CHALLENGES IN FABRICATION OF PRECAST PRESTRESSED CONCRETE SUPER GIRDERS

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ABSTRACT

Construction is underway on a California Department of Transportation (Caltrans) widening project on SR 99 in Nicolaus, CA. A major element of this project is Precast/Prestressed bulb tee super girders with a maximum height of 8’6”, up to 120’ long and weighing up to 90 tons each for a bridge over the Feather River. Fabrication of these tall and slender girders posed unique challenges such as arrangement of post tensioning ducts in a thin web, high performance concrete with compressive strength of 8,500 psi, transportation and handling issues. As the owner, California Department of Transportation enforced a rigorous Quality Assurance scheme to ensure fabrication met its challenges. This process included submission of a detailed Quality Control Plan by the fabricator. Caltrans material engineers and inspectors were involved from the onset of fabrication and worked closely with the fabricator for a quality product. This paper details the unique difficulties and challenges encountered during the course of the fabrication and how Caltrans’ and the fabricator’s combined proactive approach resulted in a successful delivery of the product.

Keywords: Super Girder, Concrete, Precast, Prestressed, Construction,

BACKGROUND

A project was undertaken by California Department of Transportation (Caltrans) to widen State Route 99 to four lanes in Nicolaus, CA. The project included constructing two new bridges including one over the Feather River. This bridge is 3148' long, founded on two abutments and fifteen piers, and includes concrete super girders. The super girders are California modified precast/prestressed bulb-tee girders. Bridge elevation, typical cross section and girder cross section are shown in Fig.1. Erection of super girders started in May of 2013 and will continue throughout the year.

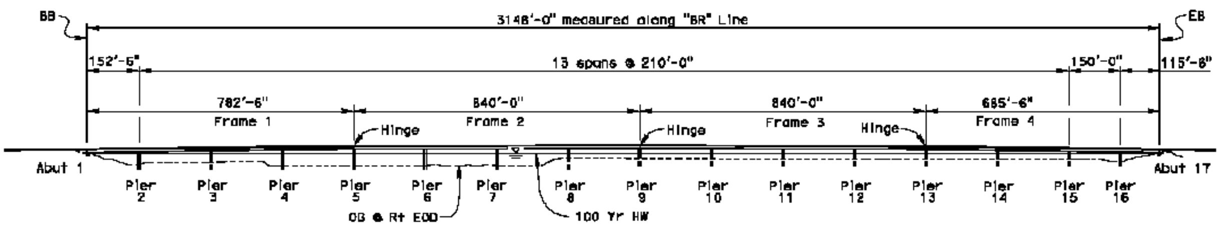

Fig. 1(a): Bridge elevation

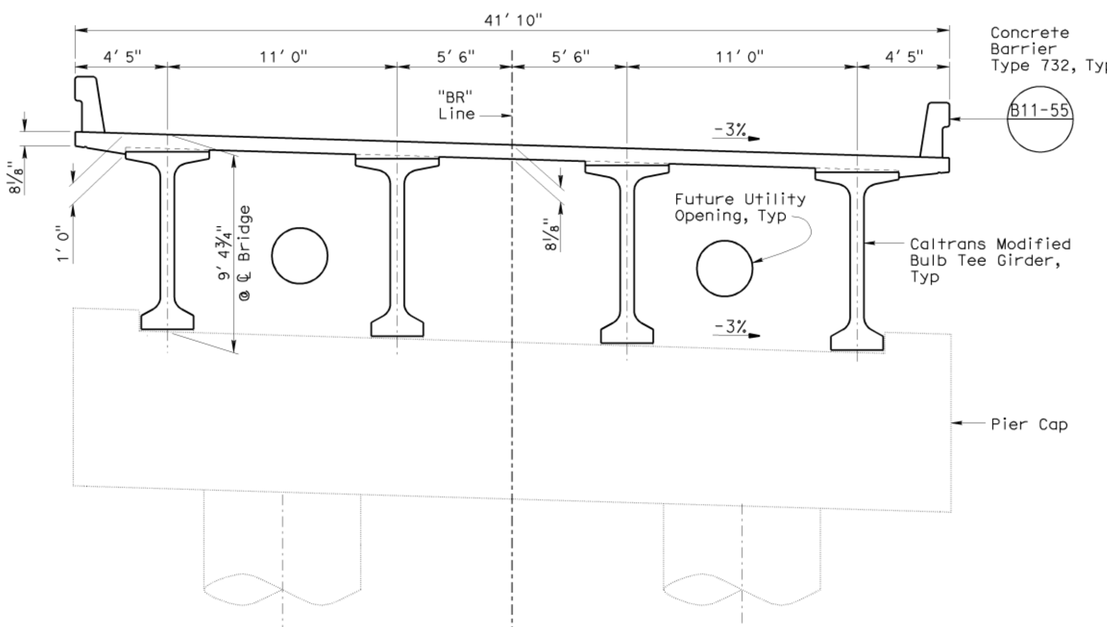

Fig. 1(b): Bridge typical cross section per Contract Plans

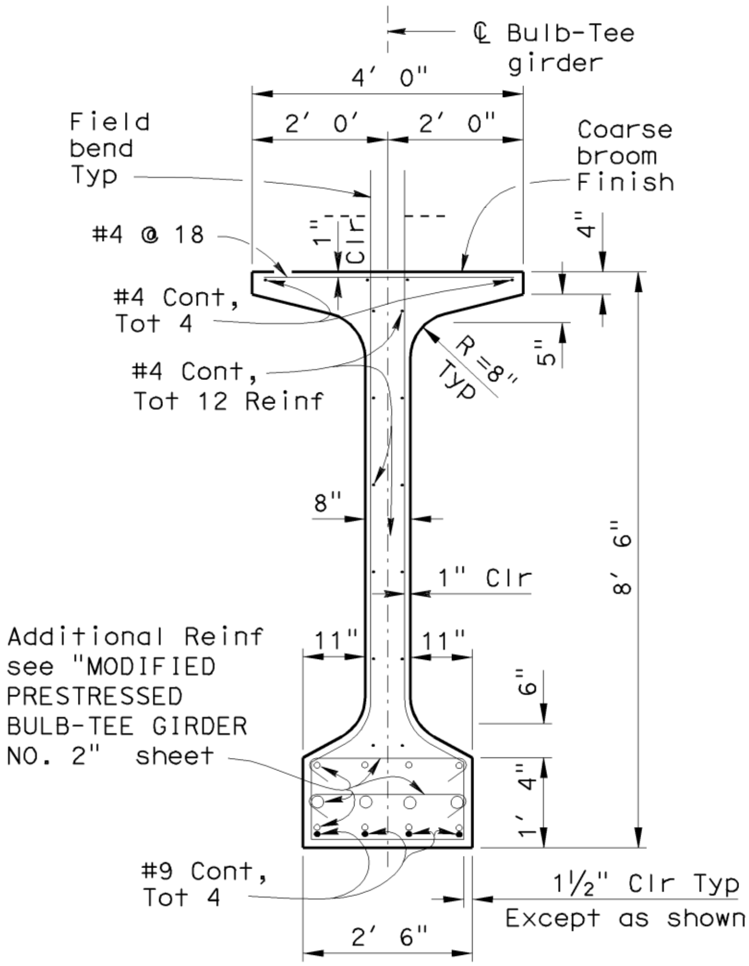

Fig. 1(c): Super girder cross section per Contract Plans

The super girders are spliced in between piers, which are located at the centers of most girders (Fig. 2). There are also three hinges located throughout the length of the bridge (Fig. 3). During fabrication no field splicing of girders was performed in the plant but duct locations were checked thoroughly by QC and found to be within ¼" accuracy.

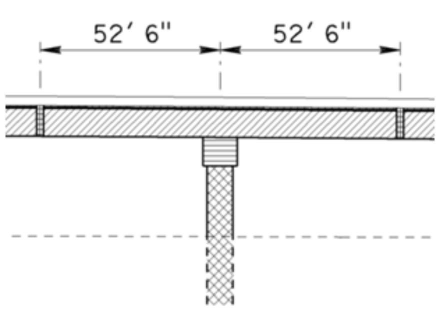

Fig. 2: Girder splice details

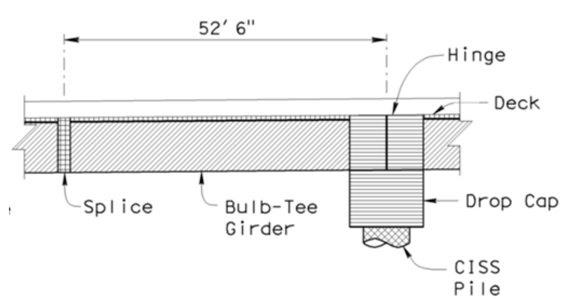

Fig. 3: Hinge details

QUALITY ASSURANCE

California Department of Transportation, as the owner of the project, followed a rigorous Quality Assurance (QA) plan to ensure adequate preparation and fabrication of the girders. This started with an initial meeting between the prime contractor, the precaster, construction engineer and materials engineer. The intent of the meeting was to review the requirements and establish the framework for the Precast Concrete Quality Control Plan (PCQCP). This document, submitted later, was to include all QC processes by the precaster's QC department. In addition to QC activities, Caltrans also utilized its own inspection personnel during the pre-pour, pour, and post-pour stages to verify adequate QC presence and documentation. Prime contractor had a major role as all casting and documentation were reviewed and approved by the prime contractor's designated individual prior to release and incorporation into the project.

UNIQUE FEATURES

Bulb-Tee girders are common for long spans, usually limited by hauling length. California Bulb-Tee super girders have a preferred span length of 95' to 150'. The design used for Feather River Bridge is a modified design that incorporates additional reinforcement. A number of design features posed significant challenges to fabrication of these including:

a) Girder cross sectional dimensions
b) Post tensioning
c) Strength requirements
d) Girder end preparation
e) Stirrup orientation and reinforcement cage fabrication
f) Additional reinforcement
g) Girder mock-up
h) PTFE bearing assemblies
i) Pick-ups
j) Pouring concrete
k) Handling
l) Forms
m) Storage

These features will be discussed in this paper.

a) GIRDER CROSS SECTIONAL DIMENSIONS

The original design called for an 8 inch web thickness. Ducts had a diameter of 4" with a center spacing of 5". However, at ends of each frame duct spacing increased due to anchor geometry. In the cross section, the web needed to accommodate the post tensioning ducts, #4 continuous reinforcement bars, #5 stirrups, and a concrete cover of

1" (Fig. 4). In order for the ducts to meet the loading requirements of post tensioning, the girder web width needed to increase. The width was subsequently increased to 8 5/8" by approval of an RFI submitted by the precaster. In addition, #4 rebar splices needed to be located where they would not interfere with the parabolic profile of post tensioning ducts (Fig. 5 and Fig. 6).

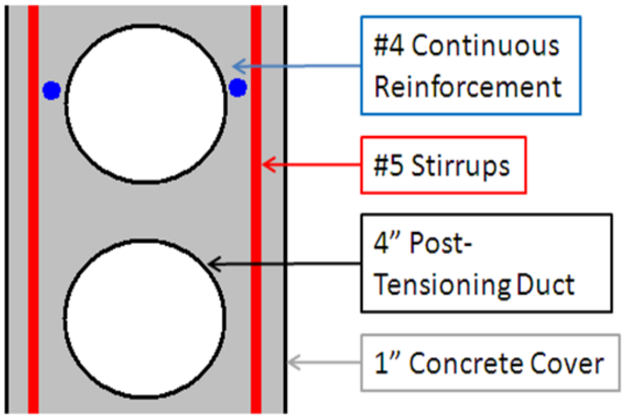

Fig. 4: Girder web cross-section

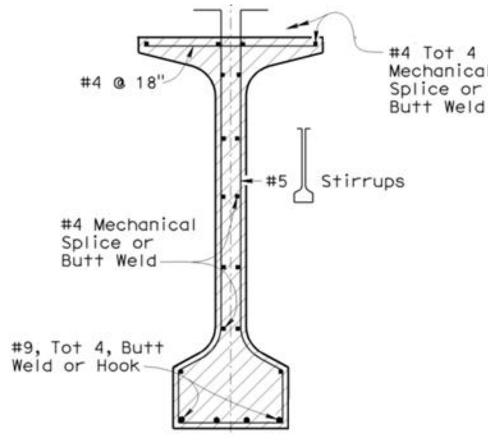

Fig. 5: Girder splices

b) POST TENSIONING

The girders have two stages of post tensioning; the first stage to provide girder continuity between hinges and the second stage for deck dead load and live load. Post tensioning is not typical for precast girders in California, and is usually found in cast-in-place structures. The girders have 6 ducts that run continuously between hinges (Fig 6, Fig.7 and Fig. 8). For this reason, the duct profiles of individual girders vary.

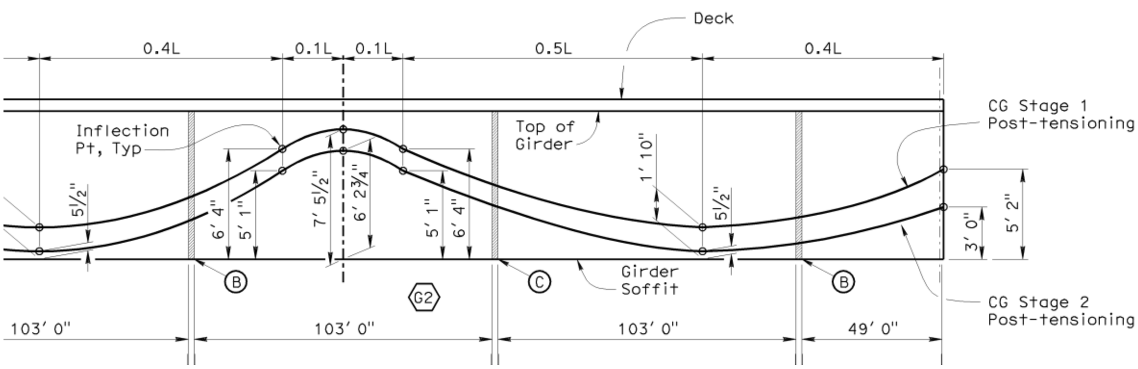

Fig. 6: Parabolic post-tensioning stages

Fig. 7: Post-tensioning ducts

Fig. 8: Post-tensioning ducts positioning

During casting the precaster overlooked putting the duct vents in at the high points over the bents. This issue was resolved relatively easily by coring a 3/4" diameter hole into the top half of the duct and then installing a 19mm flexible plastic vent tube that extended up above the final deck elevation. Locating duct was relatively easy as duct placement was accurate particularly at the high point. Each hole was inspected by camera to ensure penetration of duct. Coring was used in lieu of rotohammer drill so as not to damage the post tensioning duct.

c) STRENGTH REQUIREMENTS

The girder design specified a high performance concrete (HPC) with a minimum required compressive strength of 8500 psi at 28 days. Typically, precast girders have a minimum requirement of 6500 psi. With a modified low water/cementitious material ratio, the precaster was able to achieve 9000-9500 psi at 28 days. Prior to starting fabrication the precaster did a rigorous trial mix regime to establish that the required concrete strength could be achieved. After adding plasticizer, the final mix had a slump of 7.5±1.5" with no air entrainment. Water reducing agent was also used. The water/cementitious material ratio was 0.3 and total cementitious material content was 9.5 sacks/CY.

d) GIRDER END PREPARATION

Typically precast girders are required to have the girder tops fabricated with a ¼" amplitude surface roughness. The intent is to prevent development of a shear plane between the girders and bridge deck. Since there are girders on this project that are spliced between piers, this requirement was also extended to the girder ends. To achieve this requirement, the precaster used a paste-type retarder (Fig. 9) to provide exposed aggregate surfaces. The paste was applied to the end forms prior to the pour. Once the girders were released from the forms, the ends were water blasted to remove the cement paste at the surface and achieve the roughness requirements (Fig. 10, Fig. 11 and Fig. 12).


Fig. 9: Paste retarder applied to end forms


Fig. 10: Girder ends


Fig. 11: Surface profile close-up


Fig. 12: Surface profile close-up

e) STIRRUP ORIENTATION AND REINFORCEMENT CAGE FABRICATION

Typically girder stirrups are required to be continuous. However, due to girder depth constraints, a one piece stirrup could not be produced. The precaster submitted a request to use spliced stirrups. This request was approved by the designer allowing spliced stirrups to overlap in the bottom flange. Stirrups were tied together with wire (Fig. 13 and Fig. 14).

Fig. 13: Spliced stirrups

Fig. 14: Stirrups in cage

To fabricate the reinforcement cages with an overall depth of 10', the fabricator constructed special rolling scaffold assemblies that allowed access for tying the reinforcement.

f) ADDITIONAL REINFORCEMENT

Since many of the girders rest on the piers at their midpoint, additional 60 foot long reinforcement bars are placed in the bottom flange. This included four #18 and eight #9 bars. The intent of this design change is to provide additional bending resistance at these points (Fig. 15). Since girders will be post tensioned, the negative moment capacity will not be an issue at the piers and the extra reinforcement will provide additional capacity to resist compressive stresses.

Fig. 15: Bottom flange additional reinforcement

g) GIRDER MOCK-UP

In order for the precaster to check their ability to produce an unusually tall girder, a 10-ft mock-up section was planned and produced (Fig. 16). The mock-up allowed the precaster to verify they could achieve adequate concrete consolidation around the post-tensioning ducts and rebars as well as verification for girder web clearance and girder end preparation. Initially, the precaster was anticipating roughening the end surface with sand blasting (Fig. 17). However, sandblasting alone was not sufficient to achieve the required end surface profile leading to the use of the retarder paste and water blasting as previously shown in Fig. 11 and Fig. 12.

Fig. 16: Mock-up

Fig. 17: Sandblasted surface profile

h) PTFE BEARING ASSEMBLIES

At the ends of the frames at bent locations the girders are supported on PTFE Spherical bearing assemblies. The contract plans indicated that the fabricator would cast the assembly into the soffit of the girder. This arrangement is more suited to a cast in place application. The precaster was concerned about exposing the assembly to the hot and moist environment during steam curing of the girders. The precaster proposed modifying the detail to allow the sole plate to be cast into the girder with the remaining portion of the assembly be welded in the field. This request was approved by Caltrans and incorporated into the girders.

i) PICK-UPS

The precaster used 0.6” diameter prestressing strands as lifting pick-ups. These pick-ups are typically cast into the middle of the webs with adequate depth to ensure anchorage. The challenge faced in this instance was the location and size of the post-tensioning duct that were sometimes only 2’-0” from the top of the girder. To work around this the precaster splayed out the pick-ups placing them in the same plane as the stirrups. Lift points were angled to coincide, to the extent possible, with the sling angle which was approximately 60˚.

As most of the girders will be erected using a single crawler crane it was necessary to move the girder pick up points as close to the mid span as possible. It was determined that the pickups for erection needed to be located 20' from each end. The cantilevering effect combined with the pretensioning may introduce relatively high stresses in the top flange at the pick-up location. To mitigate cracking during the installation period additional mild steel reinforcement was added in the top flange over the inner pick points located 20' in from each end. Very minor hairline vertical cracks were noticed during the installation. The cracks, however, closed up immediately once girder was placed with supports at ends.

j) POURING CONCRETE

Caltrans standard specifications do not allow concrete to be dropped from a height greater than 8’-0”. Therefore, the precaster considered several options to get the concrete into the form since the girder was 8'-6" deep. The three options considered were pumping, use of a tremie chute, or openings in the steel side forms. The tremie chute was selected and used successfully to bring the outlet or start of concrete fall to less than 8’. The ducts were typically lower than 8’ above soffit of girder so did not interfere with tremie.

k) HANDLING

Due to size and weight, girder handling presented several challenges. In the precast yard the precaster uses MiJack Travel Lifts to move product and material around. Attached to the travel lifts are special spreader bars to carry the load. The precaster had to develop bespoke spreader bars for this project to enable carrying the reinforcement cages that were over 110’ long using one lift and to pick up the heaviest piece that weighed 90 tons.

At this time, transportation and jobsite erection of girders are underway. The hauling units requires both pilot cars and California Highway Patrol escort over several bridges en route identified as deficient to carry the girder loads. At the deficient bridges on I-5, the traffic control plan is to stop all regular highway traffic and the girder rigs will have to travel at 5 mph in the middle of the bridge one at a time. These operations will be at night with a strict erection schedule at the jobsite approximately 80 miles from the precast yard.

Girders are planned to be erected at night with each frame taking approximately 5 nights. Frames 3 & 4 were erected over an 8-day period in May 2013. Frame 2 is scheduled for erection in late August and Frame 1 will be erected towards the end of 2013. Figure 18 depicts girder transportation while Figures 19 to 21 show current jobsite erection operations. Shoring towers are shown in these figures. Pier segments are simply supported between shoring towers each side of the bent. No hangers were used for this project.

Fig. 18: Girder transportation

Fig. 19: Girder erection

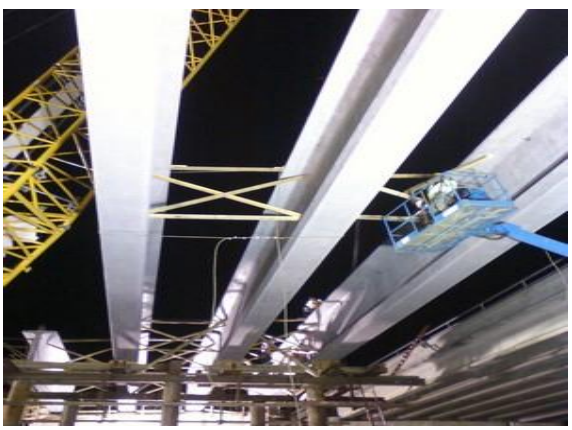

Fig. 20: Girder erection

Fig. 21: Daytime view of erected girders

l) Forms

The steel forms used by the precaster are adaptable to accommodate varying depths by introducing different height fillers in the web section of the form. To fabricate these girders, the precaster purchased the necessary web filler as well as a filler to increase the depth of the bottom flange. Meeting tolerances was not an issue as the steel forms were designed and fabricated with tolerances tighter than those of the girder.

The precaster fabricates its girders in a depressed casting bed as shown in Fig. 22. During the removal of the side forms there were several instances where the flange suffered relatively minor damages in the process. The damage included cracks ranging from 0.01" to 0.03" in width. Cracking was limited to underside of the top flange at one corner at one end for three girders. An investigation was performed by the precaster and it was determined that cracking was caused by the side form during the preparation for the girder removal from the casting bed. Epoxy injection was performed to repair the cracking.

Fig. 22: Girder form

m) Storage

There were several contractual delays in the installation of the precast girders which required the precaster to store them in the precast yard for more than 18 months. The pretensioning of the girders was minimal and was only intended for handling purposes. Consequently there was a minor sag of ¼" typically at release and there was a concern that over time the sag would increase. The precaster monitored the cambers of the girders and found that the sag either remained as it was or an upward deflection was exhibited. As standard procedure the precaster braces its girders when in storage in case of an earthquake. Extra attention was given to these slender units during storage.

CONCLUSION

The experience and challenges of fabrication of a concrete super girder, as documented in this paper, can be used as a guide for future projects featuring non-typical girder design and fabrication. The fabrication process faced a number of challenges due to size and weight of the girders, low pretensioning and the presence of post tensioning ducts. Close cooperation between the owner (Caltrans), the prime contractor and the precaster enabled the girder fabrication to overcome the challenges allowing the fabrication to proceed efficiently and successfully. It also demonstrated the value of pre-planning of quality activities and proper record keeping for future reference.

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