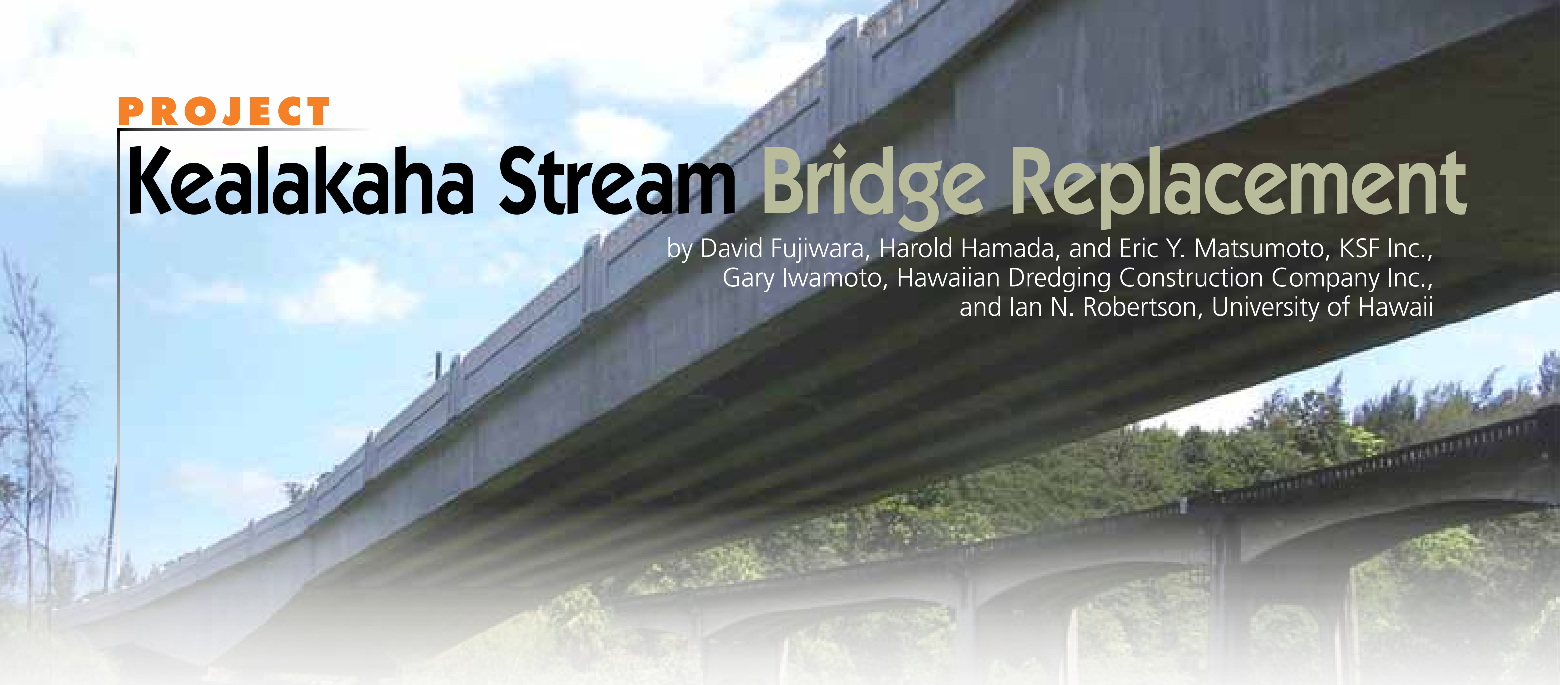
PROJECT

Kealakaha Stream Bridge Replacement

by David Fujiwara, Harold Hamada, and Eric Y. Matsumoto, KSF Inc.,
Gary Iwamoto, Hawaiian Dredging Construction Company Inc.,
and Ian N. Robertson, University of Hawaii



The completed bridge with existing structure in the background was opened to traffic on March 20, 2010. Photo: Glenn Koki, Hawaiian Dredging Construction Company Inc.

Cast-in-place and precast concrete combine to solve challenges at remote and beautiful construction site

Located on Hawaii Belt Road on the island of Hawaii, Kealakaha Stream Bridge traverses a 165-ft-deep and 610-ft-wide ravine. This structure is situated approximately 33 miles northwest of Hilo and provides for traffic traveling from Hilo to the northern part of the island.

Kealakaha Stream Bridge is a 720-ft-long, concrete bridge with a radius of curvature of 1800 ft, a 6.2% travel way superelevation, and a 3.46% vertical grade. The bridge has three spans—180 ft, 360 ft, and 180 ft. It is approximately 48 ft wide and provides two 12-ft-wide travel lanes and two 10-ft-wide shoulders. Due to its close proximity to an active volcano, this bridge is subjected to high seismic activity. It was required to be designed for an acceleration of 0.4g.

Contract Plans

The original contract plans called for a three-span, single-cell box girder without a concrete overlay and with depths ranging from 10 ft to 20 ft. The 180-ft-long end spans were designed to be constructed on falsework. Due to the length required between piers and steep terrain below, segmental cantilever construction was selected as the best option for the 360-ft-long center span.

In order to increase the period of the bridge and to decrease foundation loads, the 22 ft 11½ in. by 6 ft 8 in. rectangular piers were designed to be 42 ft tall. In addition, precast concrete casings were required around the bottom of the piers to isolate them from the backfill. A significant number of soil nails were required to stabilize the steep cuts needed to locate footings. These footings were supported by 5-ft - 0-in.-diameter drilled shafts.

Value Engineering Change Proposal

The contract was awarded in 2005. The contractor felt that a curved segmental box structure with a travel way superelevation plus shoulder slope with no topping was very difficult to construct. The slope, terrain, and enviromental controls that the project would require, the deep foundations, and the soil nail walls, made access all but impossible. The contractor then contacted KSF Inc. to design a different bridge that would resolve the construction issues.

In 1996, the Washington State Department of Transportation (WSDOT) developed their W95PTG "super girder" which was capable of spanning

profile

KEALAKAHA STREAM BRIDGE / NORTH HILO, HAWAII

BRIDGE DESIGN ENGINEER: KSF Inc., Honolulu, Hawaii

PRIME CONTRACTOR: Hawaiian Dredging Construction Company Inc., Honolulu, Hawaii

PRECASTER: Central Pre-Mix Prestress Company, Spokane, Wash., a PCI-certified producer

POST-TENSIONING CONTRACTOR: AVAR Construction Systems Inc., Fremont, Calif.

GIRDER LIFTING JACKS: Enerpac, Milwaukee, Wis.

CONCRETE SUPPLIER: Yamada and Sons Inc., Hilo, Hawaii

REINFORCEMENT SUPPLIER: Associated Steel Workers Ltd., Kapolei, Hawaii approximately 200 ft. The solution, then, became cast-in-place concrete variable depth box girders cantilevered from each pier with precast bulb-tee girders spanning between both cantilever ends for the center span and between the cantilever ends and the abutments for the end spans. Once the bulbtees were erected, the contractor constructed a conventional 8.5-in.-thick, cast-in-place concrete deck with the required slopes. The specified compressive strength of the deck was 6000 psi at 28 days.

Superstructure

The value-engineered superstructure consists of 100-ft-long and 205-ft-long WSDOT W95PTG precast, prestressed concrete bulb-tee girders and 150-ft-long cast-in-place concrete box girders above each pier. The framing of these superstructure units creates five chords to provide for the curved horizontal alignment. The three spans are made continuous with post-tensioning.

Due to sharply curved roads leading to the bridge site, the maximum length of precast girder segments that could be transported to Kealakaha Stream was 50 ft. The girders, which are 95 in. deep with a 4-ft 3-in.-wide top flange and 3-ft 4-in.-wide bottom flange, were cast in Spokane, Wash., and shipped to Hilo Bay and stored at a location 2 miles from the bridge site. To produce the required 100-ft and 205-ft-long girders, 50-ft-long precast concrete segments were spliced together and post-tensioned at the bridge site. A total of 48 segments was required. The 28-day concrete design compressive strength of these girders was 9000 psi.

Five-cell box girders were cantilevered in both directions from the two piers. The depth of these 150-ft-long girders ranged from 9 ft 9 in. to 18 ft 0 in. A total of 26 post-tensioning tendons, consisting of four 0.6-in.-diameter strands are located in the top slabs of each box girder.

Five-cell box girders were cantilevered from the two piers.

Base Isolation

Additional analysis of the structure determined that utilizing seismic base isolation would result in substructure cost savings. By increasing the dynamic period of the structure and thereby decreasing foundation loads, the footings were raised, the soil nails eliminated, and drilled shaft sizes were minimized.

Two friction pendulum seismic isolation bearings were installed on each abutment and pier. Each bearing has an 88-in. effective radius of curvature that results in a dynamic period of 3 seconds. Displacement capacities are 12 in. at the abutments and 10 in. at the piers.

According to Dr. Anoop Mokha of Earthquake Protection Systems, "Friction pendulum bearings use the characteristics of a pendulum to lengthen the natural period of the isolated structure so as to mitigate the strongest earthquake forces. Since earthquake-induced displacements occur primarily in the bearings, lateral loads transmitted to the structure are greatly reduced."

Substructure

The value engineering change proposal did not change plan locations of the abutments and piers. However, seismic isolation allowed stiffer piers than those indicated in the original contract drawings. Therefore, footings were raised and pier heights were reduced by 28 ft 6 in. at Pier 1 and 21 ft 0 in. at Pier 2. This eliminated the need for costly soil nailed walls around the footings. Foundation sizes and drilled shaft lengths were altered as well. By maintaining vertical loads at the center of supports, thereby reducing bending moments, the quantity of drilled shafts was reduced significantly by 2226 lin. ft. Footing sizes were also reduced by over 60%.

The center span is shown under construction. One girder has been launched and a second is being assembled in the staging area.
Photo: Mark Joosten, Acrow Corporation of America.

720-FT-LONG, THREE-SPAN, POST-TENSIONED PRECAST SPLICED BULB-TEE GIRDER AND CAST-IN-PLACE CONCRETE BOX GIRDER BRIDGE / HAWAII DEPARTMENT OF TRANSPORTATION, OWNER

SEISMIC ISOLATION BEARING SUPPLIER: Earthquake Protection Systems Inc., Vallejo, Calif.

LAUNCHING TRUSS SUPPLIER: Acrow Corporation of America, Parsippany, N. J.

BRIDGE DESCRIPTION: Three-span bridge consisting of cast-in-place, haunched multi-cell box girders varying from 9 ft 9 in. to 18 ft deep, 150 ft long combined with 95-in.-deep WSDOT bulb-tee girders spliced from 50-ft-long segments to achieve 100-ft-long girders in the end spans and 205-ft-long girders in the center span, cast-in-place concrete deck, and seismic isolation bearings

BRIDGE CONSTRUCTION COST: $27,000,000

50-ft-long precast concrete segments were spliced together and post-tensioned at the bridge site.

The 150-ft-long, cast-in-place concrete box girder above Pier 2 was cast on falsework and post-tensioned prior to launching the spliced girder drop-in span. Photo: Eric Y. Matsumoto, KSF Inc.

Two precast girder segments, 50 ft long, were set on falsework and spliced together for the end spans. Photo: Eric Y. Matsumoto, KSF Inc.

Construction Process

Construction began in March 2007. After installation of drilled shafts, footings, piers, and abutments were constructed. Next, the friction pendulum bearings were set in place.

Falsework was installed on the stream side of the piers to support the box girder construction. In order to minimize loads on the falsework, box girder construction was sequenced so that the bottom slab and the two interior webs would support the remaining box construction. At the conclusion of the box girder construction, deck tendons were stressed.

The precast girder segments of the end spans were set on falsework, spliced, and post-tensioned. At each abutment, a continuous end diaphragm was cast. After the closure concrete between the precast girders and box girders was cured, six tendons each consisting of twenty-two 0.6-in.-diameter strands extending from abutments to the ravine end of the box girders were stressed to 483 kips each, 50% of final jacking force. Construction continued with installation of midspan diaphragms and cast-in-place slabs for the end spans. The six tendons were then stressed to 100% of the required jacking force of 967 kips. This post-tensioning, combined with tendons in the top slab of the box, supported all loads during construction of the center span.

The next challenge in this project was launching the 205-ft-long girders across the ravine. To assemble the girders, on the Hilo end span, girder segments were placed on a rail system consisting of wide flange members and rollers. These precast pieces were then spliced and post-tensioned. To address lateral stability concerns, a horizontal steel truss was placed over the middle 90 ft of the girder and two tendons of four 0.6-in.-diameter strands were placed and stressed in ducts in the top flange of the girder.

A launching truss was installed between the center span ends of the box girders. The spliced girders were then pulled across the ravine on the truss. Enerpac hydraulic strand jacks, placed 50 ft above the deck on shoring towers, lifted the girder above the truss. The truss was moved laterally and each girder was lowered to its final position. This process was repeated until all six girders were placed.

The precast girders were then spliced to the box girders and post-tensioned. Three stages of post-tensioning were conducted. In the first stage, a total of 12 tendons of twenty-two 0.6-in.-diameter strands were stressed to 483 kips each. Diaphragms were cast. Then, the 12 tendons were stressed to 100% of the required jacking force of 967 kips each. Next, the concrete deck was cast. In the third stage of post-tensioning, another twenty-two 0.6-in.-diameter strand tendon in each girder line was stressed; then the shoring was released and removed.

After each girder was lifted, the launching truss was moved laterally and the girder set in its final position. Photo: Eric Y. Matsumoto, KSF Inc.

Conclusion

Awareness of innovations, such as availability of deep girders and seismic isolators, leads to more options in design and construction of bridges. The options can result in easier construction of complex structures and in increased cost savings.

Kealakaha's remote location, steep terrain, seismic activity, and daily deluge of rain created a challenging environment for construction. However, the collaborative effort of all parties involved resulted in a successful completion of the project. Kealakaha Stream Bridge was opened to traffic on March 29, 2010.

David Fujiwara is vice-president, Harold Hamada is a technical consultant, and Eric Y. Matsumoto is a project engineer at KSF Inc. in Honolulu, Hawaii. Gary Iwamoto is senior project manager with Hawaiian Dredging Construction Company Inc. in Honolulu, Hawaii, and Ian N. Robertson is a professor at the University of Hawaii at Manoa, Hawaii.

For more information on this or other projects, visit www.aspirebridge.org.