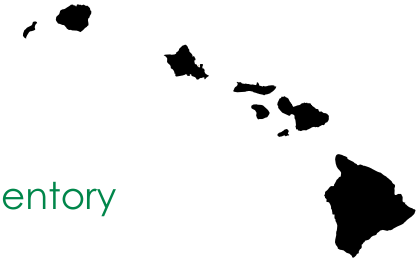
STATE

HAWAII



Concrete bridges dominate the state's bridge inventory

by Paul Santo, State of Hawaii Department of Transportation

Kahoma Stream Bridge. All photos: KSF Inc.

The first recorded bridge built in Hawaii was constructed in 1840. The first concrete bridges in Hawaii's bridge inventory are recorded as being built in 1900 and are still in service. Since then, concrete has been the predominant construction material for bridges.

More than 85% of the more than 1160 bridges in the state's inventory (including the counties) are constructed with concrete. In the last 50 years, over 95% of all permanent bridges constructed (not including culverts) have been made of concrete. Recent history shows that about nine out of every 10 bridges constructed in Hawaii are made of precast, pretensioned or post-tensioned concrete elements. Concrete bridges have proven to be a durable, cost-effective solution with lower maintenance concerns compared to timber and steel bridges.

Hawaii constructed its first bridges using precast, prestressed concrete girders in 1959. Approximately 30% of the bridges in the state's inventory are constructed using pretensioned or post-tensioned concrete technology. Hawaii's first concrete segmental box girder bridge—constructed by the balanced cantilever method—was the Kipapa Stream Bridge on Interstate Route H-2 on the island of Oahu built in 1975.

Recent History

Over the last few years, a number of bridges with significant innovative applications have been constructed by the State of Hawaii Department of Transportation, Highways Division (HDOT).

North-South Road (Kualakai Parkway) Separation

Completed in 2009, the North-South Road (Kualakai Parkway) Separation supporting Interstate Route H-1 on the island of Oahu provided some innovative developments of high-performance concrete in drilled shafts and bridge decks. The twin, single-span structures are each 165 ft long with integral abutments. Four 5-ft-diameter drilled shafts support each abutment.

Application of drilled shafts for Hawaii highway bridges had historically demonstrated several undesirable concrete properties. The aggregate usually segregated from the concrete matrix during placement resulting in lower density concrete at the top of the drilled shaft. In addition, data indicated extremely high concrete temperatures.

To overcome these difficulties, the project structural engineer designed a cohesive concrete that did not segregate, remained at temperatures below 160°F, and displayed temperature differentials of less than 35°F during hydration. The mixture proportions, which included polycarboxylate plasticizers and stabilizers, also resulted in a flowable concrete with slumps of about 10 in. This flowable characteristic was maintained throughout the casting process.

A low cement content (630 lb/yd^3) reduced the hydration temperature. This was accomplished without much loss of compressive strength because a low water-cement ratio was maintained by using a proprietary, synthetic, air-entraining admixture. Bleed water was almost non-existent.

The deck concrete materials and proportions were selected to minimize drying shrinkage, enhance fatigue endurance, minimize bleeding, and reduce plastic shrinkage compared with previous deck mixtures. The concrete contained a shrinkage-reducing admixture and synthetic air to improve workability, in combination with water-reducing, hydration-stabilizing, corrosion-inhibiting, and viscosity-modifying admixtures. For increased durability of the riding surface, synthetic fibers were added to the deck concrete to address micro- and macro-cracking. As a result of the success from this project, a number of other bridges have subsequently used similar concrete mixture proportions, especially for the deck concrete.

Kealakaha Stream Bridge

The Kealakaha Stream Bridge, located on Hawaii Belt Road (Route 19) on the island of Hawaii, was featured in the Summer 2010 issue of *ASPIRE.*™ It is a 720-ft-long, three-span, continuous concrete bridge on an 1800-ft-radius curve with a maximum span of 360 ft. This bridge utilized Washington State Department of Transportation bulb-tee girders that were spliced and made continuous with post-tensioning.

Kealakaha Stream Bridge with existing bridge in background.

Innovative features associated with this bridge included the use of friction pendulum seismic isolation bearings and a unique launching system for the long-span girders. This bridge is instrumented to monitor its behavior due to seismic loads as well as other loading conditions as part of an HDOT research project being conducted by the University of Hawaii.

Kahoma Stream Bridge

One of the most unique and innovative bridges constructed in Hawaii is the Kahoma Stream Bridge. This bridge is located on the proposed Honoapiilani Highway (Route 30) realignment on the island of Maui. This bridge was designed and constructed as part of a design-build contract. The structure is a 60-ft-wide, 360-ft-long, single span, low-profile, inverted tied concrete arch bridge on a 1200-ft radius curve.

Due to the shape of the structure, the top chord was subjected to tremendous axial forces, bending moments, and torsion. Thus, a considerable amount of reinforcing steel was placed in all top chord components—U-girders, precast concrete panels above the U-girders, deck topping, cast-in-place bent caps that connect the girders, and the top portion of the end block. Concrete for these components also required a higher level of attention in the design, handling of materials, and placement.

For increased durability of the riding surface, the deck concrete included alkali-resistant glass and synthetic fibers to address micro- and macro-cracking. In addition, admixtures were incorporated to enhance fatigue endurance, minimize bleeding, increase workability for proper placement, and reduce plastic shrinkage. At each abutment, two friction pendulum bearings were placed to accommodate rotation, expansion, and contraction of the structure.

After two years of construction at a cost of about $24 million, the bridge was opened to motorists in March 2013. As part of an HDOT research project, the University of Hawaii has instrumented this bridge and will be monitoring its behavior.

Lahainaluna Road Separation and the Kauaula Stream Bridge

Two other bridges on the proposed Honoapiilani Highway realignment on the island of Maui are the Lahainaluna Road Separation and the Kauaula Stream Bridge. Constructed in 2010, the Lahainaluna Road Separation is an elegant, slender, 130-ft-long single-span, cast-in-place post-tensioned concrete, rigid frame bridge with integral abutments that takes advantage of the massive basalt rock formations at each abutment.

The Kauaula Stream Bridge, completed in 2013, is the first geosynthetic reinforced soil (GRS) integrated bridge system (IBS) constructed in Hawaii. The 112-ft-long and 47-ft-wide superstructure is comprised of precast, post-tensioned concrete U-girders; precast, stay-in-place concrete deck panels; and a cast-in-place concrete deck. The abutments are also skewed at 31 degrees.

This system was proposed by the contractor as a value engineering proposal in lieu of an I-girder type superstructure on conventional type abutments on spread footings. The GRS-IBS technology provides a cost-effective, accelerated bridge construction solution.

The GRS abutments have been instrumented for monitoring as part of an HDOT research project being conducted by the University of Hawaii. Funding for the research associated with this project was provided by the Federal Highway Administration's Innovative Bridge Research and Deployment Program.

Current Practice

The majority of new or replacement bridges in Hawaii range in span lengths from about 30 to 130 ft. Common practice in the past has been to use precast, prestressed concrete I-girders with a composite, cast-in-place concrete deck slab. Although still used in appropriate conditions, other structural systems such as adjacent slab beams (or planks), adjacent U-girders, and adjacent tee beams with a composite, cast-in-place, concrete topping are being used to accelerate bridge construction.

Being an island state, a number of Hawaii's highways circle around each island along the coast in flood prone areas. These alternative structural systems, especially the adjacent slab beams or planks, have been effective in providing increased freeboard for replacement bridges over waterways. A recommended upper limit for spans for a precast, prestressed concrete plank system would be about 60 ft partly because of the limitation of the precast stressing beds available in Hawaii. The 80-ft-long, single-span, integral abutment Kii Stream Replacement Bridge built in 2005 on the island of Oahu utilized this system; however, the precast concrete planks were sequentially post-tensioned rather than pretensioned to achieve the prestressing.

HDOT's preference has been to use partial-depth precast concrete deck sections with composite cast-in-place concrete topping. The topping provides a means to correct any differential elevations of the precast concrete elements due to variations in camber from prestressing of adjacent elements, superelevation of roadway, vertical curves, surface imperfections, and combinations thereof. The reinforced structural concrete topping also serves as a tie between the adjacent precast concrete elements, in addition to the grouted keyways, to make the units behave as a more cohesive structural system.

Advances in technology of concrete admixtures have greatly improved the performance and behavior of concrete. Some of the admixtures routinely specified for HDOT bridge deck construction are water-reducing admixtures, shrinkage-reducing admixtures, water-based migrating corrosion-inhibitor admixtures, and polymer-based air-entrainment admixtures.

Other means to enhance concrete performance of deck slabs include more concrete cover for top reinforcing steel, use of synthetic fibers, and specifying maximum shrinkage strains at various ages of concrete. Also, the use of shrinkage-reducing admixtures and corrosion-inhibiting admixtures are usually specified for other bridge elements including walls but not for footings and drilled shafts.

Despite the limited funding available for bridge construction and maintenance, HDOT's goal is to build durable bridges that require minimal maintenance. The use of concrete has been the primary means for HDOT.

Paul Santo is bridge design engineer with the State of Hawaii Department of Transportation, Highways Division, Bridge Design Section in Kapolei, Hawaii.