Garvey Avenue Bridge Replacement

An Aesthetic Application of Precast Prestressed Bulb Tee Girders

By Peter Liu, P.E.

The project consists of the onsite replacement of the Garvey Avenue Bridge over the Rio Hondo Channel, sponsored by the Highway Bridge Replacement and Rehabilitation (HBRR) Program in the City of Rosemead, California.

The Garvey Avenue Bridge Replacement illustrates that bridges, including precast bridges, can be built artistically even for the typical bridge located in your own neighborhood. This article outlines the technical details of the Bulb Tee girder design, and discusses the aesthetic scheme developed for this type of bridge.

Existing Site Condition

The existing Garvey Avenue Bridge (*Figure 1*) was built in 1937, when Rio Hondo Channel was a natural watercourse. In the 1950s, the U.S. Army Corps of Engineers (Corps) improved the channel with a trapezoidal concrete lining, narrowing it considerably. Because the bridge was constructed to span the natural width of the channel, several end spans of the structure now extend outside the channel banks.

A number of design constraints affected the planning of this project. Garvey Avenue is a busy traffic corridor. The City required that Garvey Avenue remain open for vehicular and pedestrian traffic during the construction of the project. Therefore, staged construction became a necessity. Both traffic detouring and scheduling played an important role.

It is anticipated that the Corps will require the work within the channel to be limited to the dry season between April 15th and October 15th. During the dry season, the contractor may be able to stage the operation within the channel; however, a low flow diversion will be provided and maintained by the contractor during the dry season.

Structure Types Discussion

The selection for the project is the precast prestressed Bulb Tee girder post tensioned for continuity (*Figure 2*). The new bridge will span 420 feet long and 100 feet wide. It consists of two 93-foot exterior spans and two 117-foot interior spans. This reduces the number of piers in the channel from the original five to three.

The precast, prestressed Bulb Tee girder bridge meets all of the design constraints discussed earlier. This alternative enables a highly condensed staged construction schedule that limits the construction activities in the channel to one dry season. This is feasible, as no falsework will be required for the erection of precast girders and the casting of the concrete deck. Once the pier walls are constructed, the final construction can be performed out of the confines of the channel. The precast prestressed Bulb Tee girder provides for more consistent structural performance during earthquakes without increasing the construction cost. Splicing the precast Bulb Tee girders together with closure pour and post-tensioning enables the bridge superstructure to behave essentially like a continuous structure during seismic activity.

Aesthetic Considerations

Representatives of the City of Rosemead expressed a strong desire that the new bridge not only provide a sound structure and meet the current traffic needs, but also create a monument at the entrance to the City. The design incorporated aesthetic features requested by the City, such as entry monuments, decorative lighting, and historic features of the original bridge.

Bulb Tee Girder Analysis and Design

The precast, prestressed Bulb Tee girders, post-tensioned for continuity, have recently become more popular in California. The advantage of building a longer span with short, light precast segments with no falsework required makes this structure system favorable over watercourses where physical restraints and environmental sensitivity play a major role in bridge type selection. Providing monolithic girder-substructure joints makes this system comparable to conventional box girder structures in terms of seismic performance.

Superstructure Material Properties

Careful selection of construction material is important in Bulb Tee girder design, due to the required construction technique. Particularly, prestressing steel and concrete creep and shrinkage characteristics greatly influence the predicted structural behavior.

The materials used in the design for the Garvey Avenue Bridge are:

Concrete
Precast Bulb-tee Girders:
$f'c$ = 6,000 psi @ 28 days
$f'ci$ = 5,000 psi @ Pre-tensioning

Pier Diaphragms & Girder Closure Pour:
$f'c$ = 6,000 psi @ 28 days
$f'ci$ = 5,500 psi @ Post-tensioning

Bridge Deck & Intermediate Diaphragms:
$f'c$ = 4,500 psi @ 28 days

Prestressing Steel
Strands–ASTM A416, Grade 270
Low Relaxation

Figure 1: Photo of existing bridge

Design

The initial plan was to design the straight pre-tension tendons just large enough to resist the dead load moment at the midspan of the Bulb Tee girders. After further analysis, it was determined that this would result in significant girder deflections. These deflections could be so large that even the later post-tensioning would not bring the superstructure back to level. This is because, unlike cast-in-place box girder construction, precast girders are cast in the plant without camber. Thus, even with the help of post-tensioning, the bridge superstructure may still develop downward deflection.

One solution is to use greater pre-tension stress to "force" a desired camber in the precast girders. This proved to be more effective than increasing the post-tension stress.

Typical precast girder bridges use drop caps or inverted bent caps to provide a temporary seat for the girders. Neither of these options was adopted for the Garvey Avenue Bridge design because inverted bent caps do not provide the continuity of girders at intermediate supports, especially for the bottom reinforcement, while the drop cap design cap would force the plastic hinge to form away from the joint. Due to the short pier wall height of this bridge, it was found that even a 2-foot-deep drop cap would increase the plastic hinge shear in the pier walls by 15 percent by lowering the potential plastic hinge zone. In addition, concealed joints provide a better appearance to the decorative side panel of the girder.

To create a concealed joint, pier diaphragms/bent caps were designed at the same depth of the girders. During construction, the pre-cast girders will be lifted onto temporary bearing pads supported by either temporary falsework or steel brackets attached to the reinforced concrete piers. Pier diaphragms were designed 1 foot wider than the pier walls at each side. The horizontal side bars along the pier diaphragms will run through the holes formed in the precast girders. This will result in an integral connection between the superstructure and substructure.

Figure 2: Rendering of reconstruction

Analysis Issues

Because the construction techniques for this bridge are not conventional, there are no existing codes that address many aspects of the analysis, nor do most software programs provide comprehensive computer-aided design. Therefore, the analysis and/or design issues rely heavily on the engineers' judgment.

For example, PCBridge™ (McTrans) was programmed to design prestressed box girder bridges. In order to obtain the correct results for this bridge, some of its input data would have to be manipulated to reflect the difference between precast prestressed girders and box girders, i.e., the skew angle. Box girders with skew angles have larger shear modification factors than precast prestressed girders. Therefore, the skew angle used in the PCBridge analyses was adjusted manually based on the expected shear modification factor for a precast girder.

Another issue is the post-tension cable paths. Caltrans Memo to Designers (MTD) provides the minimum prestress clearance at both high and low points. These values are based on a 12-inch-wide section. Caltrans standard BT-1550 has a web width of a mere 8 inches. Instead of solely relying on the MTD recommendations, we did our own calculations to estimate the required number of strands in each cable and the corresponding conduit size. With help from some experienced girder manufacturers, we finalized the cable path profile with confidence.

Seismic Design Issues

The Garvey Avenue Bridge was designed based on the latest Caltrans' Seismic Design Criteria (SDC). The analysis was completed using the GT-Strudl® program. Only the final completed structure was considered in the seismic analysis.

All pier walls are fixed at the top and pinned at the bottom in the weak direction, but are assumed to be fixed at the bottom in the strong direction. As recommended by SDC, a plastic hinge is assumed to form at the top of the piers. This subjects the superstructure to a very large positive moment at the face of the piers. The required positive moment capacity is provided by extending the pre-tensioning tendons into the pier diaphragms combined with additional mild reinforcement made continuous with mechanical splices. In the strong direction of pier walls, the walls were designed to remain essentially elastic during an earthquake. The reaction at the bottom of the pier walls is taken by the piles and surrounding channel invert slab.

Further Advancement

Even though precast prestressed Bulb Tee girders post-tensioned for continuity have been constructed successfully in the past, this structure type still poses many challenges to bridge engineers because of its complexity. There are still many questions that need to be answered before we can fully understand its behavior. During our design, we encountered a number of issues that may require additional research from the engineering community.

The current Caltrans *Standard Specifications and Special Provisions* do not address the construction of precast pre-stressed girders post-tensioned for continuity. The engineers must refer to the requirements for conventional precast prestested girders and prestressed box girders, which do not address the particular issues with Bulb Tee girders. Without well-thought-out construction standards, many important construction specifics are left up to the contractor's interpretation. This poses a potential for serious construction problems for Bulb Tee bridges.

Since this construction technique is still a novelty, statistics of construction cost and construction duration for various Bulb Tee girder configurations are needed in greater quantity.▪

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