PROJECT

Waikoko Stream Bridge Replacement

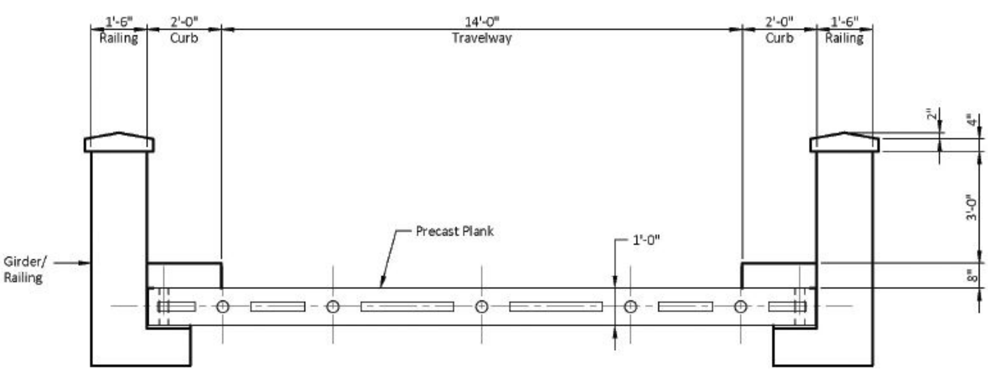
by David K. Fujiwara, Gary T. Iwamoto, and Eric Y. Matsumoto, KSF Inc.

Waikoko Stream Bridge is located on the north shore of Kauai, Hawaii. This structure is a vital component of Kuhio Highway as it provides the only access to the communities of Wainiha and Haena.

The original bridge, which was completed in 1912, had withstood earthquakes, tsunamis, and countless storm events over the years. In April 2018, thunderstorms produced a record rainfall of 49.69 in. in a 24-hour period in the Hanalei and Haena areas of Kauai. This downpour caused extreme flooding and numerous landslides. An unprecedented amount of restoration and repair work on homes, buildings, and roadways was needed. The storm also damaged Waikoko Stream Bridge, which limited vehicular traffic. To transport the necessary equipment and materials for the recovery effort at the sites beyond Waikoko, the original structure had to be replaced.

Planning

The Hawaii Department of Transportation (HDOT) tasked their bridge design consultant with the design, construction engineering, coordination, and communication efforts for the replacement of Waikoko Stream Bridge. Details for the new structure considered function, aesthetics, stream hydraulics, costs, environmental impacts, allowable roadway closures, community concerns, delivery of materials and precast concrete components, construction equipment, and site constraints. Residents of north Kauai, who are passionate about preserving the feel of this remote area, were consulted and became active participants in the bridge replacement decisions. The stakeholders, residents, and designers agreed to build a new one-lane, 72-ft-long, 21-ft-wide structure consisting of two precast concrete girders with transverse precast concrete slabs. The new bridge was designed to be similar in appearance to the original historic through-girder bridge. Notably, only one full weekend closure—a total of 57 hours—of the roadway was permitted for the bridge replacement project. This full closure allowed the structure to be constructed without a costly temporary bypass road. It also eliminated the negative impacts that a bypass road would have had on the environmentally sensitive areas adjacent to the bridge.



The typical bridge section for the one-lane, 21-ft-wide bridge consists of a 14-ft-wide travel lane, 2-ft-wide curbs, and the precast concrete L-girders that also serve as the bridge railing. Figure: KSF Inc.

The design was completed in approximately four months, and permits and required approvals were obtained under the governor's emergency proclamation. The project team then secured an off-site location to serve

profile

WAIKOKO STREAM BRIDGE / KAUAI, HAWAII

BRIDGE DESIGN ENGINEER: KSF Inc., Honolulu, Hawaii

OTHER CONSULTANT: WSP, Honolulu, Hawaii

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

CONCRETE SUPPLIER: O Thronas Inc., Lawai, Hawaii

PRECASTER: Hawaiian Dredging Construction Company Inc., Honolulu, Hawaii

The L-girders were transported to the site in three segments and connected with cast-in-place closure pours on site. Photo: Hawaiian Dredging Construction Company Inc.

The reinforcement at the two closure pours of the L-girder segments was detailed to facilitate placement of concrete and splicing reinforcement. Note the shear keys. Photo: KSF Inc.

as the precast concrete yard as well as parcels near the bridge site for staging and construction-related activities.

The team meticulously planned logistics for transporting the precast concrete components and necessary equipment, organizing construction efforts, and staging activities at the site. The locations of the demolition equipment, trucks, lighting, and cranes for girder and slab erection were coordinated to seamlessly operate in a relatively small area. Plans for the entire process were reviewed numerous times to ensure that the construction would be safely completed within the specified time constraints.

Precast Concrete Components

Precast concrete girders and slabs were used to construct the bridge within the allowed full weekend closure period. Two 72-ft-long, L-shaped concrete girders were designed to span the Waikoko Stream. The L-girders were cast in a controlled environment approximately 30 miles from the construction site. Load restrictions on bridges leading to the Waikoko Stream site influenced the decision to cast the girders in three segments (19 ft 4 in., 22 ft 8 in., and 19 ft 4 in. long) with a maximum weight of 17.8 tons each. The L-girder segments were transported to the site and then spliced near the end of the existing bridge.

There was limited space at the bridge site to store and splice the girder segments and to maneuver the completed girders. Therefore, the reinforcement at the closure joints was detailed to facilitate on-site placement of concrete and splicing reinforcement. The location for assembling the girders was chosen to accommodate the positions of the cranes, trucks, lighting, and other equipment needed to erect the precast concrete components.

Designing the L-girders for the construction phase was critical to safely deliver the project within the specified time constraints. When the path of the girder was mapped from storage to final placement, crane capacity, lateral torsional buckling, girder bracing, connections to the precast concrete slabs, and connections to the concrete curbs were all carefully checked, as concerns about any of these items could have jeopardized the project.

In addition to design for the construction phase, the L-girders were designed for railing test level 1 (TL-1) criteria per the American Association of State Highway

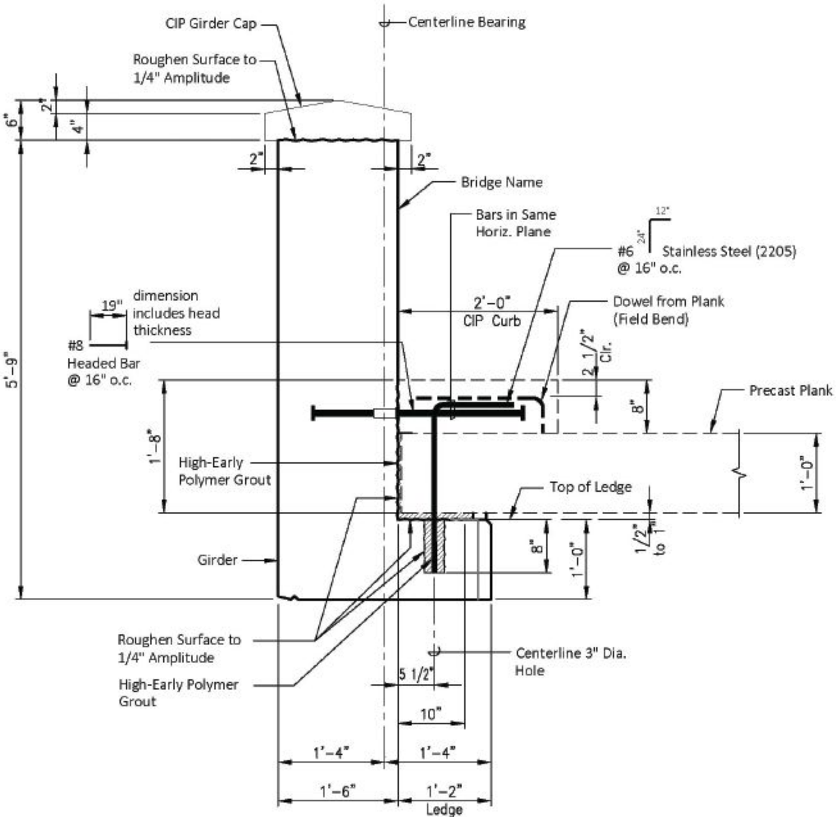
HAWAII DEPARTMENT OF TRANSPORTATION, OWNER

POST-TENSIONING CONTRACTOR: Schwager Davis Inc., San Jose, Calif.

BRIDGE DESCRIPTION: 72-ft-long, 21-ft-wide, one-lane single-span through-girder bridge using precast concrete L-shaped girders and deck slabs

STRUCTURAL COMPONENTS: Two precast concrete L-shaped girders, 17 transverse precast concrete slabs with longitudinal post-tensioning, cast-in-place concrete abutments founded on micropiles

BRIDGE CONSTRUCTION COST: $4 million



Detail for the typical precast concrete girder-to-slab and girder-to-curb connections. Figure: KSF Inc.

and Transportation Officials' *Manual for Assessing Safety Hardware*[1] because they also serve as railings for the bridge in the final condition. An unmountable curb was constructed to protect the girders from potential vehicular impacts. The design of the girders and concrete caps also took into account the aesthetics desired by the community.

Precast concrete slabs measuring 17 ft 11 in. × 4 ft 0 in. × 1 ft 0 in. were designed to span between the two L-girders. The slabs were match cast in steel forms, at the same location as the girders, to ensure quality joints. Each precast concrete slab contained five 3-in.-diameter corrugated polypropylene ducts for post-tensioning. The ducts were sized to allow for the coupling of the $1\frac{3}{8}$-in. diameter, ASTM A722[2] Grade 150 post-tensioning threaded bars. Precast concrete segmental duct couplers were used to connect the ducts in each slab. Lifting devices were placed in locations that would be covered by the concrete curb. Holes at the ends of the slabs were aligned with pockets in the ledges of the girders. For the curb connection, reinforcing bars protruding from the top of the slabs were positioned to eliminate interference with other reinforcing bars in the curb connection.

Durability

Concrete for the precast concrete components had a design 28-day compressive strength of 6000 psi. ASTM A1035[3] Type CS Grade 100 and ASTM A955[4] Type 2205 reinforcing bars were considered for the precast concrete girders and slabs. However, the lead time for delivering these materials was determined to be too lengthy because they would have to be shipped to this remote location. Therefore, the designer specified that the concrete for the precast concrete elements have a maximum water-cement ratio of 0.40 to decrease the permeability of the hardened concrete and increase the durability of the structure. In addition, the concrete included an amine carboxylate corrosion-inhibiting water-based admixture and a shrinkage-reducing admixture.

Construction Before Full Closure

Micropiles were installed near the four corners of the existing bridge to support the new structure. Equipment for the micropile installation was situated such that roadway traffic would not be disrupted. Abutment caps and grade beams were constructed with cast-in-place concrete. The precast concrete components were then delivered to the site. The L-girder segments were spliced on a sliver of land along the roadway near the bridge. Precast concrete slabs were strategically stacked to facilitate placement.

Construction During Full Closure

The weekend closure began on Friday at 7:00 p.m. Demolition equipment and trucks were immediately moved to their planned locations. The existing bridge was then demolished. After the removal of the structure was complete, two small cranes were used to set the girders in their final positions. The girders were braced at their ends. The contractor then installed 1-in.-diameter tension rods through holes at the bottoms of the L-shaped girders, and timber blocking

The substructure was installed before the full closure of the roadway. Photo: KSF Inc.

Slow-set epoxy paste adhesive was applied to the joint faces of the precast concrete slabs before erection. The slow-set epoxy was used to ensure that there was adequate time to set and post-tension the slabs. Photo: KSF Inc.

Bracing is in place between the L-shaped girders while the precast concrete slab segments are set. Photo: Hawaiian Dredging Construction Company Inc.

and compression struts were placed near the tops of the girders to resist the rotation of these components due to the eccentric loading from the slabs. Extruded polystyrene foam was placed on the girder ledges to temporarily support the slabs. The thickness of the foam was varied along the girders based on calculations that accounted for girder deflection and the final grade.

A separate crew prepared the precast concrete slabs by cleaning the ducts and edges of the components, installing seals for the ducts, and applying slow-set epoxy paste adhesive to the joint faces of the slabs. After the slabs were set, the post-tensioning bars were installed, corrosion-inhibiting amine carboxylate powder was blown into the ducts, and the bars were tensioned. As the slabs were squeezed together, excess epoxy oozed out of the joints and was subsequently removed. Upon completion of the post-tensioning, the ducts were grouted. After losses in the post-tensioning, there should be approximately 320 psi of compressive stress in the slabs. Post-tensioning was used to provide a better product with fewer long-term maintenance requirements.

For the permanent connection between the slabs and L-girders, ASTM A955[4] Type 2205 stainless steel dowels were inserted into the holes in the slabs and pockets in the girder ledges. High-early-strength polymer grout, which can achieve 2500 psi compressive strength in three hours, was placed between the slabs and girders. The temporary tension ties and compression struts were subsequently removed. In the completed structure, the dowels and grout between the sides of the slabs and the L-girders resist any loads that would cause girder rotation

Reinforcement in the curbs was placed, and the concrete curbs were cast. The no. 8 reinforcing bars that connect the L-girders to the curb are designed to transfer vehicular (TL-1) loads from the girders to the curb, and from there to the entire bridge system. Finally, the approaches were prepared for vehicular use, and after the proper curing of the curb, the bridge was opened to traffic at 4:00 a.m. on Monday at the conclusion of the 57-hour full closure.

Conclusion

The brief roadway closure window, transportation limitations, and construction area constraints were extremely challenging. However, open communication, earnest collaboration, and meticulous planning resulted in the successful completion of this project in June 2019. HDOT and the community were pleased that Waikoko Stream Bridge was replaced within the time frame permitted. Much-needed equipment and materials for the recovery efforts could then be transported to the other storm-ravaged sites.

After the slabs were set, the longitudinal post-tensioning bars were installed and tensioned. Photo: Hawaiian Dredging Construction Company Inc.

References

1. American Association of State Highway and Transportation Officials (AASHTO). 2016. *Manual for Assessing Safety Hardware*, 2nd ed. Washington, DC: AASHTO.
2. ASTM International. 2018. *Standard Specification for High-Strength Steel Bars for Prestressed Concrete*. ASTM A722/A722M-18. West Conshohocken, PA: ASTM International. https://doi.org/10.1520/A0722_A0722M-18.
3. ASTM International. 2020. *Standard Specification for Deformed and Plain, Low-Carbon, Chromium, Steel Bars for Concrete Reinforcement*. ASTM A1035/A1035M-20. West Conshohocken, PA: ASTM International. https://doi.org/10.1520/A1035_A1035M-20.
4. ASTM International. 2020. *Standard Specification for Deformed and Plain Stainless Steel Bars for Concrete Reinforcement*. ASTM A955/A955M-20c. West Conshohocken, PA: ASTM International. https://doi.org/10.1520/A0955_A0955M-20C.

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