HYBRID PRECAST BRIDGE PULLS IT ALL TOGETHER TO SAVE TIME AND MONEY

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ABSTRACT

This presentation will show the widening of an existing cast-in-place (CIP) post-tensioned (PT) concrete box girder superstructure using a post-tensioned combination of precast/pre-tensioned and CIP concrete elements. The result is an efficient, hybrid superstructure that meets project goals of minimizing traffic disruptions and reducing construction costs and time.

The existing bridge at US60 and SR303L northwest of Phoenix is a four-span, CIP post-tensioned concrete box girder superstructure integral with the piers. A portion of Span 3 is a "drop-in", custom shaped, precast/pre-tensioned concrete box beam over the BNSF Railway. The Construction Manager at Risk (CMAR) contractor requested the widening utilize precast girders to eliminate falsework over US60 traffic. The span arrangement of 105'+194'+118'+114' would have permitted the use of standard precast/pre-tensioned AASHTO girders for all but Span 2. The selected method combined AASHTO girders post-tensioned with CIP concrete pier tables to mimic the structural behavior of the existing bridge. AASHTO girders were erected on temporary shoring towers in Spans 1, 2 and 4 and then spliced with the CIP pier tables. AASHTO girders were also used for the "drop-in" portion of Span 3. This spliced precast concrete girder approach provided compatible structural behavior, while reducing falsework requirements, traffic disruptions, construction costs and time.

Keywords: Accelerated Bridge Construction, Spliced, Hybrid, Precast, Post-tensioned.

INTRODUCTION

The US60 (Grand Avenue) SR303L Underpass Bridge provides a cost-effective, hybrid concrete solution to some common challenges encountered during urban freeway construction today.

Urban bridges are increasingly wider, require longer spans to accommodate expanding roadways, and must be constructed with limited disruption to the existing roadway network. Public agencies, traffic engineers, and the public expect this. These new structures and their many components must work together aesthetically, as well as structurally. The US60 (Grand Avenue) SR303L Underpass combines conventional precast, cast-in-place (CIP), prestressed, post-tensioned (PT) and reinforced concrete structural elements to meet these goals.

In 2004 voters approved Proposition 400 Regional Transportation Plan (RTP), a 20-year extension of a one-half percent sales tax approved by voters in 1985. Tax revenue generated by the RTP was earmarked specifically to fund new freeway projects for the expanding Phoenix metropolitan area. Among those freeways were a series of loop freeways, SR101L (Agua Fria, Pima and Price Freeways), SR202L (Red Mountain, Santan and future South Mountain Freeways) and currently under construction, SR303L (Estrella Freeway).

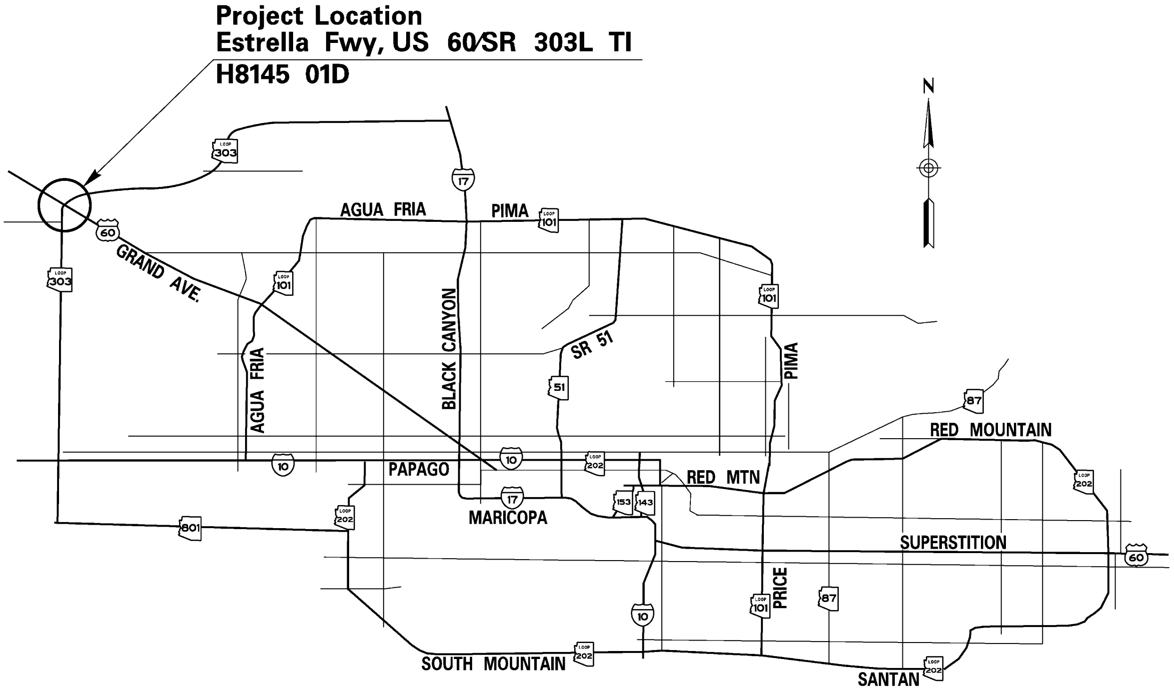

Figure 1 – Phoenix Regional Freeway System and Project Location

SR303L is a 40-mile long new freeway in the western and northwestern portions of the Greater Phoenix Metropolitan Area. SR303L is part of the Regional Transportation Plan Freeway Program (RTPFP) adopted by the Maricopa Association of Governments (MAG) in

November 2003 and is a major element of the Regional System in the northwest portion of Maricopa County. It opened for traffic as a two-lane facility in 1992 with the primary purpose of providing an alternate route for US60. Future growth and traffic projections are driving the need to expand the regional freeway facility in the northwest valley.

Bridge construction along many segments of SR303L was simple because significant development had not taken place throughout the corridor. Bridges were frequently constructed over two-lane roadways or streets with low traffic volumes. Traffic on those roadways could be detoured on- or off-site which allowed bridges to be constructed as CIP concrete box girders, using soffit fill to support the bridge during construction, eliminating costly falsework.

Continued growth of the Phoenix metro area has significantly impacted freeway and bridge design and construction methodology. Bridge widening on existing freeways and new bridge construction over busy urban arterials require bridge engineers to explore innovative designs in order to maintain traffic during major bridge construction activities. The challenge for the designer is the development of simple, time-saving and cost-effective solutions permitting bridge construction in congested urban areas.

US60/Grand Avenue (Wickenburg-Phoenix Hwy) is a major arterial that runs northwest from central Phoenix through numerous suburbs and continues to Wickenburg, Arizona. Average weekday 2013 traffic volumes of 24,000 and 12,700 vehicles per day on US60 and SR303L respectively needed to be accommodated during the bridge widening operations.

The challenge of maintaining traffic during construction was complicated by the limited detour options. The high traffic volumes on US60/Grand Avenue precluded extended closures with off-site detours. On-site detours were not practical due to the presence of interim traffic on the freeway. Consequently, the final design of this bridge was substantially defined by the need to maintain both vehicular and railway traffic through this interchange.

The US60/SR303L Traffic Interchange (TI) is a two-level, interim interchange configured as a partial cloverleaf in the southwest and southeast quadrants of the TI arranged to minimize impacts to adjacent existing residential development in those quadrants. The cross-section for US60/Grand Avenue was designed for an ultimate configuration of four through lanes and two left-turn lanes. SR303L was designed for an ultimate configuration of six northbound (NB) and six southbound (SB) lanes.

The final design consisted of a 536-foot long, 197-foot wide, four-span bridge, with a span arrangement of 105’+194’+118’+114’ matching the existing bridge.

Figure 2 - Rendering of the US60/SR303L Interim TI

CONSTRUCTION MANAGER AT RISK (CMAR)

For the construction of the US60/SR303L Interim TI, ADOT decided to use the Construction Manager at Risk alternative delivery method. The CMAR process allows selection of a contractor based on qualifications during the project development process. Once selected, the CMAR becomes a collaborative member of the project team. As the contract documents are developed, the CMAR and the owner (ADOT) negotiate a Guaranteed Maximum Price (GMP) the owner agrees to pay the contractor for the completed project.

The CMAR's involvement in the design of the project provides a means to allocate the risk between the construction manager and the owner, eliminating or greatly reducing change orders during construction. By providing constructability reviews during the design process, the CMAR can verify the project can be constructed in the best, most economical manner consistent with the interests of the owner as well as the CMAR. The CMAR method allows the project to be designed to take advantage of the specific strengths of the contractor. Thus, the CMAR alternative contracting method engages construction expertise, and advance knowledge of the planned construction means and methods, during the design process to enhance constructability and manage risk.

A HYBRID OPTION

The existing US60/SR303L Bridge was constructed in 2000 for the Maricopa Department of Transportation. Ownership was subsequently transferred to ADOT. The bridge is a four-span, CIP post-tensioned concrete box girder superstructure, with integral piers and a precast drop-in span over the railroad. It carries SR303L over US60 (Grand Avenue) and the Burlington Northern Santa Fe (BNSF) Railway.

Figure 3 – Existing US60/SR303L Bridge

This project required widening the existing bridge approximately 120 feet, from an out-to-out width of 73’-8 to 197’-1, about 2-½ times its original width. Pier location, span arrangement and joint locations were all dictated by the configuration of the existing bridge.

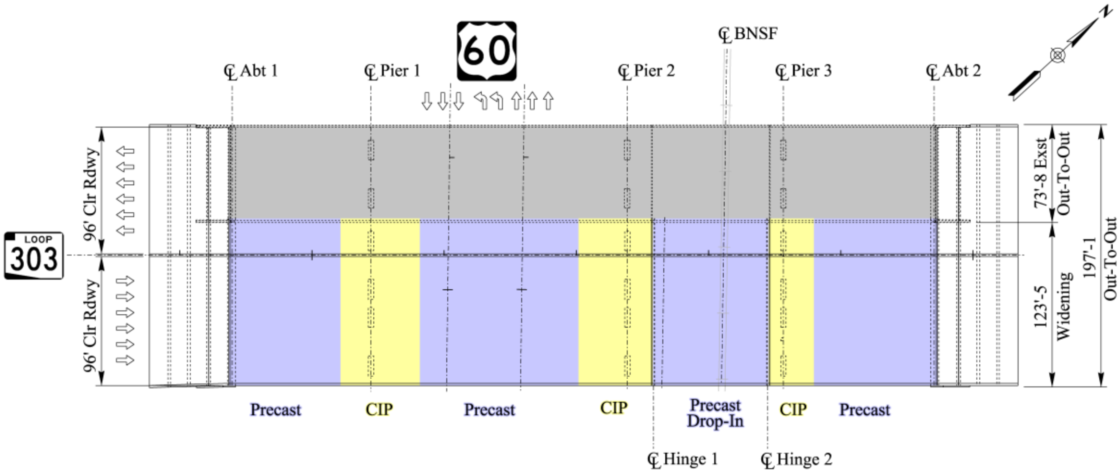

Figure 4 – Plan View of Bridge

A conventional approach would have been to widen with an identical CIP post-tensioned concrete superstructure. The 23 feet plus of vertical clearance over US60 due to the proximity of the BNSF tracks created ample vertical clearance for falsework over traffic. At 194 feet, the length of Span 2 was beyond the typical capabilities of conventional precast AASHTO girders used and available in the Phoenix area.

CIP concrete however comes with a number of key issues:

- Falsework construction is costly and time consuming.
- CIP concrete forming and reinforcing steel placement are also time consuming and critical path items.
- Falsework carries additional risk that is magnified when over live traffic.
- Falsework opening limitations constrain existing roadways.
- Traffic closures are required for large volume concrete pours over US60.

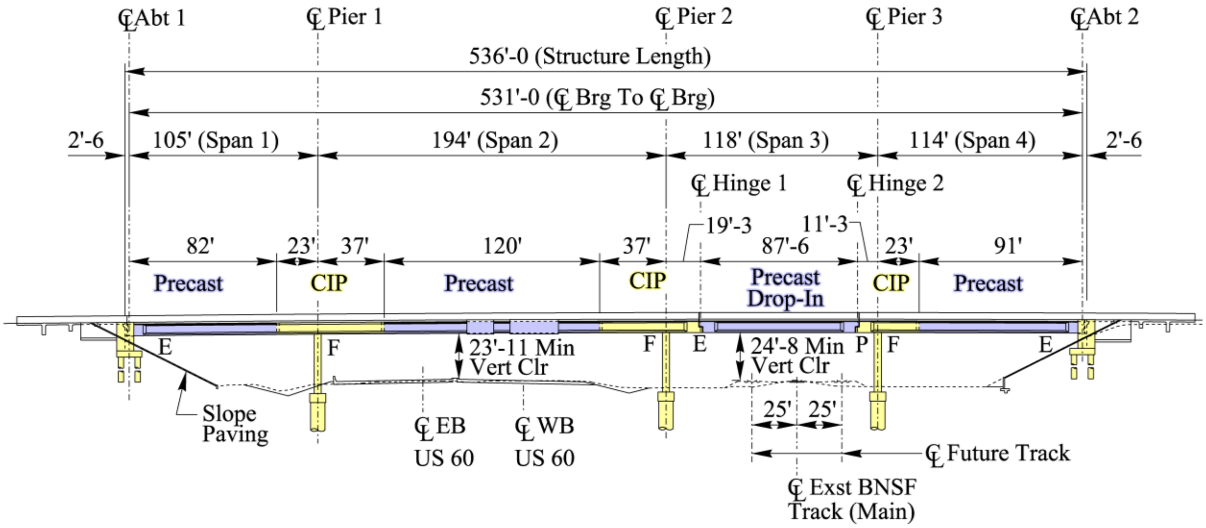

Figure 5 – Elevation View of Bridge

Working with the CMAR contractor, an improved method for the bridge widening combined AASHTO precast girders, post-tensioned with CIP concrete pier tables. CIP concrete was used where structure behavior compatibility was most desirable and precast was used where reducing traffic impacts and durations was most critical. Large segments of falsework were eliminated, most importantly falsework over US60. The two structure types were configured and married to provide comparable structural behavior to the parent bridge. Splice locations were determined based on where dead load moments were low and where shoring towers could be placed without significant impacts to US60.

The structure depth of the existing bridge is 7’-5”. AASHTO Type “Super” VI girders were selected for the widening to provide comparable structural behavior and depth to the existing bridge. The only difference between the Type “Super” VI girder and a standard Type VI girder is the depth of the girder. The Type “Super” VI girder is 6’-6” deep, 6” deeper than the standard Type VI. The 8” web accommodated the 4” nominal diameter PT ducts without requiring any modifications.

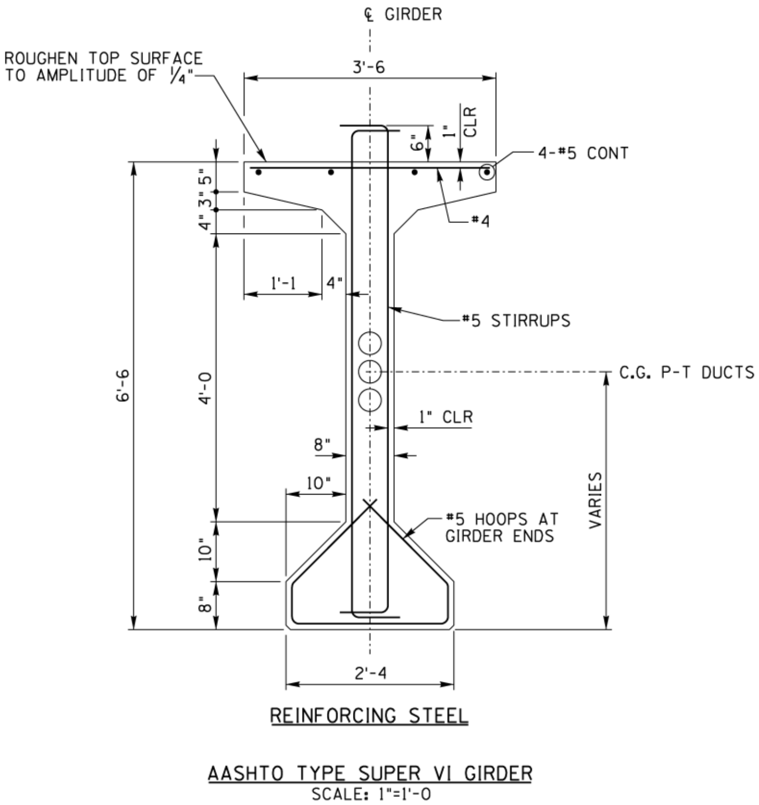

Figure 6 – Typical Precast Girder Section

The AASHTO LRFD Bridge Design Specifications, 6th Edition, Section 5.4.6.2 limits the size of the PT duct to 40% of the gross concrete thickness at the duct. Based on our research previous ADOT projects successfully used spliced girders with 8” webs and 4” nominal PT ducts. It was also noted that the PCI Bridge Design Manual, 3rd Edition, Section 11.4.5.1 listed multiple state agencies, existing bridges and numerical examples in which this AASHTO criteria was not met.

The shear capacity of the girder was checked and found to be adequate for the loads prior to grouting of the PT tendons. Therefore it was determined that the 8” webs would function adequately and be more cost effective than increasing the web width.

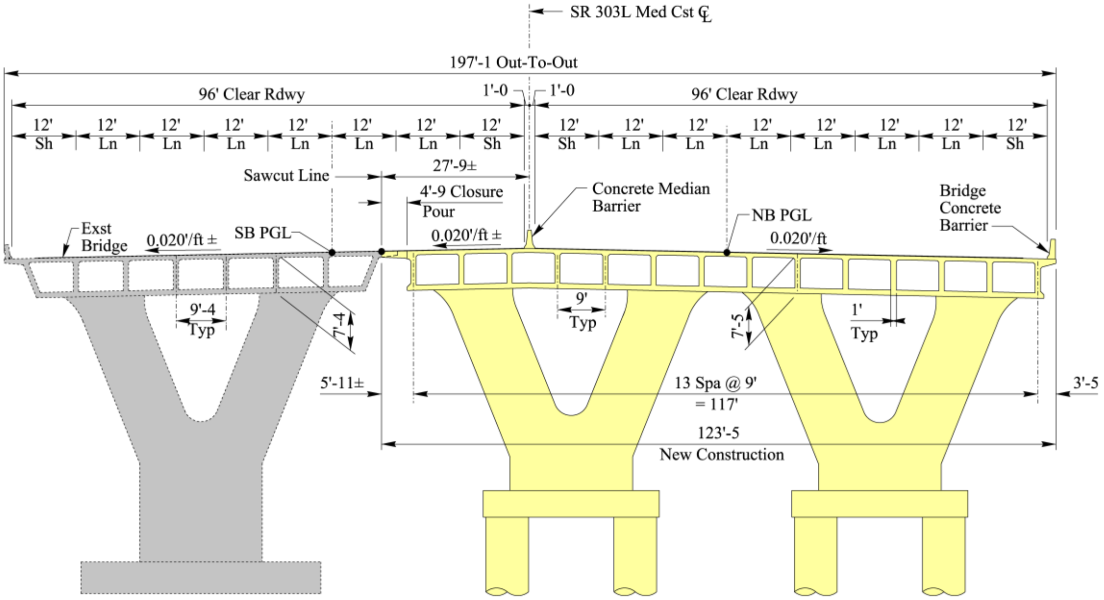

Figure 7 – Typical Section at CIP Box Girder Pier Tables

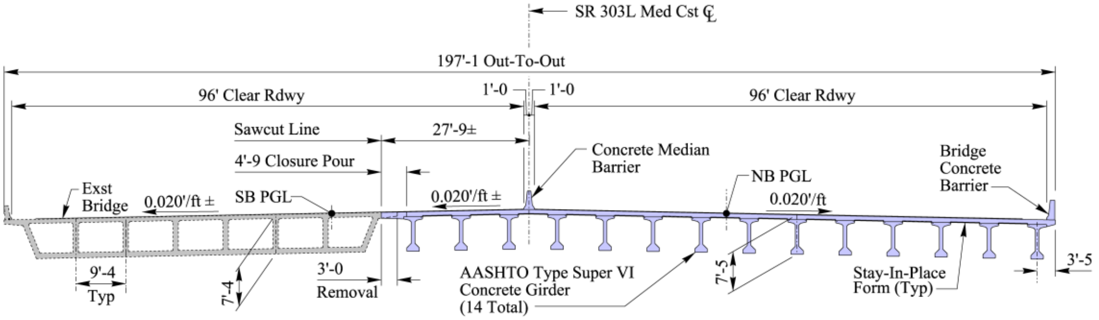

Figure 8 - Typical Section at Precast Girders

Joining the new and existing structure was accomplished with a 4’-9± wide by 1’-4± thick deck closure pour after completion of post-tensioning and grouting operations. The existing deck overhang concrete was removed saving and exposing the existing deck reinforcing. New deck reinforcing was spliced with the exposed existing reinforcing and additional reinforcing was added to account for the additional thickness.

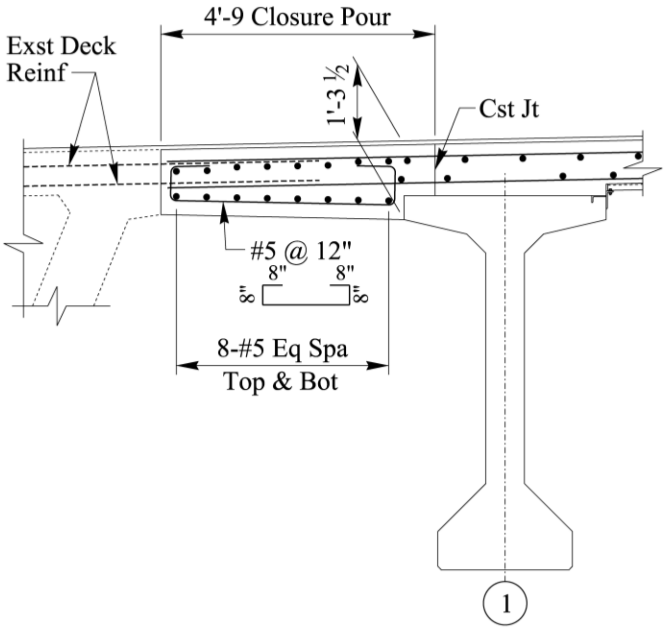

Figure 9 – Deck Closure Pour Detail at Precast Girder

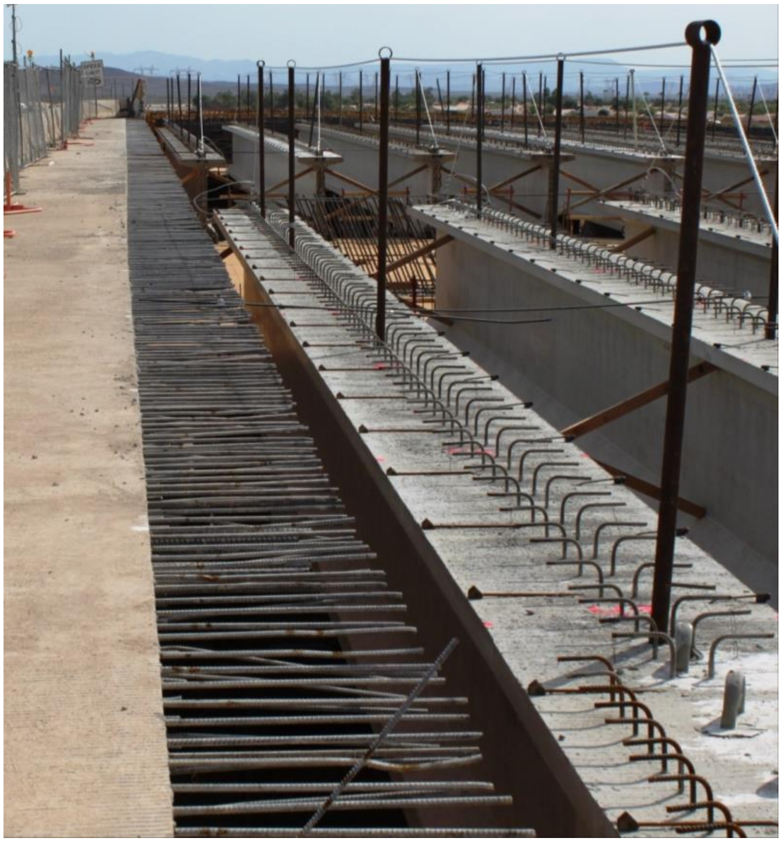

Figure 10 – Existing Reinforcing at Deck Closure Pour

The 6’-6” deep girders combined with the relatively short interim spans (the interim span length from shoring tower to shoring tower prior to post-tensioning), required minimal pre-stressing to accommodate the initial loads. All precast girders were designed for two-stage stressing, an initial pre-stress for dead loads, and post-tensioning for final loads.

The initial pre-stressing utilized 0.6” diameter straight strands to carry the self-weight of the girder, the plastic deck concrete and a nominal construction load. Harped strands could not be used due to the draped PT ducts installed in the girder webs. It was also desirable to minimize initial girder camber to allow for the additional camber from the second stage post-tensioning and to control screed grades. The minimal initial pre-stressing produced about 0.5” upward camber in the girder prior to post-tensioning.

Figure 11 – PT Ducts in Precast Girder Web

Figure 12 – PT Ducts and Precast Girder End Treatment

To provide similar structural behavior between the precast girder segments and the CIP box girder segments, the precast girder deck concrete was placed prior to post-tensioning of the superstructure. Erection of the precast girders coincided with the construction of the CIP box girder webs; this was to ensure proper alignment of the PT ducts.

Figure 13 – Girder Lines at CIP Webs & Precast Girders

A two-foot splice closure pour was provided between the ends of the precast girders and the ends of the CIP box girder webs to allow for the splicing of the PT ducts. This end diaphragm also accommodated the end rotation of the precast girders resulting from the deck placement.

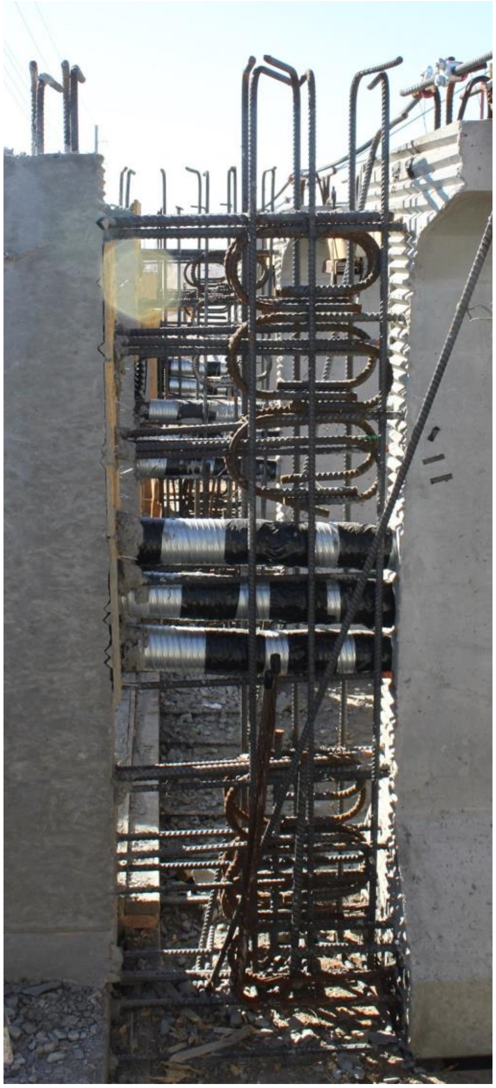

Figure 14 – Splice Closure Pour at Interior and Exterior

The superstructure was post-tensioned once the deck and splice closure pour concrete reached strength. This tied the precast and CIP superstructure elements together to provide continuity, mimic the structural behavior of the existing bridge and carry the applied live loads.

The bridge is composed of two frames. Frame A (ABT 1 to Hinge 1) is approximately 318 feet long and Frame B (Hinge 2 to ABT 2) is approximately 125 feet long. The 87-foot precast drop-in span provides connection between the two frames. Each tendon was comprised of between 16 and 18, 0.6" diameter, Grade 270 low relaxation strands. Frame A required three, 18 strand tendons due to the length of Span 2 whereas Frame B required only two 16 strand tendons. Jacking operations took place from the hinge ends of each frame. Post-tensioning from the hinge anchorages took advantage of friction losses and reduced the jacking forces in the precast girder anchorage zones at the opposite ends.

Figure 15 – PT Ducts and Reinforcing at Precast (Photo by Jason Kuck, Tpac)

At the abutment end of each precast girder of Spans 1 and 4, an 8’-6” long by 2’-4” wide end block was created by flaring the 8” web out to match the width of the bottom flange of the girder. The end block accommodated the post-tensioning anchorage hardware and provided the additional beam cross-section needed to resist post-tensioning forces.

Figure 16 – PT Anchors at Precast Girder End Block (Photo by Jason Kuck, Tpac)

PRECAST GIRDERS "DROP-IN" OVER RAILROAD

The BNSF Railway has strict guidelines and restrictions concerning bridge construction within their Right-Of-Way and over existing tracks. One key restriction prohibits falsework over existing railway tracks; as such a portion of Span 3 used precast/prestressed "drop-in" girders. This configuration matched the existing bridge which utilized custom shaped, precast/pre-tensioned concrete box beams over the existing BNSF track. To reduce costs, we used standard AASHTO Type Super VI precast girder shapes.

Figure 17 – Elevation Pier 3 at Drop-In Span

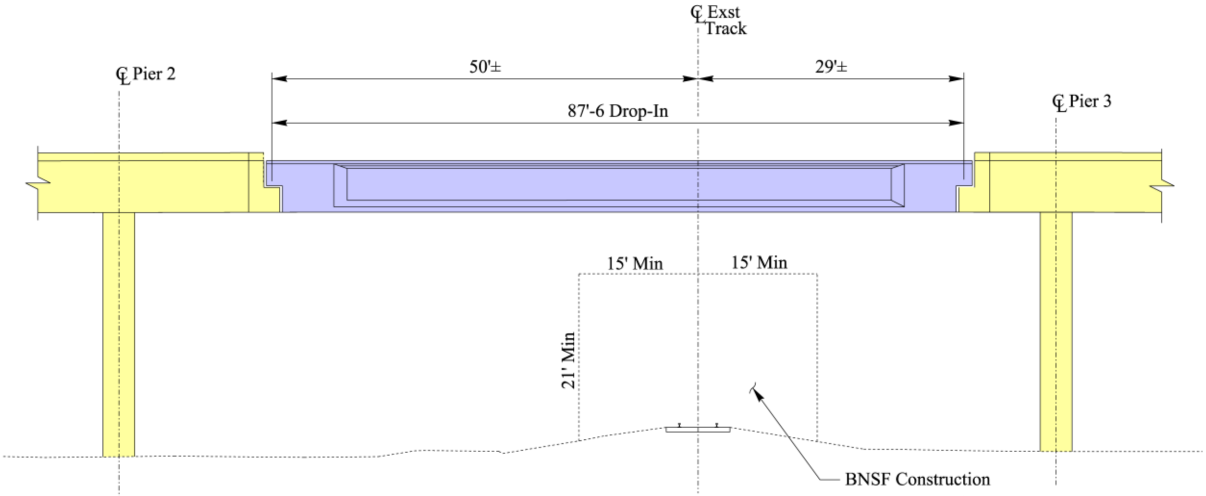

Figure 18 – Elevation View of Span 3

Hinge locations were dictated by the span configuration of the existing bridge and resulted in a short "drop-in" girder at Span 3. Shallower girders than the AASHTO Type Super VI could have been used for the 87'-6" span or the spacing of the girders could have been increased. However, the larger girder at the typical 9'-0" spacing provided the necessary dead load to counteract the upward hinge curl at each hinge. Also, a uniform structure depth for the entire length of the bridge was preferred for aesthetic reasons.

Figure 19 – Photo of Similar Completed Hinge

The CIP box girder cantilevered 19’-3” ahead and 11’-3” back from piers 2 and 3 respectively. The precast girders were supported on CIP hinges or beam ledges and the ends of the girders were dapped to maintain a uniform structure depth. The webs of the precast girders were flared at the ends to provide the necessary width for bearing and to provide the shear capacity needed as a result of the reduced depth at the dapped end. To provide visual continuity between CIP and precast, the exterior webs of the CIP hinge ledges were formed to match the end flares of the precast girder dapped ends.

Figure 20 – Dapped End Detail at Span 3 Precast Girders (Photo by Jason Kuck, Tpac)

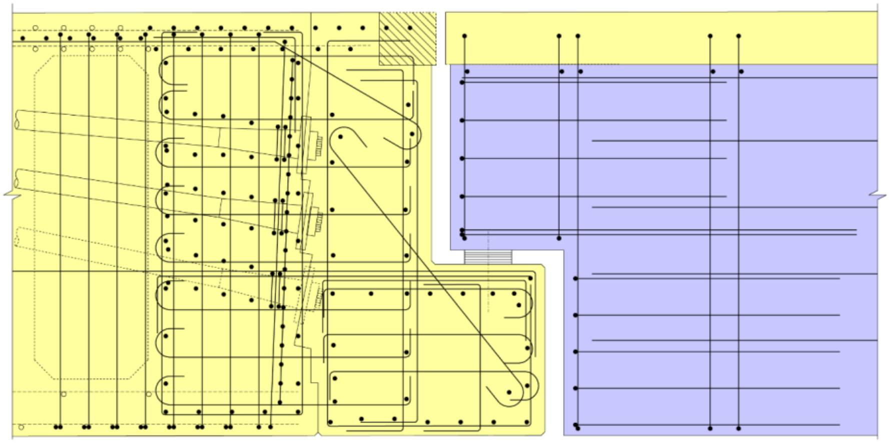

Figure 21 – Reinforcement at Hinge and Dapped Girder

PRECAST SAVES TIME AND MONEY

The existing bridge was widened about 120 feet, this equates to approximately 64,000 square feet of bridge deck. The spliced-girder hybrid bridge option with precast girder segments of 82 feet, 120 feet and 91 feet were erected in Spans 1, 2 and 4 respectively. Prior to being post-tensioned with the CIP pier tables, the precast girders were supported on temporary shoring about five feet from each end.

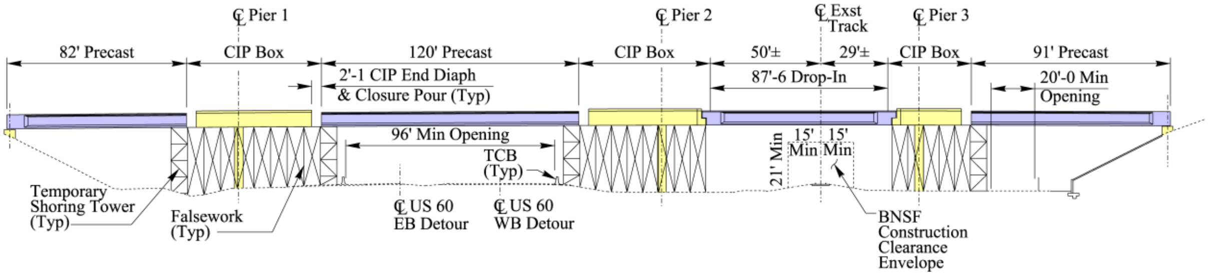

Figure 22 – Falsework Layout

Using precast girders eliminated approximately 265 linear feet of falsework or approximately 31,800 square feet of falsework with a net savings of over $954,000.

Figure 23 – Setting Girders at Span 2

In addition to the tangible monetary savings associated with eliminating falsework, another benefit of using precast girders was time savings. The man hours that would have been required to erect and break down almost 32,000 square feet of falsework could be directed toward other activities. There was also a time savings associated with the concurrent construction of different bridge elements. Portions of the superstructure were no longer dependent on the completion of the falsework, thus allowing for the simultaneous construction of bridge substructure elements and the fabrication of precast girders. The CMAR estimated that the construction schedule was accelerated seven weeks by using precast girders in place of CIP concrete.

PRECAST OPENS THE WAY

A crucial project requirement was maintenance of traffic on US60 during bridge construction. CIP construction on falsework over traffic is invariably disruptive to traffic below. Detouring US60 traffic was not practical and maintaining four lanes of traffic would have required large openings through any falsework. Two separate falsework openings would have been likely, one for each direction of US60 traffic. Using fixed falsework openings would have eliminated any possibility of shifting traffic to accommodate various construction phases.

Span 2 Precast Girder Data:
f’c = 6,500 psi
f’ci = 5,250 psi
Strands = Grade 270 Low Relax
No. of Strands = 28 (0 draped)
Pre-stressing Force = 1,230 k
Length = 120 ft
Producer: TPAC, Phoenix, AZ

At Span 2, a 120-foot long precast girder was spliced with 37-foot long CIP pier tables. Prior to post-tensioning the superstructure, the precast girders were supported on shoring towers. This created an available clear opening of almost 100 feet. This large opening, with high vertical clearance, easily accommodated all traffic with two lanes in each direction plus a turn lane; it also provided some flexibility during construction which permitted minor traffic shifts to accommodate phasing and improved public safety.

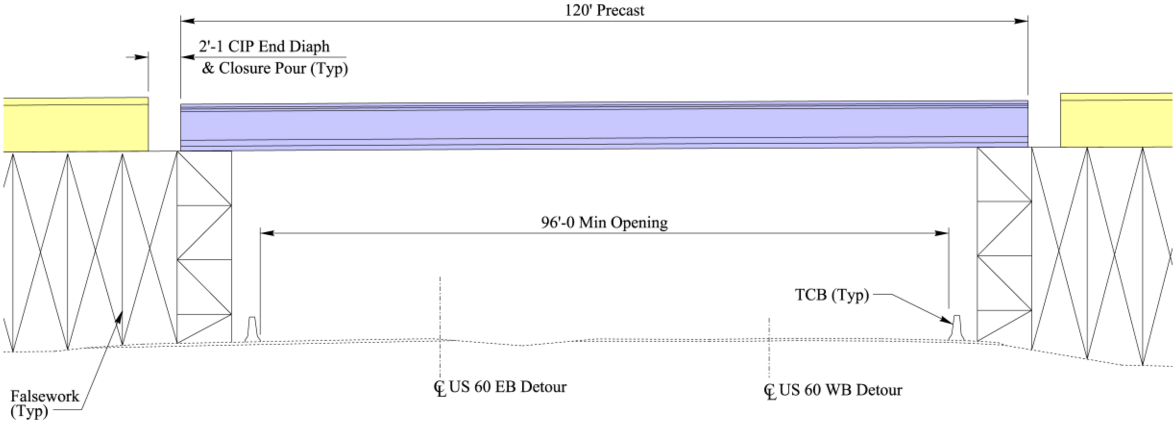

Figure 24 – Traffic Opening at Span 2

Figure 25 – Traffic Opening at Span 2

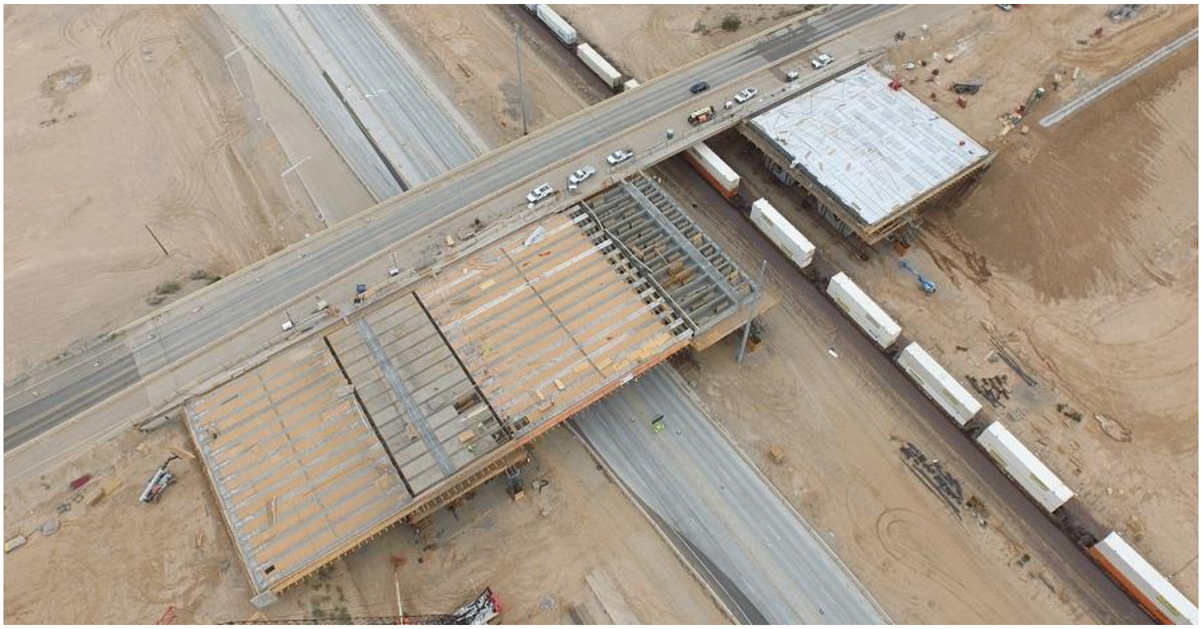

Figure 26 – Aerial View of Bridge Layout
(Photo by Chance Raser Haydon)

CONCLUSION

The Phoenix metro area continues to grow and expand. This growth fuels the need to expand our urban freeway system and challenges designers to do so without disruptions to the traveling public. The goal for bridge designers and builders is to deliver innovative, cost-effective, time-saving and aesthetically-pleasing solutions that minimize impacts to traffic and surrounding development. The challenge of maintenance and protection of traffic during urban freeway construction was solved through the use of precast/prestressed concrete.

The US60/SR303L bridge widening demonstrated that the “obvious” approach, widen “in-kind”, isn’t necessarily the best approach. Widening the existing bridge using an identical superstructure type would have been simple from a design standpoint but wasn’t the best solution to meet the project goals. This innovative approach used relatively simple locally familiar construction methods and materials consisting of conventional, locally available precast/prestressed AASHTO girders combined with post-tensioned and reinforced concrete structural elements.

The hybrid spliced precast concrete girder approach provided compatible structural behavior to the maximum practicable extent. The widening reflects the existing bridge span configuration, structure depth, hinge locations, support configurations and PT jacking points. This approach also reduced falsework requirements, traffic disruptions, construction costs and time. Construction of the widening began in December of 2014 and is expected to be completed by the end of November 2015. The estimated construction cost is $**7,300,000.**

Figure 26 – Rendering of Completed Bridge

Project Contributors:
Project Owner: ADOT - Arizona Department of Transportation
Municipality: City of Surprise, Arizona
Design Consultant: Stanley Consultants Inc., Phoenix, AZ.
CMAR Contractor: Haydon Building Corporation, Phoenix, AZ.
Precast Producer: TPAC, Phoenix, AZ.
P-T Contractor: DYWIDAG Systems International, USA.