SR 179 OAK CREEK BRIDGE – SEDONA, ARIZONA

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ABSTRACT

This is the first bridge in Arizona that incorporates a large portion of a roadway roundabout within the first Span of this three-span precast prestressed concrete box girder bridge. This unique geometric feature was incorporated through a framing plan that utilized a series of side-by-side and splayed box beams. The benefit of utilizing precast box beams both mitigated and minimized construction work in Oak Creek, an environmentally sensitive perennial stream. Utilizing precast box beams also made it feasible to phase the new bridge construction which overlapped the existing structure. The unusual geometry of this bridge required special live load considerations not covered by traditional AASHTO distribution factor treatment; in addition, the roundabout configuration introduced some unusual loads into the first pier cap.

Keywords: Roundabout, Bridge, Unusual, Superstructure

INTRODUCTION

State Route (SR) 179 traverses one of the most pristine and uniquely scenic areas in the world and is used by hundreds of thousands of tourists each year. As the main route connecting the business and residential communities of the greater Sedona, Arizona area, SR 179 is also an important intercity link for residents, commuters and commercial traffic of the Sedona/Verde Valley region. SR 179 is classified as a Rural Minor Arterial from I-17 to the Sedona city limit (MP 309.3) and as an Urban Principal Arterial from the Sedona city limit to SR 89A.

To address forecasted traffic volumes, improvements to SR 179 included the enhancement of the roadway by improving traffic, pedestrian and bicycle movements. Due to the total construction costs of the proposed improvements, the project was divided into Project 1 and Project 2. Project 2 improvements included the construction of seven roundabouts and one of them was located at the existing crossing of Oak Creek; therefore, Project 2 included the removal of the existing Oak Creek Bridge and construction of two new bridges: a shared pedestrian/utility bridge and a vehicular bridge over Oak Creek – see Project Overview Map (see Figure 1). The roundabout bridge structure was designed in accordance with the *AASHTO Standard Specifications for Highway Bridges, 17th Edition (2002).* The design of the bridge structure was completed in 2004 and the bridge construction was completed in 2010.

Fig. 1: Project Overview Map

The design and construction of both projects begun in 2004 and were completed in 2010. Figure 2 shows the existing bridge and temporary river crossing used for construction vehicles and equipment. Figure 3 shows the end product: the SR179 Oak Creek vehicular and pedestrian/utility bridges.

Fig. 2: Existing Bridge and Temporary River Crossing

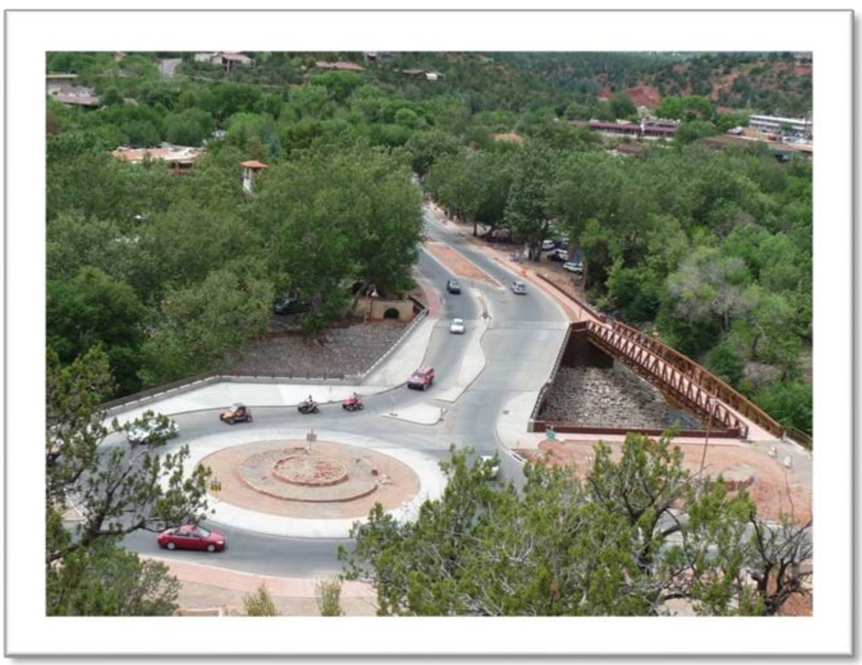


Fig. 3: New SR 179 Oak Creek Vehicular and Pedestrian/Utility Bridges

UNIQUE BRIDGE FEATURES

1. **Bridge Configuration and Bridge Selection –** The existing bridge on SR 179 over Oak Creek was a three-span continuous steel girder bridge constructed in 1948 and widened in 1967. The superstructure consisted of seven steel girder lines and provides a structure length of 150’-6” and an overall width of 45’-0”. The bridge accommodates one lane of traffic for the northbound and southbound movements and a left turn lane onto Schnebly Hill Road.

   The improvements for SR 179 included a roundabout on the east side of Oak Creek and a quadrant of it falls within Span 1 of the proposed bridge (see Figure 4). The new bridge provides one lane of traffic for each of the northbound and southbound traffic movements. Due to the geometry of the roundabout, the traffic lanes and raised sidewalks vary in width. A raised variable width median separates the northbound and southbound lanes. SR 179 at the crossing of Oak Creek is asymmetrical about its construction centerline.

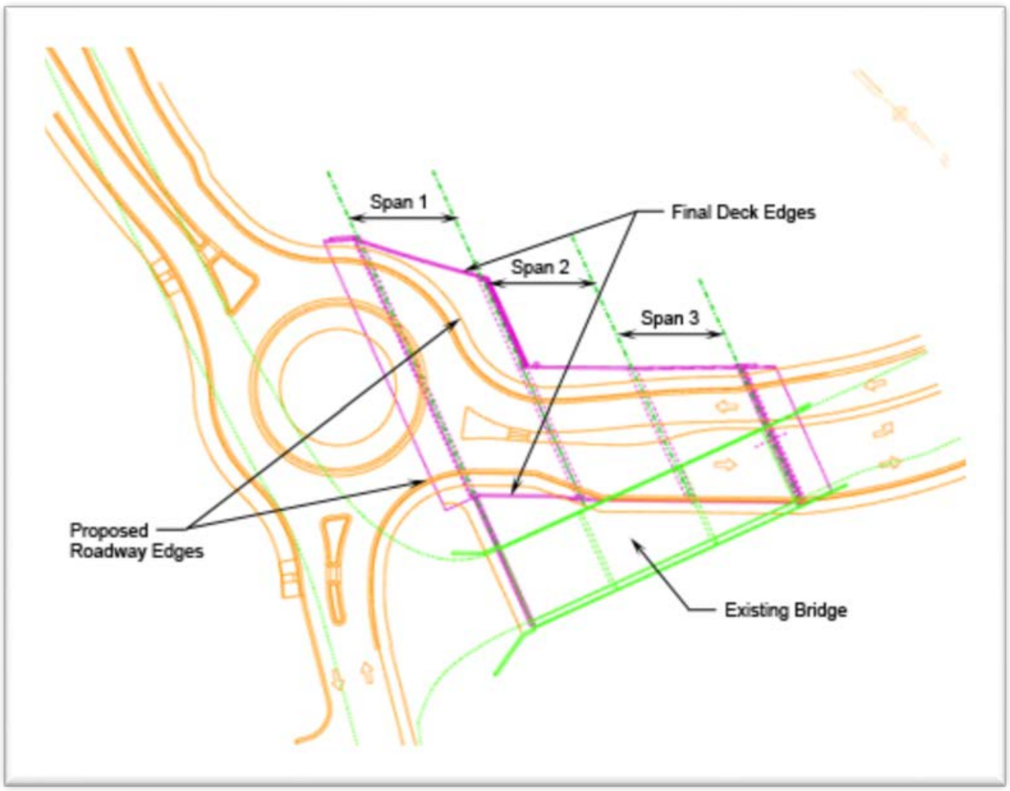


Fig. 4: Proposed Roadway Configuration at Existing Bridge

A three-span bridge was recommended for this location to satisfy the vertical geometry and hydraulic opening constraints. The bridge abutment and pier locations closely match those of the existing bridge and are located away from the low-flow channel to facilitate construction and reduce environmental impacts. A cast-in-place (CIP) reinforced concrete box girder bridge, a precast-prestressed box beam bridge and a steel frame alternative were evaluated for this bridge. A reinforced concrete box girder superstructure would have provided the best aesthetic appearance for this signature character bridge. However, a precast-prestressed box beam bridge was recommended since this superstructure type does not require the construction of falsework over the perennial creek which would have posed difficulties during construction.

2. **Superstructure** - The bridge is comprised of three spans with lengths of 61’- 9 3/4", 56’-11 1/4", and 55’-1 3/4” for a total structure length of 177’- 11 5/8”. The deck in Span 1 varies in width from 145’-10 1/2” at Abutment 1 to 125’-6 7/8” at Pier 1. Span 1 consists of twenty-four BIII-48 box beams (39”H x 48”W). The first eight box beams are splayed due to the varying bridge width of Span 1 and have a maximum length of 66.52 feet (see Figure 5); design challenges that were mitigated by the splayed configuration are presented in section “Unusual Design of Girders and Pier Cap” beginning on page 11 herein. These beams have an 8-inch deck and the resulting maximum superstructure depth is 4’-2”. The remaining 16 box beams in Span 1 are placed side by side and have a length of 54’-4 1/4” (see Figure 6). These beams have a 6-inch deck and the resulting maximum superstructure depth is 3’-11”. The width of the deck measured perpendicularly from edge of deck to edge of deck in Spans 2 and 3 varies. The deck in Span 2 has a minimum width of 67.63 feet and a maximum width of 68.95 feet at Abutment 2. Spans 2 and 3 each consist of sixteen BII-48 (33”H x 48”W) box beams placed side by side and have a length of 55’-2 3/16” (see Figure 7). These beams have a 6-inch deck and the resulting maximum superstructure depth is 3’-5”. BII-48 beams were utilized for Spans 2 and 3 as opposed to the BIII-48 beams used in Span 1 since the beams in Spans 2 and 3 did not exhibit the splayed configuration which resulted in shorter beam lengths and lower live load contributions.

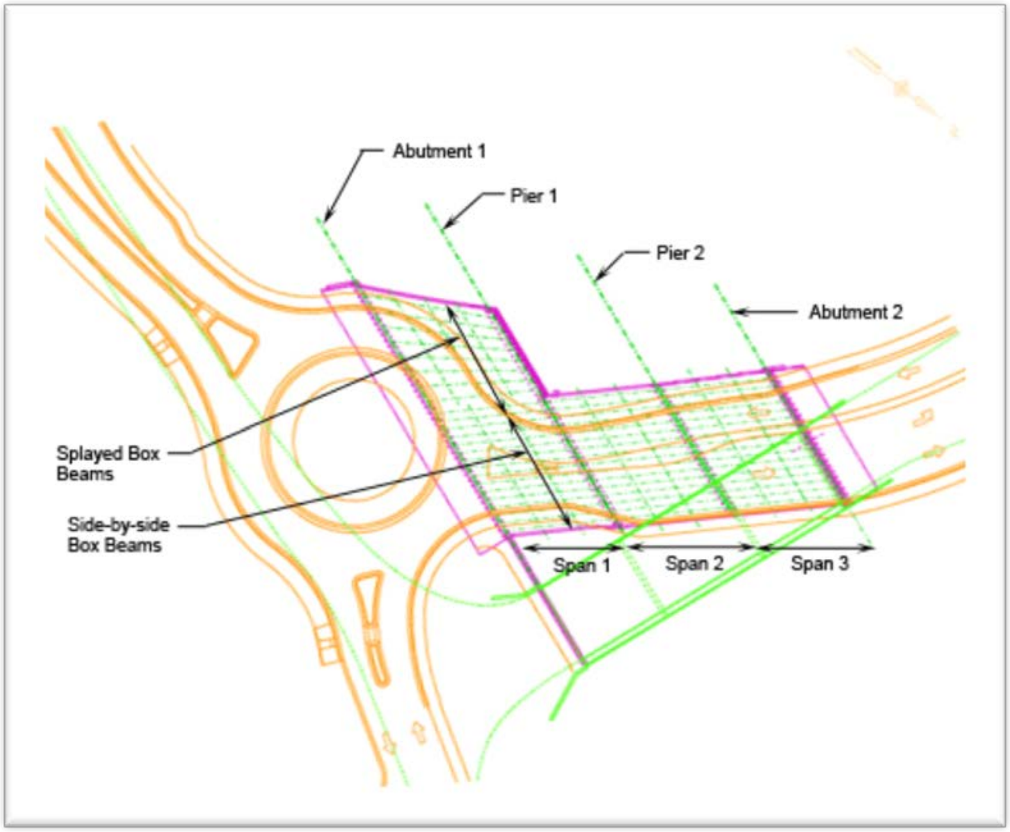


Fig. 5: Superstructure and Substructure Configuration

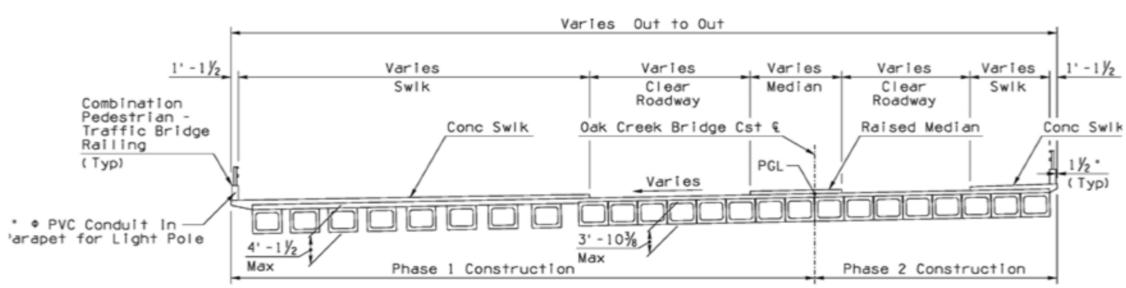
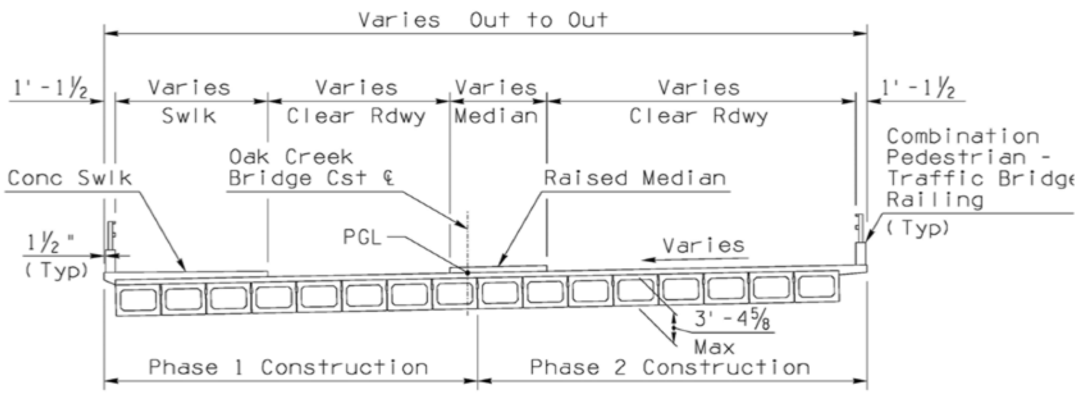


Fig. 6: Typical Cross Section Span 1



Typical Cross Section – Spans 2 and 3

Fig. 7: Cross Section Spans 2 and 3

The recommended precast-prestressed box beam bridge has cantilevered deck overhangs. Oregon Department of Transportation BR216 and BR220 54-inch combination bridge rails were selected to provide vehicle and bicycle protection. The combination railings have a Test Level rating of 4 (TL-4). The BR216 railing has been modified to be mounted on the deck as opposed to the sidewalk. For that reason, the width of the concrete parapet was increased from 10 1/2" to 12" due to the increased height and corresponding higher moments.

3. **Substructure and Foundations** - The abutment and pier centerlines closely align with the existing abutment and pier centerlines. Abutments 1 and 2 are full-depth abutments supported on spread footings bearing on rock and on drilled shafts, respectively. Cantilever retaining walls are required beyond both abutments to retain roadway embankment. At the piers, a reinforced pier cap beam transfers the superstructure loads to each pier column. Each pier consists of multiple 3'-6" diameter columns supported by 48-inch drilled shafts.

4. **Phased Construction** – Sequence of construction drawings were provided with the final plans detailing the phases of construction and the temporary re-routing of the low-flow channel. The bridge was constructed in two phases (see Figures 8 and 9). Phase 1 included the removal of approximately eight feet of the existing deck (shown in red in Figure 8) to allow construction of the south half of the superstructure and substructure of Spans 2 and 3 (as denoted by the deck area in blue with Spans 2 and 3 identified in Figure 8) of the new bridge while a minimum of one lane in each direction of traffic was maintained on the existing bridge. A 24-foot clear width was provided on the existing bridge during this phase of construction. The substructure

elements for Abutment 1 and Pier 1 did not interfere with the existing bridge and were constructed in their entirety during Phase 1 along with the superstructure. The northern half of the superstructure and substructure of Spans 2 and 3 were constructed during Phase 2 when traffic from the existing bridge was shifted to the south half of the new bridge.

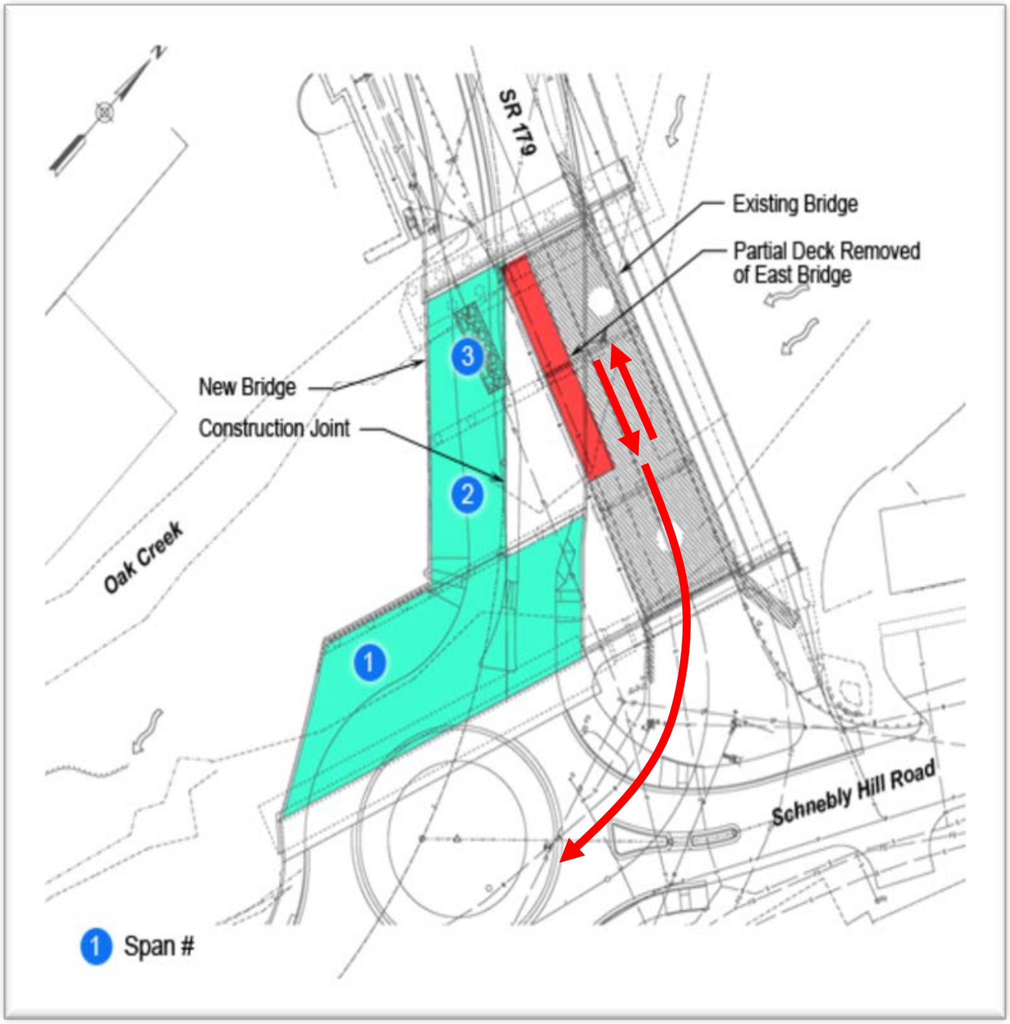


Fig. 8: Phased Bridge Construction – Phase 1

Fig. 9: Phased Bridge Construction (Phase 2)

5. **Relocation of Existing Utilities Prior to Bridge Construction** - The existing bridge supported water, gas, gravity sewer and Qwest telephone lines. Unfortunately, these lines interfered with Phase 1 of bridge construction and had to be temporarily or permanently relocated before bridge construction. The team decided to construct a pedestrian/utility bridge upstream of the vehicular bridge in order to permanently relocate the utilities ahead of construction. Additionally, conduits for cable, lighting, electrical and two 5" conduits for future demands were added as well.

6. **Deck Screed Limitations –** The SR 179 alignment is on both a curved alignment and a tangent through the bridge crossing. The roadway geometry required a transition in the bridge cross slope in Span 1. The cross slope varies from 0.01 ft/ft at Abutment 1 to 0.02 ft/ft at about Pier 2. To mitigate for this transition and the curved alignment in Span 1 and to facilitate construction, Bidwell recommended the use of an independent profile grade line (PGL) for the Oak Creek Bridge from the SR 179 construction centerline (see Figure 10). The PGL has the same bearing as the tangent portion of the

bridge that occurs in Spans 2 and 3. The PGL is on both a constant grade and a vertical curve through the bridge crossing.

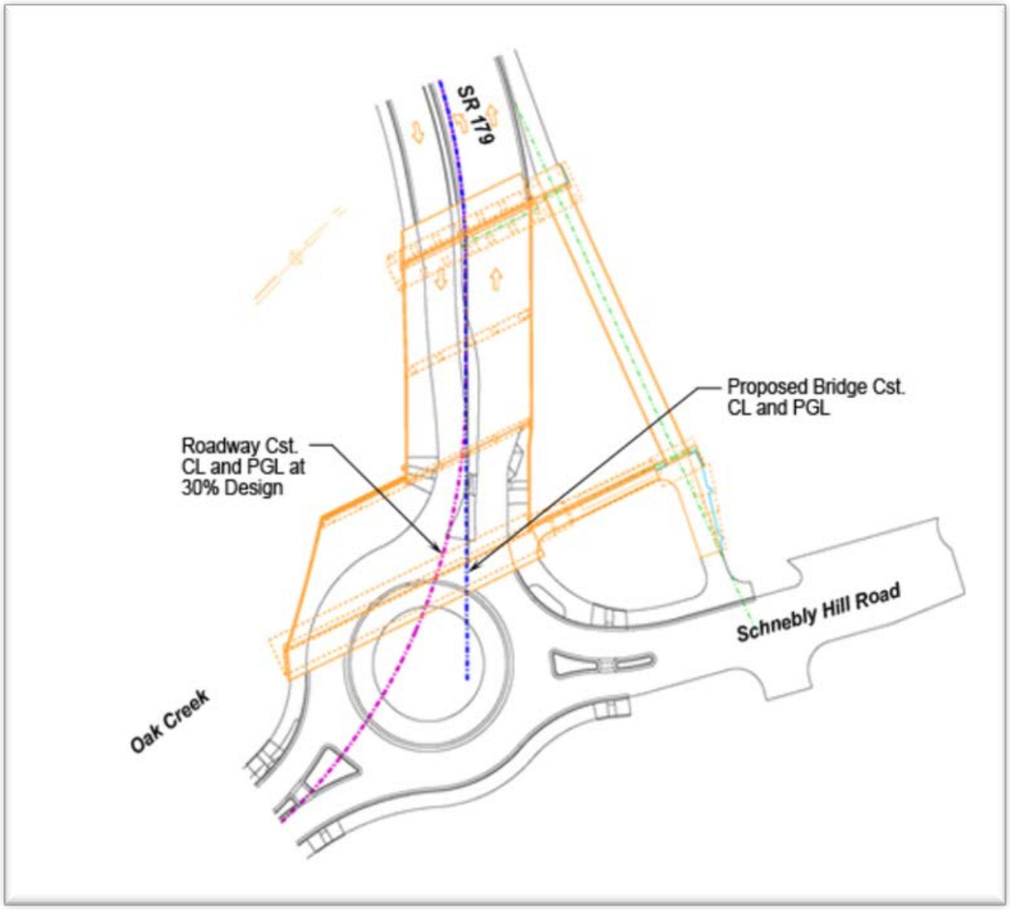


Fig. 10: Independent Profile Grade Line to Accommodate Bidwell Configuration

UNUSUAL DESIGN OF GIRDERS AND PIER CAPS

Several design challenges were introduced given the disparate configuration of the roundabout in Span 1 and the more conventional roadway configuration in Spans 2 and 3. In order to mitigate the structural load disparities, the decision was made to place an expansion joint at the first pier to mitigate structural in compatibilities that would have been introduced with continuity.

Side-by-side box beams in Spans 2 and 3 were lined up with the box beams in Span 1. However, another challenge introduced by the roadway configuration was the substantially large deck area that would have been required to maintain the same side-by-side configuration throughout Span 1. To minimize the deck area required by such a configuration, the side-by-side configuration was abandoned and replaced with a splayed box beam configuration to reduce the deck area (see Figures 11 and 12). The splayed box beam configuration and the resulting large sidewalk area provide a pleasant observation deck on the bridge from which visitors can view Oak Creek.

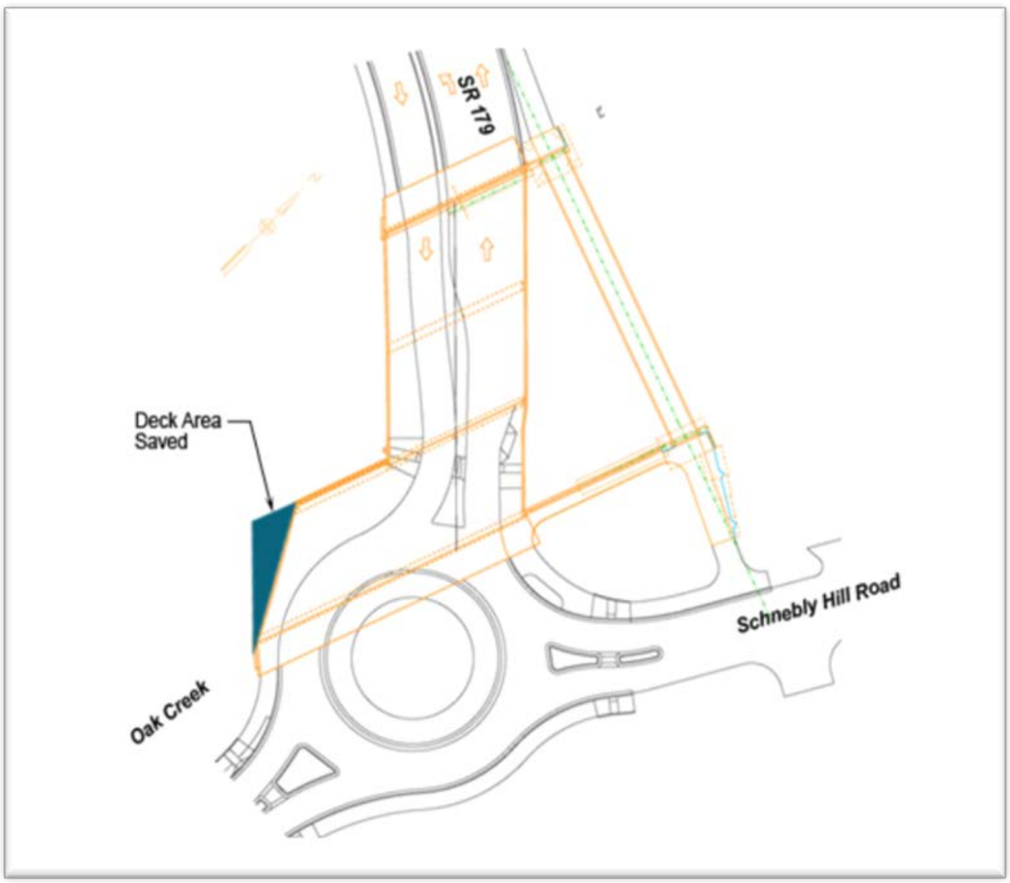


Fig. 11: Deck Area Saved by Splaying Box Girder

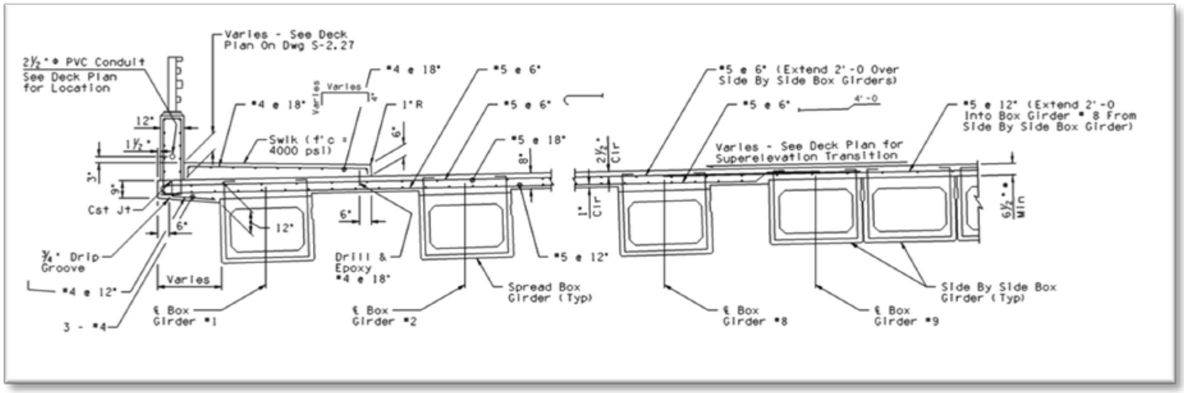


Fig. 12: Typical Section Detailing of Side-by-side/Splayed Box Beams

The unique superstructure configuration of splayed box beams with variable skews at Pier 1 was complicated further by live load configurations. The roundabout located within Span 1 allowed for traffic to traverse the span in both longitudinal and transverse directions that could potentially allow several heavier axles of trucks to be aligned along the box beams that could not be accounted for using traditional AASHTO distribution factors (see Figure 13). The splayed box beams, therefore, were designed using two distinct sets of live load considerations: 1) traditional design using AASHTO-prescribed distribution factors, and 2) a tailored live load vehicle that simulated the presence of live load configurations traversing the bridge in a transverse direction. To simulate the loads in the transverse direction, AutoTURN was utilized to model truck patterns across the bridge to ascertain potential locations of point load locations; CONSPAN was then utilized to simulate this behavior utilizing these point loads with wheel loads conservatively acting on the box beams that were traversed.

Figure 14 shows the moment results from CONSPAN models from both the HS-20 run and a run that utilized a series of point loads to simulate transversely loaded members. Ultimately, the traditional load from the HS-20 truck governed; however, this unusual bridge superstructure configuration does highlight the need for load considerations for bridge structures that accommodate unusual geometry not necessarily covered by typical AASHTO code considerations.

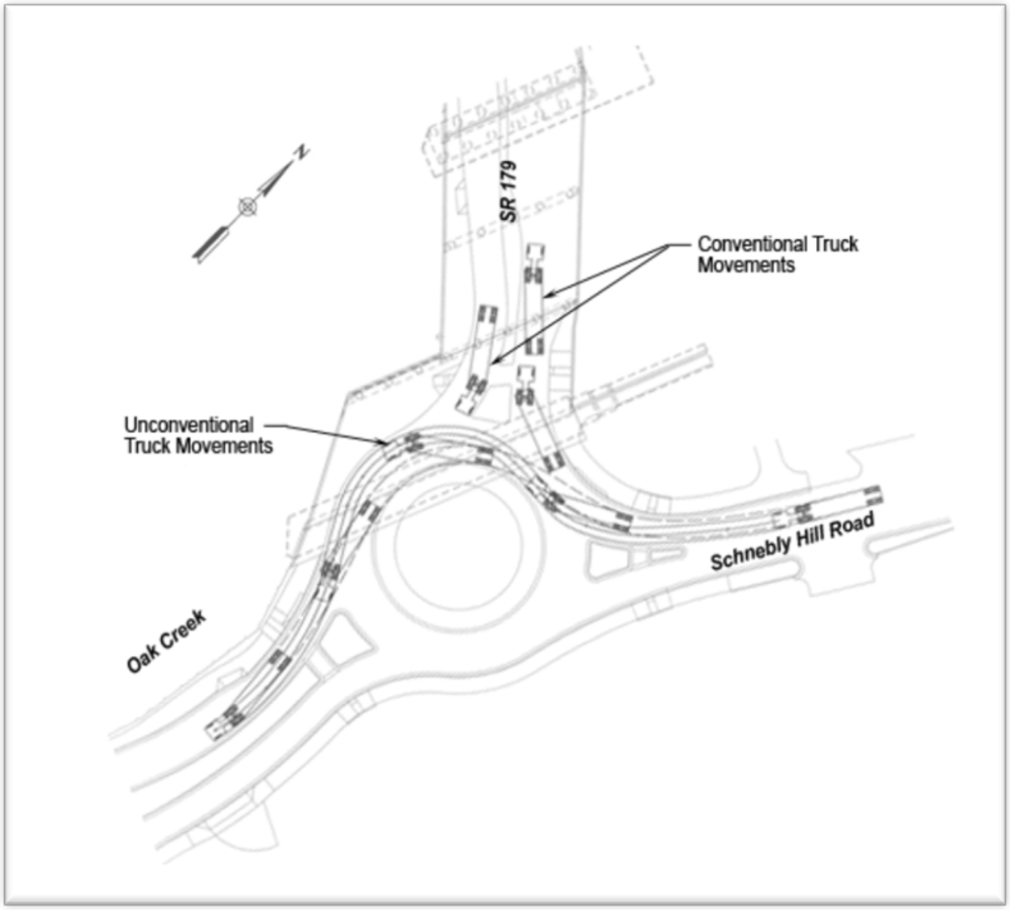


Fig. 13: Unconventional Live Load Configurations

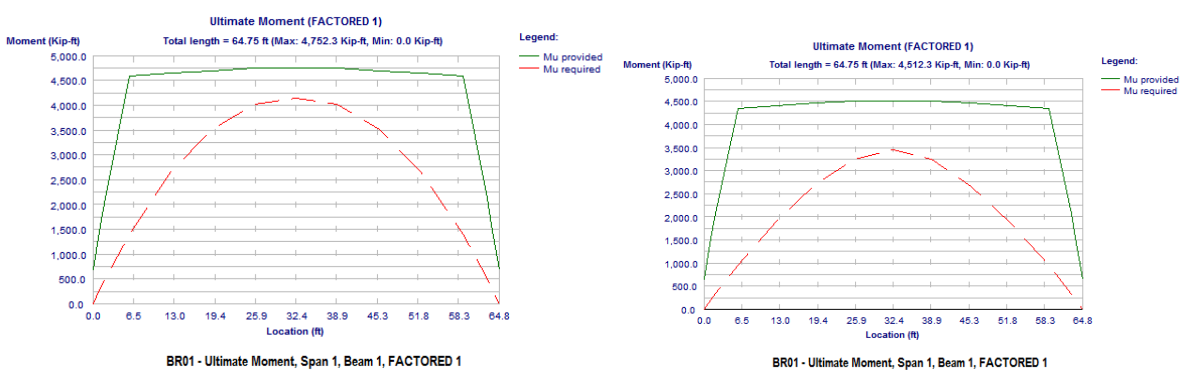


Fig. 14: Side-by-side Comparison of Moment Results Using Traditional Loading Methods with HS-20 Truck (Left) and Non-Traditional Loading Patterns (Right)

Further complications were encountered in the substructure design for Pier 1. The centerline of bearing for the splayed box beams was chosen to be coincident with the centerline of the pier to eliminate eccentrically induced moments on one side of the pier cap (see Figure 15). The presence of an expansion joint at Pier 1 balanced thermal load considerations for the side-by-side box beams between Spans 1 through 3. However, thermal loads under the Group VI condition resulted in interesting design considerations; the length of the pier cap that supported the splayed box beams acted as a cantilever for thermal loads. As a result of this analysis, moments were introduced in the horizontal direction which required reinforcement consideration beyond traditional temperature/shrinkage/skin reinforcement requirements. In addition, the presence of a column at the side-by-side/splayed box beam interface resulted in increasing torsional moments induced by thermal loads that also required attention and additional longitudinal reinforcement needs.

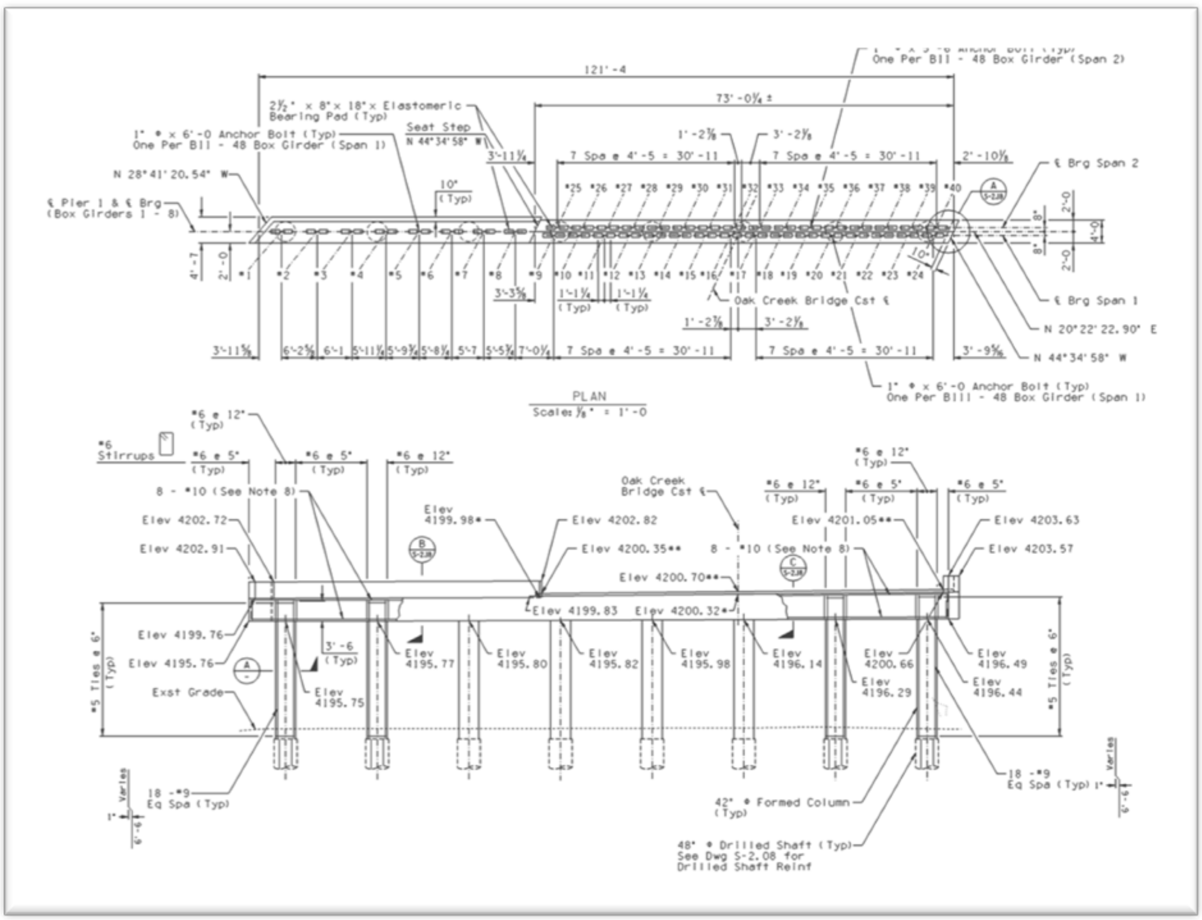


Fig. 15: Pier 1 Configuration

CONCLUSION

The final result of the superstructure and substructure design challenges reveal that careful consideration of the forces involved can be tackled to achieve a precast solution that is both practical and elegant (see Figure 16). Precast box beams were the right choice for this bridge. Their use eliminated the use of shoring for the construction of the superstructure which proved to be of great value on this project due to the high volume of water experienced during construction. These units also provided a shallow structure depth that was needed to meet hydraulic opening demands; and these units are easily splayed which helped accommodate the unusual geometry of the roadway edges. From the contractor's point of view, the precast box beams greatly reduced the amount of work over water in Oak Creek which translated into less risk during construction.

Fig. 16: Final Oak Creek Bridge