PROJECT

Precast 'Super-Girders' Aid Light Rail

by Thomas R. Barnard and Ahmad M. Abdel-Karim, AECOM

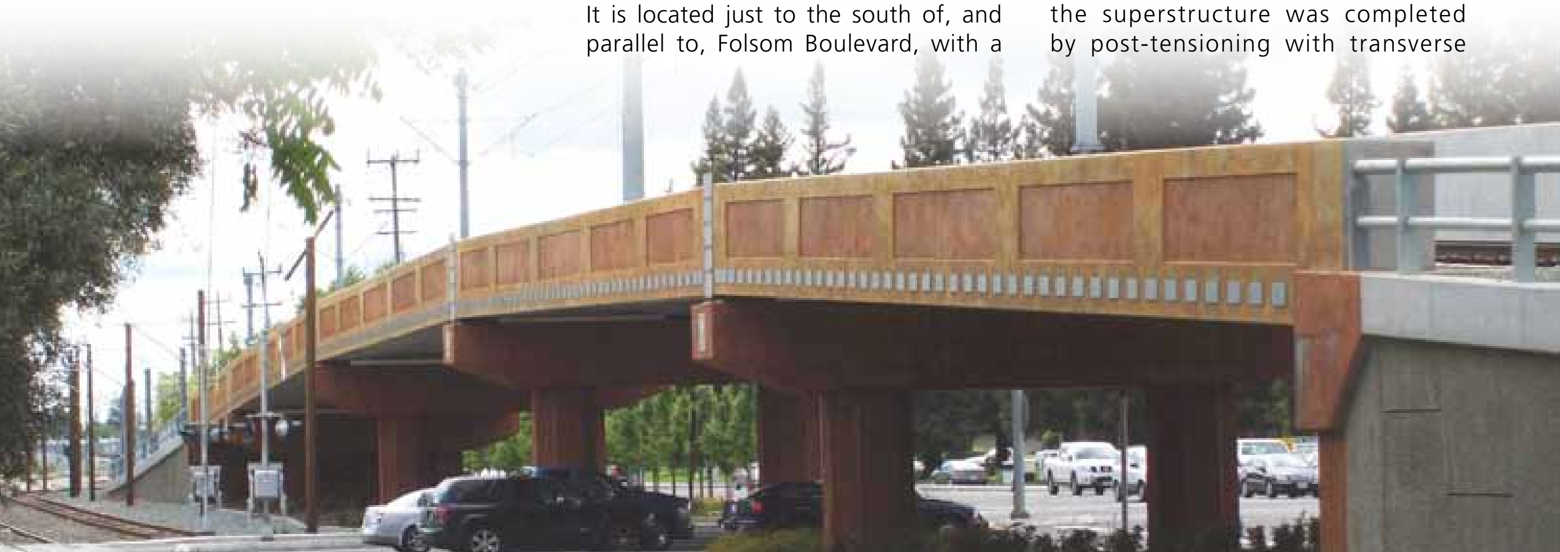
Three-girder 'trough' cross section spans longitudinally while concrete slabs span transversely between girders

Creating effective noise and visual barriers to light-rail train (LRT) traffic, while providing pleasing aesthetics that don't disrupt the community's ambience, pose significant challenges for urban planners. The recent precast concrete structure over South Watt Avenue in Sacramento, Calif., provides an example of how these challenges can be met with an innovative "trough" cross section.

The five-span, 540-ft-long project resulted from the South Watt Area Transportation Study (SWATS), which evaluated the entire Watt Avenue corridor. The SWATS study produced a list of short- and long-term upgrades necessary to improve safety and efficiency for the corridor's transportation system. Among these changes were modifications to create a grade separation between two light-rail tracks and highway vehicles at the South Watt/Folsom Blvd. intersection. It is located just to the south of, and parallel to, Folsom Boulevard, with a parking area for the Manlove Light Rail Station in the intersection's southeast corner. In addition, a freight railroad line runs parallel with the LRT tracks and Folsom Boulevard.

To accommodate the long-term plan for the Watt Avenue Corridor, the structure also had to accommodate a future grade separation between South Watt Avenue and Folsom Boulevard. As a result, the substructure was designed to allow South Watt Avenue to be lowered by up to 20 ft.

The grade-separation structure features a "trough" cross section, consisting of three precast, prestressed concrete girders spanning in the longitudinal direction, and precast, prestressed concrete slabs spanning between adjacent girders in the transverse direction. After erection, the deck-slab panels were joined through longitudinal post-tensioning. Their integration into the superstructure was completed by post-tensioning with transverse



The five-span, 540-ft-long light-rail train project over South Watt Avenue in Sacrament, Calif., features an innovative "trough" cross section of through-girders that reduced construction time, improved aesthetics, and limited road closures.
All Photos and Drawing: AECOM.

profile

SOUTH WATT AVENUE LIGHT-RAIL BRIDGE / SACRAMENTO, CALIFORNIA

ENGINEER: AECOM, Sacramento, Calif.

PRIME CONTRACTOR: Viking Construction, Rancho Cordova, Calif.

BRIDGE DESCRIPTION: A five-span, 540-ft-long light-rail bridge that features a "trough" cross section consisting of three precast, prestressed concrete girders spanning in the longitudinal direction, and precast, prestressed concrete slabs spanning between adjacent girders in the transverse direction.

tendons, which also pass through the girders and closure pours. Finally, the longitudinal tendons in the girders and slabs were stressed to produce the required composite system capacity.

The concept reflects the flexibilities of precast concrete commonly used to solve difficult site constraints or staging requirements. But the bridge also highlights an important benefit of precast concrete that is often overlooked, by transversely integrating the all-precast concrete cross sections to create a "super girder." This concept

This concept opens the door for a new generation of all-precast concrete 'super girders.'

opens the door for a new generation of all-precast "super girders" fabricated in segments, transported, and then field-assembled into a single deck element. The added flexibility of these systems allows them to economically meet a wider range of functional requirements.

Evaluation Considerations

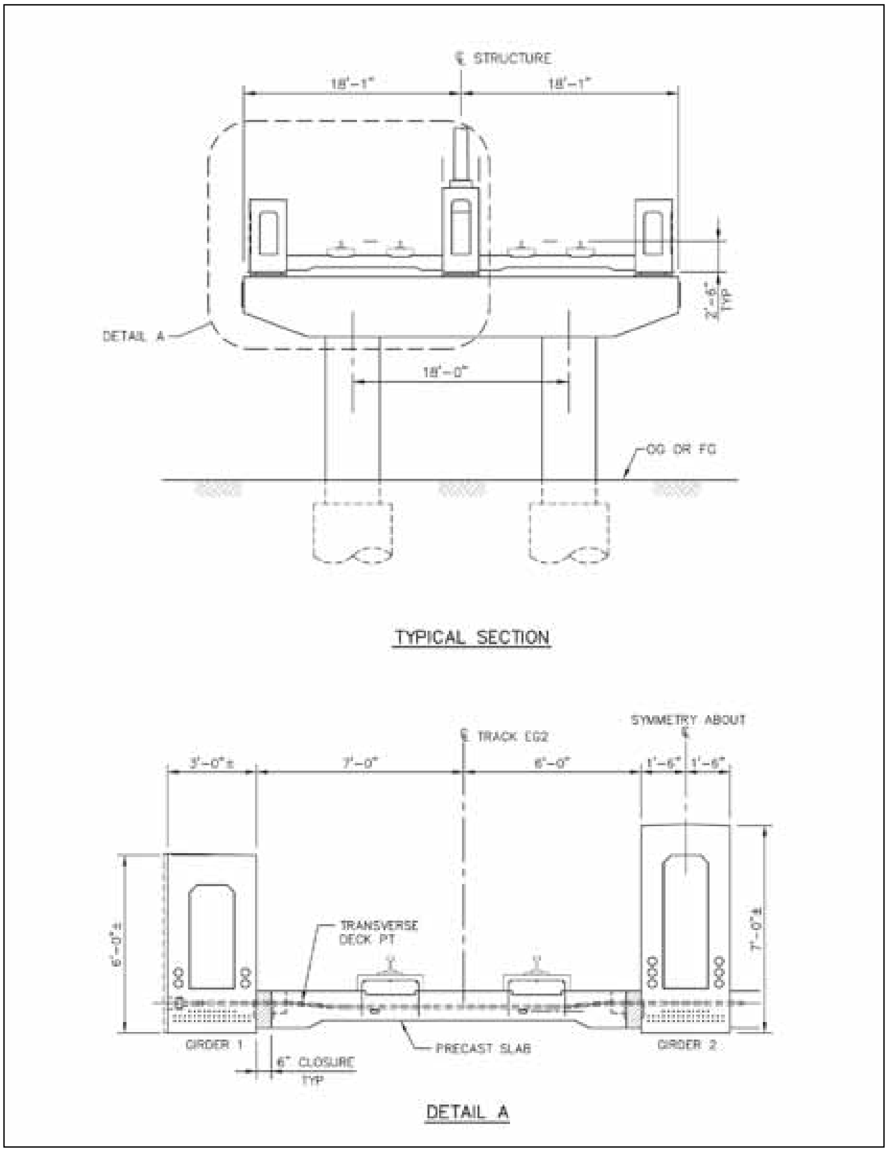
Although light-rail passenger-vehicle structures share many characteristics with those carrying freight trains, the magnitudes of the loadings to which they are subjected are more similar to loadings for highway vehicles. The lighter loads make it possible to evaluate structure types used for highway grade separations, broadening the options. For this project, multiple structure types were evaluated to determine the most practical design.

Options were evaluated on a variety of factors, comprising:

- Overall construction duration
- Impact on intersection traffic
- Safety
- Proximity to operating tracks
- Continuity of LRT operations
- Roadway clearance—temporary and permanent
- Construction cost
- Bridge aesthetics
- Superstructure depth and associated profile
- Proximity to the station and its impact on profile

Seven superstructure types were considered:

- Precast, prestressed concrete box beams
- Precast, prestressed concrete I-girders
- Precast, prestressed concrete bulb-tee girders
- Cast-in-place box girders
- Steel I- or through-girders
- Cast-in-place concrete troughs
- Precast, prestressed concrete troughs



Cross section of the through-girder light-rail bridge.

540-FT-LONG PRECAST CONCRETE LIGHT-RAIL BRIDGE / SACRAMENTO COUNTY DEPARTMENT OF TRANSPORTATION, OWNER

PRECASTER: Con-Fab California Corp., Lathrop, Calif., a PCI-certified producer

BRIDGE CONSTRUCTION COST: $24 million (including the roadway improvements, LRT power and communications systems, at-grade crossing protection, Union Pacific Railroad freight track relocation, intersection signal work, and site restoration/landscaping)

Girder end zones required strut-and-tie techniques during design to provide more reliable, economical details.

While many of these options met the basic requirements for functionality, it became clear early in the process that the site constraints, especially vertical clearances and approach grades, could be economically met using only a precast or steel-plate girder superstructure.

Through-girders, typically used in railroad crossings, are less commonly used for LRT grade separations. The most prominent feature of the trough section is that the girders project above the deck. This contrasts with conventional structure sections, where the girders support the deck from below. As a result, the structure depth required for a trough section is substantially less than for conventional types. This means the profile grade can be lowered, reducing costs associated with a raised-profile grade.

Concrete-trough (or through-girder) bridges can be constructed by a variety of methods. The most common type consists of a cast-in-place concrete trough section, with sloped sides. The deck soffit of a cast-in-place trough-girder bridge is relatively thick and often requires post-tensioning to span between girders. Precast concrete trough sections provide a viable alternative in situations where it is necessary to minimize falsework requirements and traffic impacts.

Advantages for the precast concrete trough are that it provides a low profile, expedites construction time, minimizes impact to intersection traffic, and provides high fascia girders to act as sound barriers. However, the barriers also obstruct passengers' views, and the designs can be moderately complex to construct.

The prefabrication of the structural system reduced the number and duration of complete closures to 3 weekends.

Attention Paid to Stresses

Special attention was paid in the design to ensuring that the stresses and deformation of the all-precast, multi-component deck met the required criteria. For example, the quantities of pretensioning and post-tensioning steel in the girders and slabs were carefully selected to satisfy the stress limit states during the various construction stages, while minimizing deflection. Keeping the girder deflections to a minimum reduced the chances of error in predicting the girder profile at any given time, and thereby reduced the potential for encountering excessive differential cambers.

The trough design aided durability in several ways. The combination of transverse and longitudinal post-tensioning minimized cracking, which reduced susceptibility to reinforcement corrosion. The use of glass-fiber reinforced plastic (GFRP) reinforcement in the direct fixation plinths further improved corrosion resistance.

The lack of a cast-in-place concrete deck and end diaphragm to tie the girders together and provide housing and support for the post-tensioning anchorages required in-depth analysis and design. In addition, the shape of the girder's end block and the concentration of load effects from bearing and post-tensioning resulted in highly irregular stress fields within the end regions. As a result, the girder end zones were investigated using strut-and-tie techniques to provide a more reliable, economical design.

The tolerance for fabrication errors is reduced in direct proportion to the number of components involved. All components had to be fabricated to ensure they matched with each other in the field and with the site-cast concrete foundation and substructure. Both transverse and longitudinal joints had to align perfectly to receive the post-tensioning tendons required to tie the composite structure together.

Many of these issues were related to the girder fabrication, longer-than-usual storage periods, and transportation and erection schemes. Additional issues surfaced during the erection of the slab panels and the integration of all precast girder-slab components into a single "super-girder" section.

The precast concrete girders were trucked to the site and staged nearby so they could be erected during weekend overnight lane closures.

The structure depth required for a trough section is substantially less than for conventional types.

Site Complexity Posed Challenges

The greatest challenge for the designers and contractor involved the site's multi-modal nature. The design was driven by site constraints, such as clearance and grade requirements, as well as the need to maintain freight rail and vehicular traffic while not interfering with the ongoing station operations. The difficulty of constructing a grade separation in close proximity to operating light-rail and freight tracks created significant complexities. Close coordination between the contractor and railroad operations was required to ensure construction activity did not encroach into the operating envelope without appropriate warrants in place.

Fortunately, the Union Pacific Railroad spur at the site did not have significant traffic (three or four trains per week). To ensure no difficulties, the Sacramento County Department of Transportation construction management and inspection staff, along with the contractor, coordinated any encroachment into the freight rail operating envelope with the railroads operations personnel.

Closing South Watt Avenue even for a few days created a major disruption for drivers, as well as for personnel in the Sacramento County DOT. The prefabrication of the structural system reduced the number and duration of complete closures to 3 weekends.

Construction involved creating a shoofly detour to allow trains to operate outside the construction zone, so the precast concrete structural elements could be erected without disrupting traffic. Girders were trucked to the site and temporarily stored so they could be erected overnight. The longitudinal girders were erected during three weekend night closures, while precast deck slabs were installed during normal working hours. The longitudinal girders were post-tensioned following the erection and stressing of the transverse slab tendons. Once the bridge was erected, tracks were installed and station modifications were completed. Then traffic was shifted onto the new structure and the shoofly was removed.

The construction of this bridge shows the feasibility of using a through-girder or "trough" type superstructure composed of precast concrete components integrated into a composite system via post-tensioning. The engineer's continuous involvement during the various construction stages proved critical to avoid otherwise costly problems and to achieve success. This design offers great potential for the future for other municipalities facing these light-rail challenges.

Thomas R. Barnard and Ahmad M. Abdel-Karim, are project managers with AECOM, formerly DMJM Harris, in Sacramento, Calif.

For more information on this or other projects, visit www.aspirebridge.org.

The difficulty of constructing a grade separation in close proximity to operating light-rail and freight tracks created significant complexities.

Installation of the precast concrete deck slabs took place during normal working hours.

The grade-separation structure features a "trough" cross-section, consisting of three precast, prestressed concrete through-girders spanning in the longitudinal direction, and precast, prestressed concrete slabs spanning between adjacent girders in the transverse direction.

After erection, the deck-slab panels were connected with cast-in-place concrete closure strips and longitudinal post-tensioning. They are integrated into the superstructure by post-tensioning transverse tendons, which also pass through the girders and longitudinal closure pours.