PROJECT

Gilman Drive Overcrossing at the University of California San Diego

by Dr. Tony Sánchez,
Systra-International Bridge Technologies

Completed Gilman Drive Overcrossing at the University of California San Diego. Photo: Paul Turang.

On February 7, 2019, representatives of University of California San Diego (UCSD), San Diego Association of Governments (SANDAG), and California Department of Transportation (Caltrans) cut the ribbon on the Gilman Drive Overcrossing, a bridge that had been in the campus plan for over 40 years. The structure completes the campus loop and provides a second crossing over busy Interstate 5 (I-5).

Background

Founded in 1960, UCSD is a university known for its cutting-edge research. In the 1970s, Caltrans built the I-5 freeway and an overcrossing at Voigt Drive to service the small campus.

By 2011, the campus had grown to almost 40,000 students, and a new crossing at Gilman Drive was needed. UCSD and its design team, led by Moffatt & Nichol, partnered with Caltrans and SANDAG to develop a new bridge for this location.

Design Goals and Process

The stakeholders agreed that the structure would need to be functional and cost-effective, and its design should have a strong character that would be compatible with the world-class architecture on campus.

The project goals led the design team to propose a concrete arch. The simple lines of an arch are beautiful, elegant, and timeless. The arch has been used for thousands of years and is one of the most robust structural forms. The funicular shape produces axial compression under uniform gravity loads—the type of internal loads for which concrete is ideally suited. A funicular structure is one that achieves an ideal equilibrium state by adopting the right form. For example, an arch under uniform gravity loads should be parabolic in shape, and, in that case, all sections of the arch will be under direct compression with no internal shear or bending forces. The arch naturally adapts to the funicular shape as loads are applied. Under self-weight or other uniform gravity loads, it takes the shape of a catenary and all sections of the cable are in direct tension, with no shear or bending. If a point load were applied, its shape would change to the new funicular shape for that applied loading (V-shape).

For an arch to be viable, it needs to have enough rise for an efficient shape, and the large horizontal thrusts must be resisted by the foundations; therefore, strong foundation material is needed near the ground surface. For the Gilman Drive project, the bridge deck would be almost 40 ft above the eight-lane I-5, providing an acceptable rise-to-span ratio of 1:9. Because the existing I-5 is

profile

GILMAN DRIVE OVERCROSSING / SAN DIEGO, CALIFORNIA

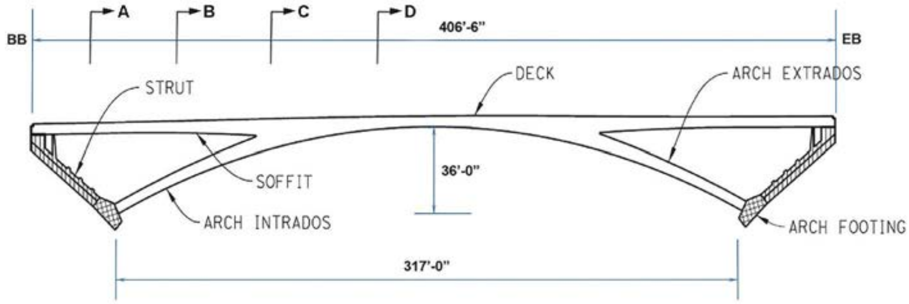
BRIDGE DESIGN ENGINEER: Moffatt & Nichol, San Diego, Calif.

CONSTRUCTION MANAGER/GENERAL CONTRACTOR: Mid-Coast Transit Constructors, a joint venture of Stacy and Witbeck, Herzog, and Skanska, San Diego, Calif.

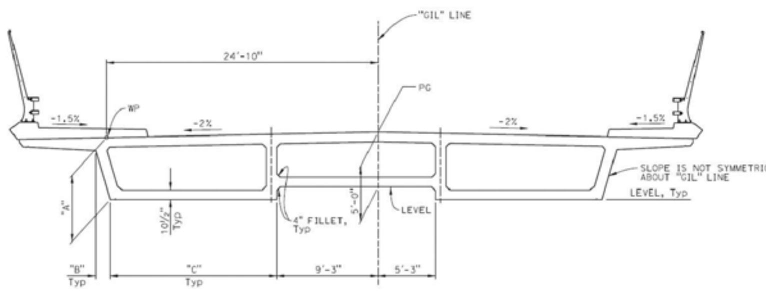
POST-TENSIONING CONTRACTOR: DYWIDAG-Systems International, Long Beach, Calif.

OTHER CONSULTANTS: Safdie Rabines Architects, San Diego, Calif. (bridge architect); Earth Mechanics Inc., San Marcos, Calif. (geotechnical engineer)

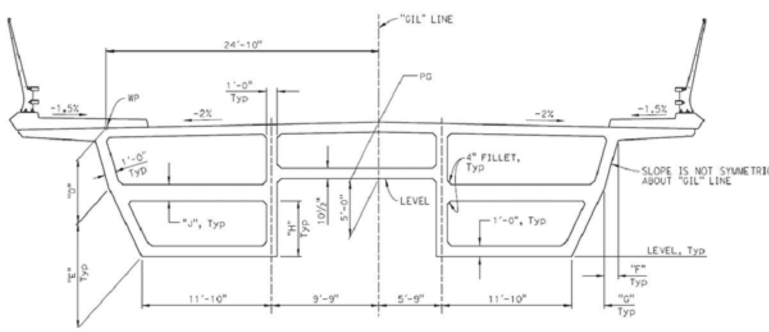
OTHER MATERIAL SUPPLIERS: Condon-Johnson & Associates, San Diego, Calif. (micropiles); Gerdau Reinforcing Steel, San Diego, Calif. (reinforcing bars)



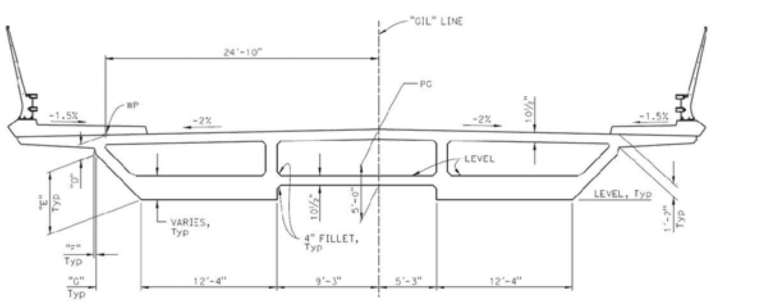
Bridge geometry. All Figures: Moffatt & Nichol.



Section B-B of the box girder within the end spans of the bridge. Section A-A is similar.



Section C-C, where the box girder meets the arch legs and the section becomes a monolithic five-cell structure.



Section D-D near the arch crown, where the arch legs fade into the girder and the section becomes a three-cell box again.

in a cut section, the designers expected the foundations would be economical.

In the 1970s, Caltrans built three similar bridges in San Diego County and after over 40 years in service, they are performing well. This history gave the designers confidence they could deliver a similar concrete arch at the UCSD site.

Design Details

Visually, the bridge's form is simple. There are only two elements: the horizontal girder and the arch. Structurally, the girder spans between abutments and is supported by the arch. The designers detailed the arch and girder to fade into each other at the crown of the arch to increase the rise and reduce the visual mass at the center.

The superstructure and the arch legs are hollow box sections. The shapes are optimized, and the geometry of each component varies. For example, the girders increase in depth as they move from the abutments to arch crowns, where demands are larger. Sections A-A and B-B are similar, they look like a Caltrans three-cell box girder. In section B-B, the bottom flanges of the outer cells deepen to better resist the bending moments that increase as the girder approaches the arch. At section C-C, the girder and arch join to become a five-cell box, and at section D-D, the arch fades into the girder and becomes a monolithic three-cell box section.

The arch legs begin as 4 x 8 ft boxes. They then expand to 7.5 x 14 ft trapezoids where they join the superstructure.

To reduce the overturning on the foundations, the designers detailed a pinned connection between the arch and the foundation. The pinned connection also reduced bending at the base of the arch and allowed the

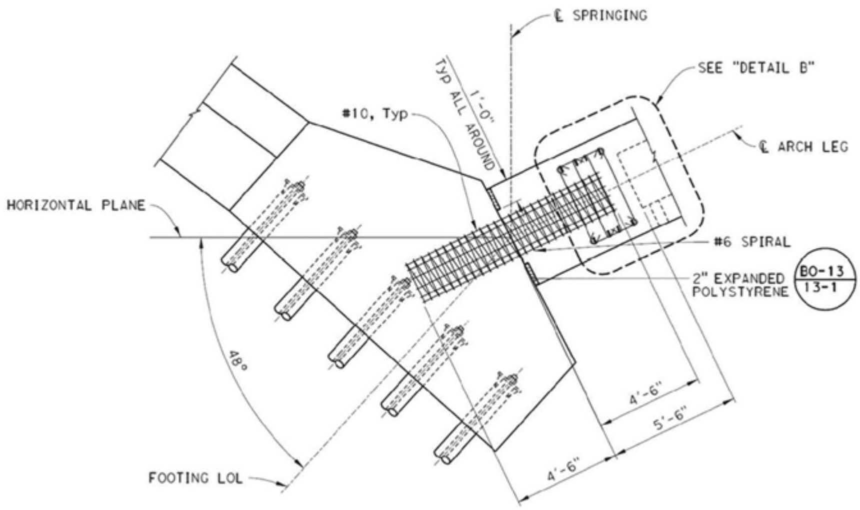
UNIVERSITY OF CALIFORNIA SAN DIEGO AND CALIFORNIA DEPARTMENT OF TRANSPORTATION, OWNERS

BRIDGE DESCRIPTION: Cast-in-place concrete arch with post-tensioned concrete box-girder superstructure, 406 ft 6 in. long, 317 ft arch span, 61 ft 8 in. wide

STRUCTURAL COMPONENTS: All components are cast-in-place concrete: four hollow arch legs, post-tensioned box-girder superstructure, pile caps, 96 micropiles (10 in. diameter), T-beam inclined struts that connect abutments to arch foundations

BRIDGE CONSTRUCTION COST: $9.5 million ($379 per square foot) for bridge items only

AWARD: Outstanding Bridge Project, American Society of Civil Engineers San Diego, 2019



Details of the pinned connection between arch and pile cap.

designers to elegantly taper the legs. The designers adapted a Caltrans column-to-footing detail commonly used in multicolumn bents. The pinned connection for the Gilman Drive Overcrossing uses three interlocking cages of no. 10 reinforcing bars (60 bars total) confined with three no. 6 spirals at a 4 in. pitch. The outer 12 in. of the arch leg is decoupled from the foundation with a 2-in.-thick layer of polystyrene.

The bridge is supported on two foundations, one on each side of the freeway. Each foundation has a group of 48 micropiles. Each 10-in.-diameter pile is 60 ft long, with the top 20 ft encased in a steel pipe that keeps the hole open and adds bending strength. The piles are connected to a 15 x 60 ft trapezoidal pile cap, whose thickness varies from 5 to 8 ft.

Structural Innovation

The ends of the horizontal girder are connected to the arch foundations with inclined struts to increase structural efficiency. These struts transfer gravity loads down the slopes and push back against the arch. This detail reduces thrust on the foundations by 20%. Thus, the design required fewer piles, which helped reduce project costs. The inclined struts have a T-beam cross section to provide an efficient section for bending; beams were cast-in-place with the webs poured into trenches. With the inclined struts, the bridge is a hybrid between a true arch and a tied arch.

Bridge Materials

For strength and durability, the designers chose concrete for all structural components. The standard Caltrans mixture proportions and details will provide at least a 75-year design life. The cast-in-place horizontal girders are post-tensioned with a total of 12 tendons, each consisting of twenty-seven 0.6-in.-diameter strands per girder with a total initial tensioning force of 14,240 kip. The prestressing force was divided equally, with three 27-strand tendons in each web. The designers specified a minimum concrete compressive strength of 3600 psi for the pile caps and inclined struts and 5000 psi for the arch legs and superstructure.

Fiber-reinforced concrete was used for the deck to reduce shrinkage cracks and improve durability. To achieve the desired look, the designers selected integrally pigmented concrete with an earthy buff color for the abutments and a warm gray tone for the bridge. The added cost of colored concrete was approximately 2% of the cost of the concrete.

Construction and Falsework

Although the contractor built the bridge with standard Caltrans-style materials and construction methods, some of the construction procedures were modified because the bridge has a distinctive shape. For example, the bridge was cast-in-place on falsework, which is standard. However, instead of the usual three placements (columns, stem/soffit/bent cap, and deck), the contractor used 10 placements. The contractor could have used as few as five, but the concrete on the east and west sides was placed separately to better control the work.

Special lateral bracing was used to resist the unbalanced loading from placing concrete on one side at a time. Once the contractor finished placing concrete for the arch, the superstructure was built as a standard bridge.


The foundation of the arch has 48 micropiles per side. Photo: Tony Sánchez.


Arch falsework in place over Interstate 5. Photo: Tony Sánchez.


The concrete being placed for the deck in July 2018. Photo: Paul Turang.

Tony Sánchez is principal engineer with Systra-International Bridge Technologies in San Diego, Calif. Previously, he worked for Moffatt and Nichol, also in San Diego, where he was the engineer of record for the Gilman Bridge.