PROJECT

GENESEE AVENUE VIADUCT

The First Curved Precast Concrete Spliced U-Girder Light-Rail Transit Viaduct in California

by Ali Seyedmadani and Pooya Haddadi, WSP

The Mid-Coast Corridor Transit Project is a 10.8-mile-long, $2.2 billion light-rail transit (LRT) link connecting downtown San Diego, Calif., to the La Jolla, Calif., business center on Genesee Avenue. This transit line uses the existing Los Angeles–San Diego–San Luis Obispo (LOSSAN) rail corridor in the southern portion of the line. It crosses over the San Diego River in parallel with Interstate 5 (I-5), then crosses over I-5 in the vicinity of the San Diego VA Medical Center, runs near the University of California San Diego (UCSD) campus, crosses over I-5 again, and terminates in the median of Genesee Avenue near Westfield UTC mall in La Jolla.

The entire Mid-Coast Corridor Transit Project includes 12 bridges, four aerial stations with side platforms, three viaducts (each over 1 mile long), and more than 70 retaining walls of various types. As the project navigates through heavily urbanized and less-urban areas, there are also significant changes in elevations. Soil conditions vary, and there may be perched water tables within foundation footprints. In addition, because Southern California is in a high-seismic zone and project alignment crosses over a seismic fault, special bridge design elements were required for potential ground movement due to fault rupture.

Project cost (guaranteed maximum price) and schedule were the major driving forces during delivery of the Mid-Coast Transit Project. When it was being planned, the owner, San Diego Association of Governments (SANDAG), was executing and overseeing the delivery of several transit projects simultaneously, and the association decided that the construction manager/general contractor (CM/GC) alternative delivery method would be the right approach for this large, complex project.

Project Delivery

When SANDAG selected the CM/GC for the project, a review of the project schedule and cost was undertaken. Through this process, it was determined that changing two bridges from the preliminary design of cast-in-place (CIP) post-tensioned (PT) box-girder designs to precast concrete girder structures would save time and minimize construction impact on the communities. The 1758-ft-long Rose Creek LRT Overhead Bridge that crosses the alignment from the east side of the existing LOSSAN track to the west side and the 5726-ft-long Genesee Avenue Viaduct were identified for redesign as precast concrete girder bridges.

Genesee Avenue is the business, shopping, and office center of La Jolla and a major arterial street. For the Genesee Avenue Viaduct, the contractor concluded that a precast concrete girder bridge would eliminate several months

Mid-Coast Transit Corridor alignment near the San Diego VA Medical Center. Photo: Mid-Coast Transit Constructors.

profile

GENESEE AVENUE VIADUCT / LA JOLLA, CALIFORNIA

BRIDGE DESIGN ENGINEER: WSP, Orange and Sacramento, Calif.

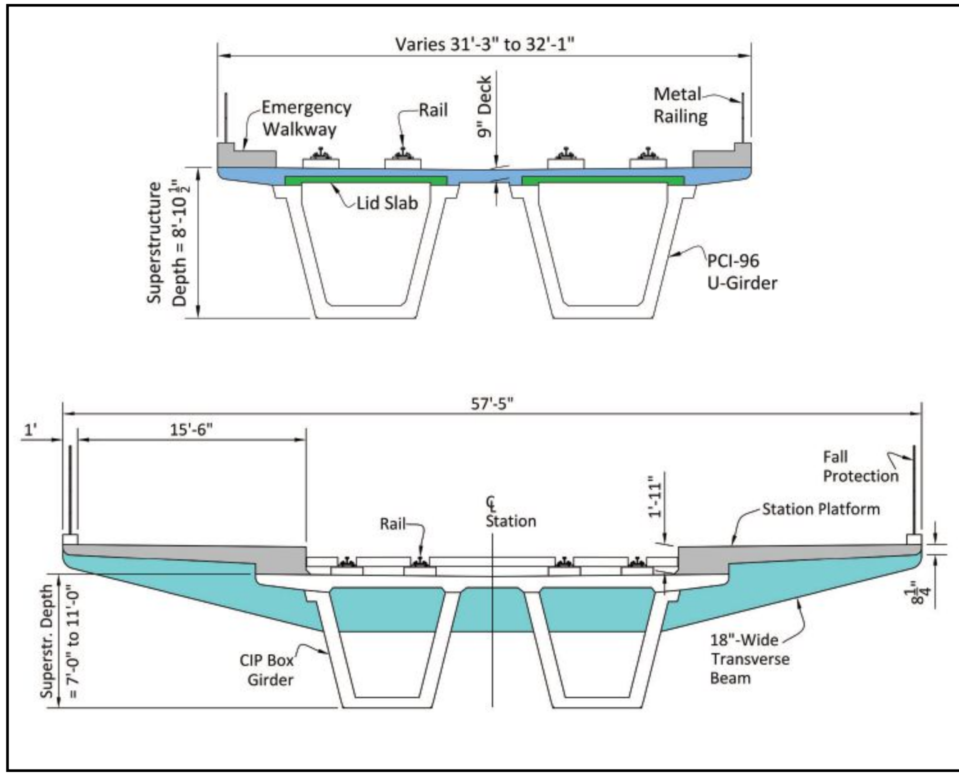
CONSTRUCTION ENGINEER: PGH WONG Consulting Engineers/Kleinfelder, San Diego, Calif.

PRIME CONTRACTOR: Stacy and Witbeck/Herzog/Skanska–Mid-Coast Transit Constructors (MCTC), San Diego, Calif.

PRECASTER: Oldcastle Infrastructure, Perris, Calif.—a PCI-certified producer

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

Genesee Avenue Viaduct alignment near the University of California San Diego campus. Photo: Mid-Coast Transit Constructors.



Typical Genessee Avenue Viaduct section (top), and typical section at stations (bottom). Figure: WSP.

of nighttime construction, reducing the project's impact on surrounding hotels, businesses, residences, and the traveling public without compromising aesthetic appearance.

Viaduct Configuration

The preliminary design of the Genesee Avenue Viaduct using CIP PT box girders had identified column and foundation locations along the median of the arterial and had set the span arrangement based on critical intersections and driveway crossings. Early utility relocation had begun, and the early construction package was underway. Therefore, the superstructure span layout was somewhat set when the design was changed to a precast concrete U-girder system.

However, the precast concrete girder layout for the 5726-ft-long bridge eliminated one span from the CIP configuration, resulting in 35 spans divided into 12 frames (units). Eleven frames have three spans and one frame has two spans. The longest frame is 590 ft and the longest span is 225 ft; most spans are 180 ft long and have three 60-ft-long girder segments. The radius of the curved viaduct is at least 990 ft, except in one section where the radius is 500 ft.

There are three types of frames on the viaduct. The first type is a precast concrete frame with three precast concrete spliced girder segments per span per girder line, integral at the bents. The second type is a hybrid of precast concrete spliced girders and CIP hammerhead pier tables to extend the typical 180-ft-long spans to accommodate the crossing over the La Jolla Village Drive intersection. The third type is a traditional CIP PT concrete box girder; this was used for the two aerial stations with side platforms. There are five in-span internal hinges on the viaduct, one at each end of the two station units and one at the interface with the UCSD Viaduct. These in-span hinges will isolate the seismic displacement of the CIP frames from the remaining frames of the viaduct during extreme seismic events.

The Genesee Avenue Viaduct's typical two U-girder-line section is 32 ft 1 in. wide, except at the stations, where sections are widened to 57 ft 5 in. The

SAN DIEGO ASSOCIATION OF GOVERNMENTS, OWNER

OTHER MATERIAL SUPPLIERS: Cosmic Inc., Athens, Tex. (spherical bearings); GERDAU, San Diego, Calif. (reinforcing steel fabricator)

BRIDGE DESCRIPTION: 5726-ft-long light-rail transit bridge consisting of 35 spans in 12 frames with two lines of straight or curved precast concrete spliced girders

STRUCTURAL COMPONENTS: One hundred forty modified PCI U-96 precast concrete girders (48 were curved), maximum of 60 ft in length and 100 tons maximum haul weight, supported on cast-in-place pier caps, 7- to 9-ft-diameter columns, and 9- to 10-ft-diameter drilled shafts

BRIDGE CONSTRUCTION COST: $60 million ($320/ft^2), including station platforms

Typical precast concrete straight U-girder segment. Photo: WSP.

The precast producer used two straight and one adjustable-curve PCI U-96 girder forms. Photo: WSP.

curved precast concrete section is the same size as the typical section and uses PCI U-96 girders with 10 in. webs and a 9-in.-thick bottom slab. To control torsional forces induced in the curved, open-section girders, $4\frac{1}{4}$-in.-thick CIP lid slabs were constructed in the fabrication plant to close the top of the U-girders. There are four $3\frac{13}{16}$-in.-diameter ducts with nineteen 0.6-in.-diameter strands in each web; four ducts were used for splicing, and four ducts were used for PT continuity. There are also four $3\frac{1}{8}$-in.-diameter ducts with twelve 0.6-in.-diameter strands at the curved section in the bottom slab of the girder for self-weight post-tensioning; pretensioned strand was used for the straight girder sections.

Each precast concrete U-girder was designed to carry one LRT track loading in addition to dead loads. The LRT loading is approximately 50% heavier than the standard highway truck loading. Because this viaduct is close to the ocean, designers chose to have no tension in the girders to improve the structure's durability and service life. The minimum concrete design strengths were 6000 psi at transfer and 8500 psi at 28 days.

Girder hauling costs in Southern California increase significantly when segment weight is over 100 tons. This weight includes any temporary stiffening braces or lid slabs in curved sections of bridge segments. Lid slabs are used to stiffen the open U-girder section during the hauling and erection operations and to serve as a stay-in-place form for the deck.

On the Genesee Avenue Viaduct project, one strategy used to keep the haul weight of segments below the 100-ton limit was to not include the post-tensioning anchorage hardware and concrete section at the girder end diaphragm. This resulted in the construction of a CIP closure section of about 7 to 9 ft prior to post-tensioning. The CIP section also provided tolerance for forming the tendon deviators and girder flares in the end zone.

Substructure Configuration

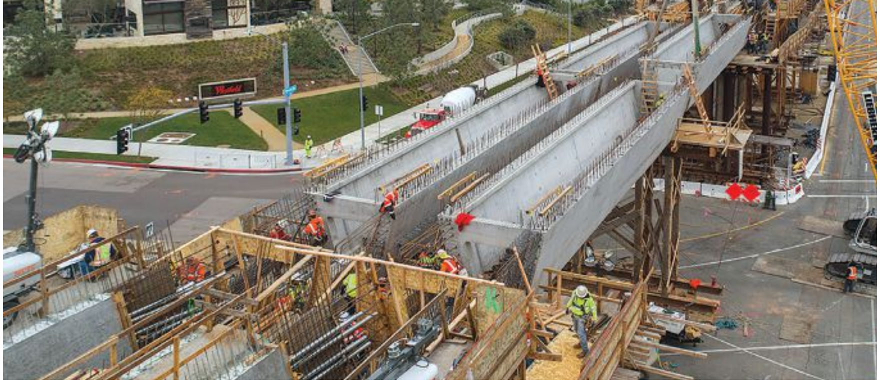
The seismic design of the Genesee Avenue Viaduct required similar substructure stiffness in each frame. In addition, it required that adjacent frames have a similar fundamental period of vibration in the longitudinal direction. Therefore, the designers had to adjust column and drilled-shaft sizes as column height and span length varied.

The viaduct substructure consists of pier caps supported by single columns with a drilled-shaft foundation. The column sizes vary from 7 to 9 ft in diameter, and the drilled shafts are 9 to 10 ft in diameter. The pier caps are 7 to 9 ft in the longitudinal direction, approximately 22 ft wide, and vary in depth from 4 ft at the outside edge to 8.5 ft at the column face. The shape of the piers mimicked the shape of the other CIP box-girder viaduct piers except the top of the pier was enlarged to accommodate a seat for the U-girders.

The superstructure/substructure connection is a pin at the interior pier caps and an expansion joint at the exterior pier caps of each frame. There are two types of pins at the pier caps. One type was designed using reinforcing bars to engage during service and post-tensioning operations; the second type has much larger pins and sockets that are designed to remain elastic during major seismic events, allowing the superstructure to rotate. All pier caps with seismic pins include transverse high-strength threaded rods at the top of the pier cap within the pin support area. These rods increase confinement and improve shear capacity of the pier caps during a seismic event.

The drilled shafts were detailed assuming wet ground conditions during construction. Cross-hole sonic testing was performed to ensure quality of the placed

Girder segment with blockout for closure pour and post-tensioning anchorage hardware. This photo also shows both pins in the pier cap. Photo: WSP.



Erection over the La Jolla Village Drive intersection. For the longest span crossing over the La Jolla Village Drive intersection, hammerhead pier tables were constructed on falsework. The two main span U-girders were spliced on the ground in the staging area and then erected on the falsework tower at the ends of the pier tables. The back-span girders were erected on falsework towers and then spliced together. Photo: Mid-Coast Transit Constructors.

Rendering of the completed Genesee Avenue Viaduct. Source: WSP.

concrete. All longitudinal reinforcing steel in the columns and drilled shafts is continuous with no lap splices.

Girder Erection Sequence

The design plans had three basic methods for U-girder erection. The first method was used for frames that do not cross over any intersection or driveway wider than 60 ft. This method involved erection of individual girder segments that are about 60 ft or shorter, weighing less than 100 tons, on temporary towers. Then, the closure pours, diaphragms, and CIP deck were constructed, followed by post-tensioning the full frame in one operation (single stage).

The second method was designed for frames that cross over an intersection wider than 60 ft. For this method, girders were erected on falsework towers at all locations except the intersection. Then, after closure pour construction, the erected U-girders were spliced using two ducts in each web (stage 1 post-tensioning). The U-girder segments for the intersection were spliced on the ground in the staging area, and then erected on falsework towers, allowing the intersection to remain open. Then, the closure pours with diaphragms and the CIP deck were constructed and the remaining two ducts in each web were used for continuity post-tensioning of the full frame (stage 2 post-tensioning).

The third erection method shown in the design plans was a hybrid method and was used to construct the longest frame crossing over the La Jolla Village Drive intersection. Hammerhead pier tables were constructed on falsework. The two main-span U-girders were spliced on the ground in the staging area and then erected on the falsework tower at the ends of the hammerheads. The back-span girders were erected on falsework towers and spliced together. To complete the construction, the diaphragms and CIP deck were constructed and continuity post-tensioning was applied to the full frame.

As the contractor gained experience and confidence in the girder erection, closure pours, and post-tensioning operations, they proposed using a quick-set, high-early-strength concrete mixture with no fly ash. It was hoped that use of this mixture would eliminate the need for a staging-area splicing operation and lifting of already spliced girders. After mock-up testing of the concrete mixture to check strength development and concrete temperature during curing, the proposal was approved. With the approval, the contractor was able to form, place, cure, and achieve required concrete strength of the closure pours in two days. Then, the first-stage post-tensioning could be completed and the intersection opened to traffic within six days. This approach reduced night work, shortened the schedule, and reduced risk.

As of this writing, the contractor had completed the viaduct and was attaching direct fixation rails and utilities to the bridge.

The use of a precast concrete U-girder bridge for this viaduct reduced the total construction duration and significantly reduced night construction. These time savings greatly benefited the nearby residences, businesses, and travelers along this major arterial street. The precaster's initial investment in U-girder forms helps provide future opportunities to design concrete bridges with more complex, longer spans and aesthetically pleasing features, with fewer construction impacts, in Southern California.

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Splicing operations for two U-girder segments crossing the Esplanade Court intersection. The contractor closed the intersection and used a quick-set, high-early-strength concrete mixture. This span terminates at the in-span hinge of the cast-in-place (CIP) box station frame in the foreground. The falsework is for the hinge and the CIP box frame. Photo: Mid-Coast Transit Constructors.

EDITOR'S NOTE

The PCI U-girder sections mentioned in this article were developed by PCI Zone 6. The full set of drawings is available at www.pci.org/PCI_Docs/Design_Resources/Transportation_Resources/PCI%20Zone6%20Curved%20Spliced%20Girders.pdf.