

PROJECT

EL SALTO FALLS STREET BRIDGE

HIGH-PERFORMANCE PRECAST CONCRETE IS KEY TO COST-EFFECTIVE ENVIRONMENTAL IMPACT AVOIDANCE

by Dr. Jay Holombo and Wade Durant, T.Y. Lin International,
and Jon Grafton, Oldcastle Precast

An innovative bridge design using high-performance precast, prestressed concrete allowed construction to proceed without entering a 170-ft-wide environmentally sensitive area (ESA) at the bottom of a creek, thus meeting resource agency permit requirements. In addition, access to the bottom of the creek was limited to a 90-ft-wide construction easement. This design was developed using a collaborative approach among the design team, the owner, the precast concrete producer, the contractor, and the city. This collaborative approach continued through the construction phase to deliver this challenging project with great success.



Background

Construction of a new community, appropriately named The Preserve, is underway in the coastal city of Carlsbad, Calif. Bisecting this community is Buena Vista Creek, which is now spanned by the newly constructed El Salto Falls Street Bridge. This bridge carries two traffic lanes, two bicycle lanes, and two sidewalks, as well as two 12-in.-diameter potable water lines, a 6-in.-diameter recycled water line, and a 12-in.-diameter gravity sewer line below the deck. The sewer line had to be operational before property sales within the community could begin, which placed it and the supporting bridge on the critical path of the project. Upon

Aerial photo shows the newly constructed El Salto Falls Street Bridge in relation to the environmentally sensitive area (ESA) within Buena Vista Creek, as denoted by the orange fence. Under the bridge, the ESA is 170 ft wide at the bottom of the creek. All Photos and Illustrations: T.Y. Lin International.

completion of all improvements within the community, the city of Carlsbad will take over ownership and maintenance responsibilities of the infrastructure from Cornerstone Communities, the developer.

Buena Vista Creek and the adjacent open space is an environmentally sensitive riparian habitat; just outside of the community is El Salto Falls, a formally designated Native American Sacred Site. To avoid a lengthy permit

process with the U.S. Army Corps of Engineers, the owner required the bridge to be constructed without entering the 170-ft-wide ESA at the bottom of Buena Vista Creek. Furthermore, the contractor was required to stay within the 90-ft-wide easement when accessing the creek from the top of the banks.

Design

The design team considered several options that allowed construction without

profile

EL SALTO FALLS STREET BRIDGE / CARLSBAD, CALIFORNIA

BRIDGE DESIGN AND CONSTRUCTION ENGINEER: T.Y. Lin International, San Diego, Calif.

PRECAST SPECIALTY ENGINEER AND PRECASTER: Oldcastle Precast, Perris, Calif.—a PCI-certified producer

ENVIRONMENTAL DOCUMENTATION: HDR Inc., San Diego, Calif.

CONTRACTORS SPECIALTY ENGINEER: D.H. Charles Engineering Inc., Cardiff, Calif.

PRIME CONTRACTOR: LB Civil Construction, Escondido, Calif.

POST-TENSIONING CONTRACTOR: Dywidag Systems International (DSI), Long Beach, Calif.

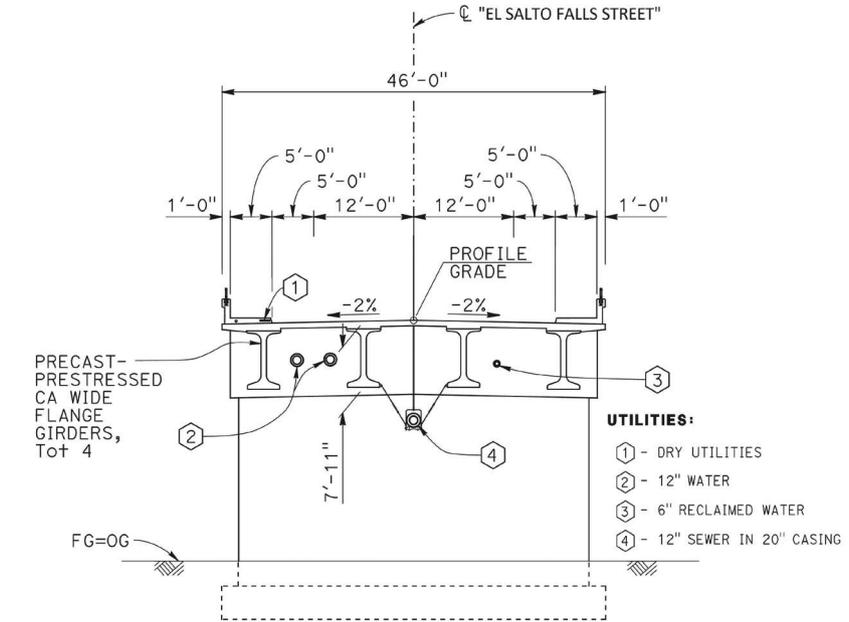
GIRDER ERECTION: Maxim Crane Works, San Diego, Calif.

entering the ESA. These included steel girder, steel truss, and high-performance precast concrete options. Long lead times and estimated higher costs precluded steel alternatives. Inspired by the *ASPIRE*SM Winter 2008 article "Precast Enables Total Environmental Avoidance" about the Daggett Road Bridge, the design team selected a high-performance precast concrete spliced-girder bridge option, where the center span girder segments are erected from previously constructed end spans.

Measuring 288.6 ft in length, the bridge has end spans of 52.8 ft and a center span of 183 ft. The concrete deck is 46 ft wide and is supported by four 84-in.-deep California wide-flange girders. The girders use high-performance concrete with a 28-day design compressive strength of 9 ksi to meet the high flexure and shear demands from the large crane loads during erection operations. Spanning between the girder flanges are 3.5-in.-thick precast, prestressed concrete deck panels, which facilitate the connection details of the hangers used to support water and sewer lines. Furthermore, these precast concrete deck panels allowed utility installation and deck construction to occur simultaneously.

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The end-segment girders run continuously from the abutments and terminate 29 ft beyond the centerline of the adjacent piers. Closing the gap are 121-ft-long midspan girder segments with 2-ft-long cast-in-place concrete closures. Full-length post-tensioning tendons provide continuity of the superstructure.



The bridge utilizes 12 high-performance precast, prestressed concrete girder segments connected with cast-in-place splices and continuous post-tensioning. The deck is comprised of 3.5-in.-thick stay-in-place precast, prestressed concrete deck panels that span between the girders and a cast-in-place reinforced concrete topping.

The substructure consists of integrally connected pier walls and abutments supported by spread footings on the south side of the creek and a pile cap with drilled-hole, cast-in-place pile foundations on the north side. To minimize the width of the footing and proximity to the ESA boundary, the pier walls are pinned to their footings with a single row of reinforcement.

The integrally connected abutment diaphragms are relatively massive, with depths exceeding 18 ft and a thickness of 5 ft. These elements served as counterweights during erection of the center span girder segments. To accommodate thermal, post-tensioning, and shrinkage movements, the abutment diaphragms were designed to translate relative to the supporting footings.

Construction Sequence

Developing a cost-effective construction sequence prior to bid and award was one of the most significant challenges of the project. The construction sequence assumed during the design process was that the foundations, substructures, and superstructure were to be constructed to the moment inflection points of the center span. An initial stage of post-tensioning would then be applied to the deck to limit stresses during erection of the center span girder segments. The deck post-tensioning consisted of two tendons with four 0.6-in.-diameter strands in the build-up regions above each girder flange.

The initial design assumed that 300-ton conventional track-mounted cranes would be centered over the piers to erect the center span girder segments.

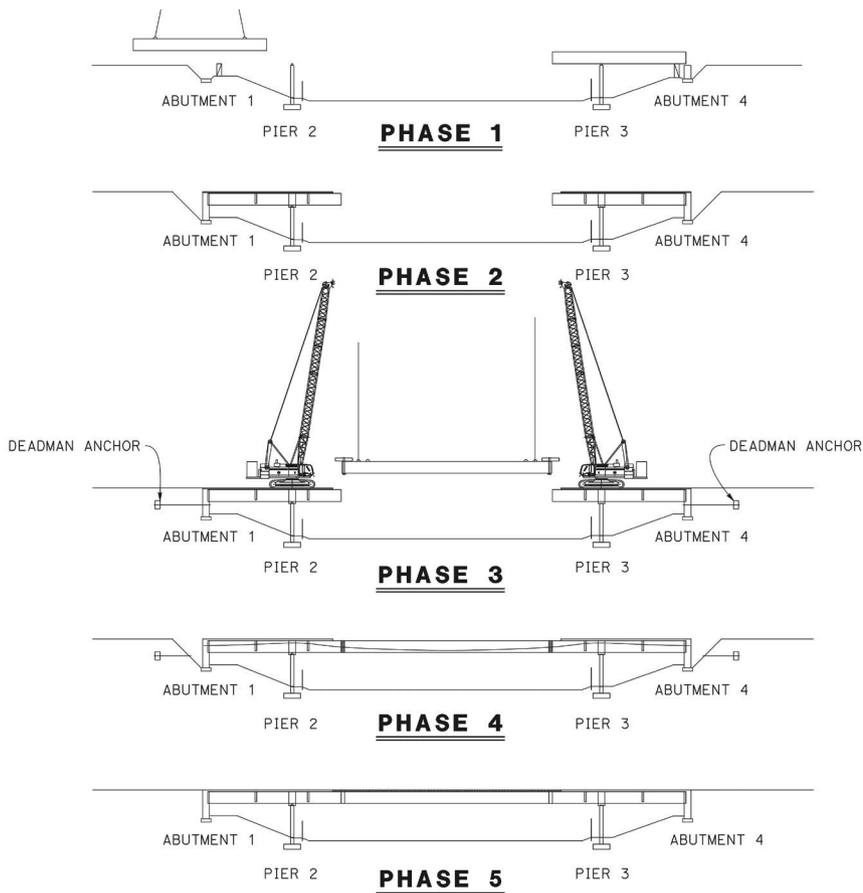
CORNERSTONE COMMUNITIES/CITY OF CARLSBAD, OWNER

BRIDGE DESCRIPTION: Three-span continuous precast, prestressed concrete spliced-girder bridge

STRUCTURAL COMPONENTS: Four 84-in.-deep by 288-ft-long precast, prestressed concrete California wide-flange girders (cast in segment lengths of 121 ft and 78 ft). One hundred and five precast, prestressed concrete deck panels with cast-in-place concrete topping slab. Concrete pier walls and abutment diaphragms are integrally connected to the superstructure.

BRIDGE CONSTRUCTION COST: \$4,400,000 (\$332/ft²) not including wet utilities

AWARDS: "2016 Project Achievement Award for Projects under \$17 million," CMAA San Diego Chapter; "2016 Outstanding Project Award," APWA San Diego and Imperial Chapter



Development of the multiphase construction sequence was a collaborative effort by the contractor, design engineer, precaster, and owner. The erection plan was revised to use a track-mounted crane and a truck-mounted crane.

Fully assembled, each crane weighs 640,000 lb, compared to the notional design truck (HL-93), which weighs 72,000 lb. The combined weight of the track-mounted crane and the supported girder equaled the weight of span 3 and the cantilever bridge deck and girders. Crane loads were the controlling load case for the shear reinforcement near the piers. Pretensioning strands at both the top and bottom of the girder controlled stresses during transport, erection, and subsequent deck construction. Girder post-tensioning provides continuity and load resistance of the completed bridge.

A key assumption was that the cranes would be fully assembled prior to driving onto the newly completed end spans of the bridge. Consequently, significant lateral surcharge pressures on the tall abutment diaphragms were anticipated when the cranes

traveled over the bridge approaches. It was also assumed that these lateral surcharge pressures would be resisted with deadman anchors that would be subsequently removed in later phases of the construction process.

The construction sequence shown in the project plans was schematic, with the intention of demonstrating feasibility and illustrating project constraints. The bid documents required the contractor to develop their own construction sequence, submit working drawings, and prepare supporting calculations demonstrating that the load-carrying capacity of the partially completed structure would not be exceeded during crane setup and girder erection operations, per the American Association of State Highway and Transportation Officials' *AASHTO LRF Bridge Design Specifications*.

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Construction

Managing submittals was a key challenge for the contractor, the owner, and the resident engineer. Documents related to construction sequence, crane loading, shoring, and pile placement were submitted and reviewed, as a first order of work. Shop drawings of the precast concrete elements were complicated because hardware embedded in the girders and the precast concrete deck panels had to line up with the utility hangers. As a result, each precast concrete girder segment and deck panel was unique, and therefore had to be labeled, tracked, and stored in a specific order to facilitate placement.

Construction proceeded according to the assumed construction sequence, in which spans 1 and 3 were constructed to create platforms for constructing the center girder segments in span 2. After the concrete for the span 1 and span 3 bridge decks was placed, the deadman anchors were attached to the abutment diaphragms and the approaches were backfilled to allow the cranes to move onto the bridge deck.

The contractor then erected the center girder segments with notable differences to the construction sequence shown in the contract documents:

1. At the southern approach, each girder segment was backed onto span 3 with one end supported by the truck and the other end supported by the 300-ton track-mounted crane centered over pier 3.
2. Both ends of the girder segment were placed on timber blocking,



where strongback brackets were attached to the ends. Upon erection, these brackets temporarily supported the center girder segments and the closure concrete until the continuous post-tensioning was applied.

3. After attaching the leads to both ends of the girder segment, the track-mounted crane lifted the girder segment over the creek.
4. Leads from a 500-ton truck-mounted hydraulic crane centered over pier 2 were then attached to the north end of the girder segment. Load was released from the 300-ton crane as the south end was lowered onto timber blocking near pier 3.
5. The leads from the 300-ton crane were then attached to the south end, which allowed the girder segment to be positioned and lowered into place with both cranes.

The contractor's choice of erecting the center segments with only one 300-ton track-mounted crane significantly reduced set-up time and cost. Analysis from the contractor's specialty engineer demonstrated that additional shear reinforcement in these girder segments was required in a critical location as a result of this choice.

Closure-pour concrete and subsequent post-tensioning were completed prior to construction of the deck in the center of span 2. Unconvinced by the designer's



The load from the girder end is transferred from the track-mounted crane (red) at pier 3 to the hydraulic crane (yellow) at pier 2. A 2-in.-thick layer of sand protected the deck surface from the tracks of the crane.



Phase 1 construction included placement of end girder on shoring towers at the abutments and timber blocks on the piers. The end girders cantilever 29 ft past the pier and extend over the environmentally sensitive area.

claim that the girders would not buckle during post-tensioning operations, the contractor installed timber bracing and metal straps at frequent intervals along the unsupported length of the girders. The bracing and straps were removed after deck placement.

Rolling platforms supported by the bottom flanges of the girders were used to install the suspended wet utility lines without entering the ESA. Installation, testing, and in-service use of the gravity sewer line were completed on time to allow the subsequent phases of the project to proceed on schedule.

Summary

The design team faced the significant challenge of developing a cost-effective design that could be constructed without entering the 170-ft-wide ESA,

within a tight schedule and with limited access. An innovative design using high-performance precast, prestressed concrete girders was developed based on a collaborative effort of the design team, the owner, the precast concrete producer, and the city. This collaborative approach continued into the construction phase, where the contractor further refined the concept with an alternative crane setup and erection plan for the center girder segments. The resulting bridge was delivered on time and with great success. ▲

Dr. Jay Holombo is a senior project manager and Wade Durant is a senior bridge engineer, both with T.Y. Lin International in San Diego, Calif. Jon Grafton is the western region business development manager of Oldcastle Precast in Perris, Calif.



After transfer, both cranes supported the center girder segment and lowered it into position. Once in place, strongback brackets temporarily supported the center segment until the closure-pour concrete attained sufficient strength and continuous post-tensioning was applied. Each center girder segment weighed 80 tons.