Hoover Dam Bypass- Colorado River Bridge
— The Longest Concrete Arch Bridge in the US —

フーバーダムバイパスーコロラドリバー橋
— 米国最長のコンクリートアーチ橋 —


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* Yuhei TAKATOKU, P.E.Jp: Obayashi Corporation
高徳　裕平，技術士（建設部門）：（株）大林組
** Hirokazu ONOZAKI, PE: Obayashi Corporation
小野崎　寛和，PE（プロフェッショナル・エンジニア）：（株）大林組
*** Hideki FUKAMI: PE: Obayashi Corporation
深見　秀樹，PE（プロフェッショナル・エンジニア）：（株）大林組
**** Toshiaki KATO, Ph.D. P.E.Jp: Obayashi Corporation
加藤　敏明，博士（工学），技術士（建設部門）：（株）大林組
Contact: yuhei.takatoku@obayashi-usa.com

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Synopsis

The Hoover Dam Bypass Colorado River Bridge (Mike O'Callaghan-Pat Tillman Memorial Bridge) is the longest concrete arch bridge in North America (**Fig. 1**). The bridge soars 270m above the Colorado River and overlooks the historic "Hoover Dam". The Dam, well known as one of the most symbolic structures in the US, was completed in 1936.
The Colorado River Bridge was named the winner of the 2012 Outstanding Civil Engineering Achievement Award (OCEA Award) by the American Society of Civil Engineering (ASCE).

Fig.1 Hoover Dam Bypass Colorado River Bridge

Structural Data

Structure: Concrete Arch Bridge
Bridge Length: 577.9m
Arch Span: 323.0 m
Width: 26.8m
Owner: Federal Highway Administration
Designer: HDR Engineering, T.Y. Lin International, Sverdrup Civil, Inc
Contractor: Obayashi Corporation/PSM Construction USA, Inc. JV
Construction Period: Jan. 2005 – Aug. 2010
Location: Nevada & Arizona, United States

1. Introduction

The Hoover Dam Bypass greatly facilitates traffic flow on U.S. Highway 93 (US93). US93 is a major commercial corridor between the states of Arizona, Nevada, and Utah and is part of a North American Free Trade Agreement (NAFTA) route between Mexico and Canada. Before completion of the Hoover Dam Bypass, traffic had to be routed across the top of the Hoover Dam (**Fig. 2**). The resulting traffic congestion imposed a significant burden on the surrounding area. The majority of truck traffic was not allowed across the dam and had to find alternate routes. Traffic volumes combined with the sharp curves on US93 in the vicinity of the dam often led to significant back-ups, increasing trip times for travelers, and the possibility for mishaps near the dam site. The purpose of the project was to accomplish the following objectives: 1) Minimize the

Fig.2 Project overview

potential for pedestrian-vehicle accidents on the dam, 2) Remove a major bottleneck to the interstate and international commerce, 3) Reduce travel time in the dam vicinity.

2. Project Overview and Construction

The 578m long Colorado River Bridge is the centerpiece of the 5.6 km long Hoover Dam Bypass project. The Bridge consists of the 9 span arch unit, flanked by the 5 span (NV) and 2 span (AZ) units. The cast-in-place concrete arch is 323m long and 84m tall, from starter segment to crown. The approach and spandrel columns similarly consist of rectangular precast segments, vary in height up to 87m, and have a slight longitudinal taper. The superstructure is framed by 4 steel tub girder lines, integrally connected to concrete pier caps, presenting a sleek continuous profile from abutment to abutment. A 240mm thick reinforced deck provides the riding surface and a nice view of the dam for pedestrians using the 2.0m-wide walkway on the north side. The bridge overview drawing is shown in **Fig. 3**.

There were many challenges and concerns besides the technical challenges, such as the surrounding environment (sheer cliff) and extreme heat. In addition, wildlife concerns, including the habitat of longhorn sheep, were important factors for the project.

(1) Rock Excavation and Foundations

Total volume of rock excavation was 52,000m^3, facilitated by blasting. Once proper elevation was achieved, spread footings for the columns were poured on the rock. Special shelves were excavated to create the right geometry for the skewback foundations that support the arch ribs. The skewbacks contained 1,450 m^3 of concrete and were anchored into bedrock with tie-back tendons. The 100m drop from deck grade made delivering concrete in one night via slick line a challenging exercise.

(2) Pier Columns

The precast yard was located near US95, 30 min from the job site (**Fig. 4**). At the precast yard, 440 permanent column segments and 68 temporary pylon segments were cast. The short-line match cast method was chosen for the casting concrete. Three beds were prepared for casting, and 1 segment at each bed had been constructed per day, total 3 segments per day. The column segments were erected with cableway (**Fig. 5**). The epoxy adhesive had been applied at segment joints, with between 12 and 20 PT-bars stressing the segments together. The geometry control of the pier column erection was one of our challenges.

(3) Arch Construction Outline

Erection of each of the four 26 segment arch cantilever headings began on shelves blasted out of the canyon rock faces where the skewback foundations were poured. Segments were individually constructed via cast-in-place concrete using under-slung form travelers designed and fabricated specifically for the project (**Fig. 6**). Advancing approximately 8.0m each move, the travelers marched steadily toward the crown from an initial angle of 48 degrees. Temporary support of the arch headings was provided by two pairs of 50m precast concrete pylons set atop the adjacent approach columns. The twin ribs were connected by eight steel

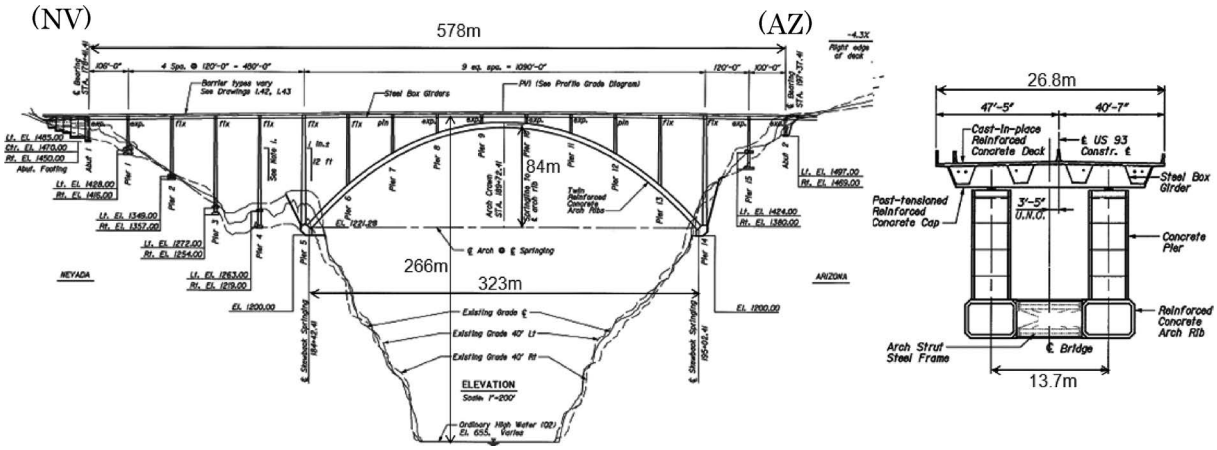

Fig.3 Bridge plan view and section view

Fig.4 Precast yard

Fig.6 Arch rib cantilever construction

Fig.5 Pier column segment erection

Fig.7 Arch rebar cage

struts at the spandrels during arch construction. The twin ribs are each 4.2m tall by 6.0m wide hollow boxes.

(4) Arch Construction Cycle and Concrete

A typical construction cycle was; 1) cast concrete; 2) cure; 3) strip forms; 4) launch and adjust traveler; 5) install rebar cage; 6) launch inner core forms; 7) top forms; 8) cast concrete. The fastest cycle for 1 segment was 6 days, the project average was 10 days. To improve the erection schedule, a rebar cage for each segment was pre-tied, and flown into and set in the forms following traveler launch (**Fig. 7**).

The arch concrete (70N/mm^2, 25cm slump) was produced by the JV' own on site batch plant. Due to thermal control requirements, Liquid Nitrogen was used to pre-cool the concrete (**Fig. 8**), and generally concrete was placed in night time hours. The concrete was placed using a 32 meter placing boom mounted to a platform that was relocated up the arch as construction progressed.

(5) Stay Cable System

The pylons were approx. 50m tall and the base acted as a pinned support to allow the pylon to lean toward the arch along with construction loads. The stays were fabricated on-site and covered with white colored HDPE to minimize temperature effects. The pylon and arch displacement was monitored by an automatic monitoring system, and checked on time as well stressing forces and elongations. After arch closure, all staycables and pylons were removed.

(6) Superstructure (Pier Caps, Tub-girder, and Deck Concrete)

The pier caps are cast-in-place concrete. The scaffolding, part of the forms and rebar had been pre-assembled on the ground then placed with cableway. The steel tub-girders were fabricated at the manufacture's factory and delivered to the job site. The girders were erected between caps by use of the cableway (**Fig. 9**), and grades adjusted to accommodate deck profile. High strength PT-bars then fixed the connection between the girders through the pier caps. The cast-in-place deck concrete strength is 30N/mm^2. Fiber concrete was selected to reduce the plastic shrinkages. The concrete paving machine was used for finishing correct grade (**Fig. 10**).

(7) Cableway System

The cableways were the lifeblood of the project. They were required for almost every operation; whether it's for transporting personnel, materials, or equipments. A

brief overview of cableways: Tower height was 101m, the cableway span was 760m. Hoisting capacity was 50 tons. To move the materials toward the transversal direction, the luffing (lean tower to side) was used.

3. 3D Erection Analysis and Automatic Monitoring System [1]

Due to the fact that the bridge was a highly indeterminate structure, the structural system changed continuously as cantilever erection progressed. To complete the 323m long span arch bridge, a 3D erection analysis was required. This 3D erection analysis predicted the arch deflections and geometry control as well as arch rib moments and stay cable forces.

This analysis was further complicated by the steel struts connecting the arches. From an engineering point of view, the 3D erection analysis was the key document that gave direction to a detailed set of construction steps, over 1,800 in all.

An automatic monitoring system was installed to assist geometry control and help track and predict arch movement. The monitoring system had provided a lot of valuable data to predict the arch behavior, especially for the temperature effect.

4. Conclusion

The Hoover Dam Bypass Colorado River Bridge was an extreme engineering challenge, due to the structure itself, advanced construction schemes, and the surrounding environment. The effort of all personnel involved made the incredibly graceful bridge into reality.

The Hoover Dam Bypass Colorado River Bridge was completed in August 2010. The bridge was opened to traffic on October 2010. This project resulted in an iconic landmark structure set in the Colorado River's Black Canyon with a view to historic Hoover Dam.

The Hoover Dam Bypass project was named the winner of the 2012 Outstanding Civil Engineering Achievement Award by ASCE.

References

[1] Yuhei Takatoku.: *Construction of the Hoover Dam Bypass Arch Bridge*, 3rd fib International Congress, 2010

Fig.8 Liquid nitrogen cooling

Fig.9 Tub Girder erection

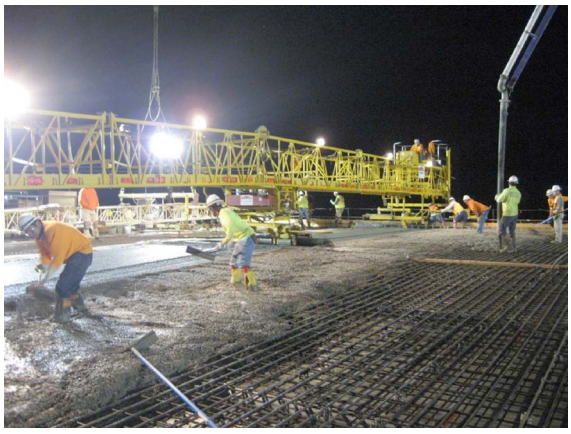

Fig.10 Deck concrete

概　要

コロラドリバー橋は , 米国国定歴史建造物フーバーダムの下流460m の地点に位置する北米最長のコンクリートアーチ橋である。本橋の施工では，その構造形式，架橋地点の特徴から，ユニークかつ技術的に難易度の高い工法が多く採用された。ピロン工法による長支間アーチリブの張出し架設をはじめ，プレキャストセグメントによる最大87m の橋脚施工，摂氏40度を超える炎天下でのマスコン対策など，克服しなければいけない課題も多かった。困難を極めた工事であったが，2010年 8 月に工事完成を迎え，同年10月に本橋を含むフーバーダムバイパスが開通した。本プロジェクトは， American Society of Civil Engineers (ASCE) より， 年度を代表する工事に与えられる Outstanding Civil Engineering Achievement Award (OCEA Award) を受賞した。このような歴史に残る橋の建設に日本企業が貢献した意義は大きい。