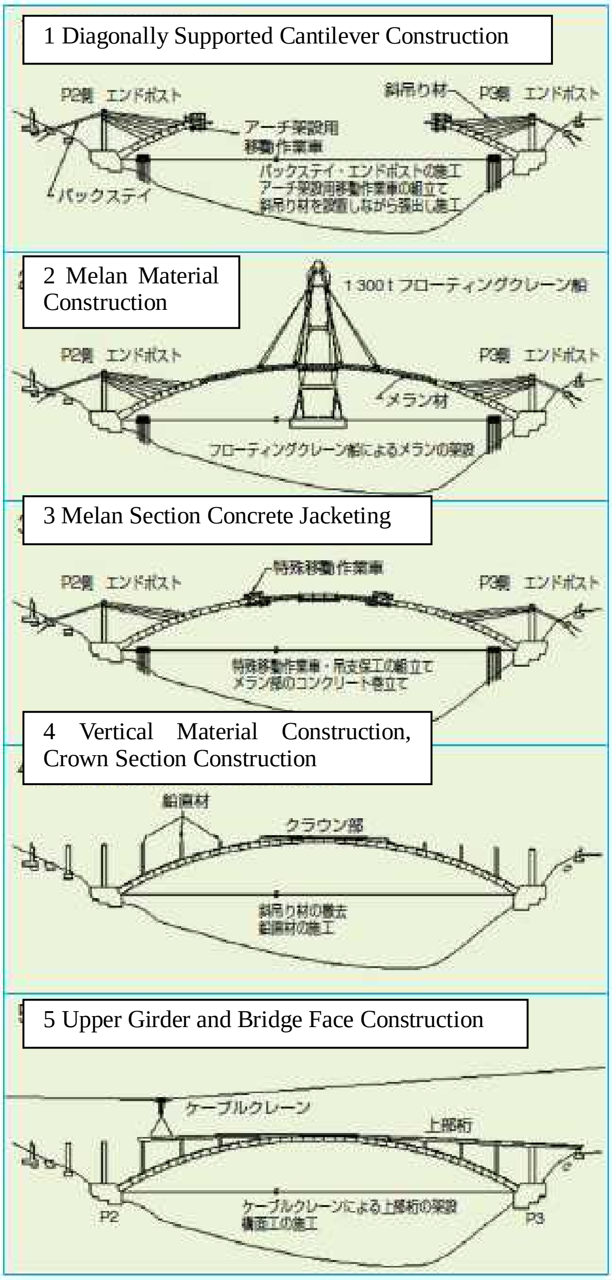

Figure 4 Overall Construction Process

Photo 2　Overhang Construction

Photo 3　Concrete Jacketing of Melan Material

on the tip of the 9 blo　cks (Figure 4-2 Melan Element Construction).　Later, the Melan element was wrapped around by fresh concrete and arch the rib was completed (Photo 3, Figure 4-3 Melan Section Concrete Jacketing).　The Melan element composite section that accounts for 60% of the arch central span was improved with a new Melan construction method to streamline construction and save labor. Traditional Melan element was embedded in concrete but in this new construction method, the Melan element and web concrete is placed in alignment within the box girder enabling the Melan to have three functions as steel reinforcement, support, and inner framework. As of December 2003, construction of the vertical member and construction of the upper girder by the cable crane is completed and the base plate is being constructed.

2. Diagonally Supported Cantilever Construction Method

The general characteristic of the diagonally supported cantilever construction method used for arch bridge or cable-stayed bridge construction is that the diagonally supported cantilever equipment interfered with the moving platform and, the moving of construction platform would have to proceed before pretensioning the diagonal stay cable. For this reason, even for arch bridges, it involves some cantilever construction and several PC steel materials are placed within the arch rib. The Kashirajima Bridge improved this point and reduced the PC steel materials within the arch rib girders by roughly 34%. This was accomplished by improving the movable construction platform so the cantilever and propulsion unit do not interfere with each other and by developing a method that allows all blocks to be diagonally supported by stay cables without cantilevering. As a result the PC steel material needed for cantilever construction was not only greatly reduced but it made construction possible with a small external cable system.

3. Simultaneous Construction of Melan Material

By lengthening Melan element to 130.4m (60% of the arch central span), it was feared that a construction error would occur during the simultaneous construction of Melan material and the configuration of the Melan element would be different from the design values. For this reason it was necessary to make the Melan material bearing support connecting the concrete arch rib structurally absorbable in regards to construction errors. For this measure, a Gelber hinge bearing support that could adjust the shim plate was adopted. As a result, hoisting the total Melan element reached the design height roughly 5 hours after beginning and the mounting was smoothly completed (Photo 4-5, Figure 5).

Photo 4　Simultaneous Construction of Melan Material

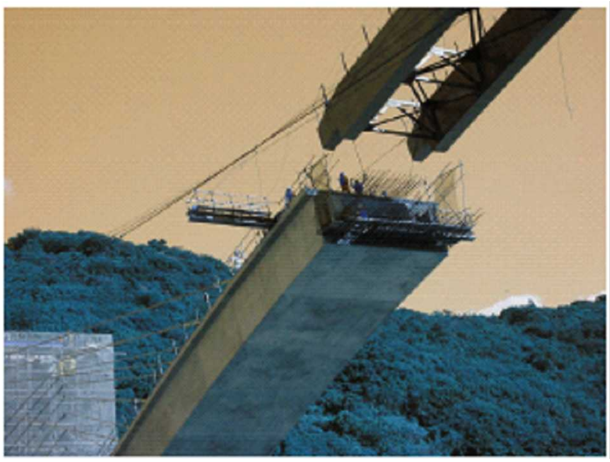

Photo 5　Gelber Hinge Bearing Hinge

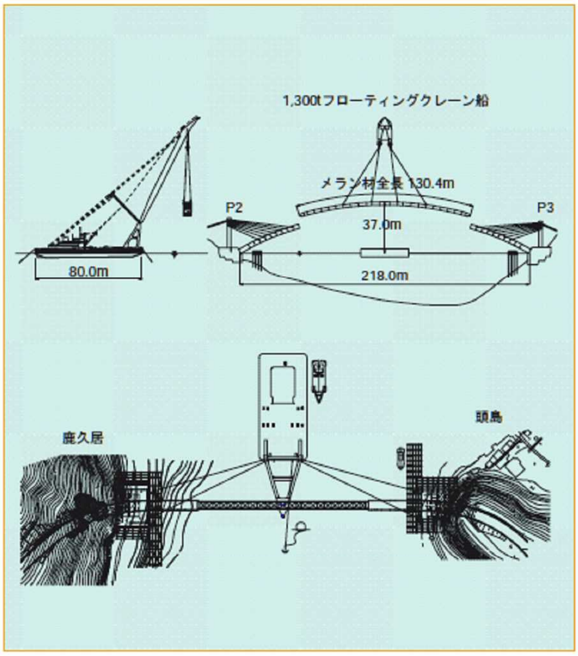

Figure 5　Melan Material Construction Process

Finishing the Article

Through the adoption of composite structures and use of various new construction method technologies, a new landmark is being completed on a remote island of the Seto Inland Sea. It is certain that through the incremental improvement of construction methods, the concrete arch bridge span will continue to lengthened continuously.

References:

1- Ito et al., Construction of Kashirajima Bridge, Beams and the Foundation, Vol. 36, No.9, 2002

2- Structural Engineering Committee of the JSCE, Design and Construction of Long Concrete Arch Bridge (600m -span Class), August, 2003