PRECAST BRIDGE DECK OVERHANG PANELS A GIANT STEP FORWARD IN ACCELERATED BRIDGE CONSTRUCTION

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ABSTRACT

With today's failing infrastructure and public demand for accelerated and economical construction, innovative methods are needed to accelerate bridge construction and lower construction costs. In Texas, a second generation full-depth precast bridge deck overhang panel (BDOP) is one bridge element currently under development to improve safety and accelerate bridge construction. Presently, bridge deck overhang construction includes erecting formwork, installing reinforcing steel, grading deck for section and reinforcement cover, placing concrete, and wrecking formwork. The BDOP eliminates the need for formwork erection and wrecking, simplifies grading, and requires minimal cast-in-place concrete. Panel placement, fabrication, and safety played a vital role in the development of the BDOP. During the design phase, multiple meetings were conducted with contractors and fabricators to collect feedback on panel fabrication and placement. Feedback was assessed and decisions were made on how to best proceed with the panel design. The precast overhang panel system was fine-tuned throughout the design process to convey fabrication and placement information in an accurate and easy to understand form. The BDOP further simplifies deck placement, reduces cost, and is a giant step forward in optimizing the bridge construction process.

Keywords: Precast, Concrete, Overhang, Panel, Accelerated, Construction

INTRODUCTION

In 2013, the American Society of Civil Engineers graded the bridges in the United States as C^+ based on the condition of the bridges, capacity of the bridges, and number of load restricted and closed bridges. Currently, 30% of the nation's bridges have exceeded their 50-year design life, approximately 11% of the bridges are structurally deficient, and approximately 14% are functionally obsolete. On the brighter side, the number of load restricted bridges has decreased by approximately 10% since 2012.[1]

As our bridges deteriorate further, their cost to replace and maintain will continue to increase while the public increasingly demands quick and economic construction. One way in which to meet the public's demand is through accelerated, innovative, and economical methods of bridge construction. One innovative way in which Texas has planned to accelerate bridge construction is through the development of a full-depth precast deck overhang panel (BDOP). BDOPs will improve construction safety and accelerate bridge construction. The traditional way of forming the bridge deck overhang region is to erect overhang brackets and formwork, install reinforcing steel, grade deck for section and reinforcement cover, place concrete, and wreck overhang brackets and formwork. This method is slow and potentially dangerous, with fall hazards during formwork erection and wrecking. However, the use of BDOPs eliminates the need for overhang formwork, simplifies grading, requires a minimal amount of cast-in-place concrete, and is safer. In 2009, a first generation overhang panel was designed for use on a 120 foot concrete beam, single span bridge on FM 1885 over Rock Creek in Parker County, Texas.

A second generation panel is currently being designed, which addresses some of the issues identified with the first generation panel. One major improvement between the panels is the first generation panel was prestressed while the second generation is not. The prestressing of the first generation panel meant a two-step fabrication process, while manufacturing of the second generation panel is a one-step process. Another difference is the second generation panel uses a "gap" in the panel to integrate the panel with the bridge girder whereas the first generation used shear pockets.

FIRST GENERATION BDOP

The first generation BDOP (FBDOP), constructed on FM 1885 at Rock Creek in Parker County, was a prestressed full depth panel using prestressing strand and conventional reinforcing steel with shear pockets over the outer beam[2]. (See Figure 1.)

Figure 1. First Generation BDOP

FABRICATION[2]

The concrete for the panel had a 28 day compressive strength of 5,000 psi and compressive release strength of 4,000 psi. The prestressing strands were grade 270, 3/8 inch diameter low relaxation[3], and they were placed only in the bottom mat of reinforcing running perpendicular to the beams. (See Figure 2.) The prestressing strands were stressed to 16.1 kips per strand. The bottom mat reinforcing steel, which ran parallel and perpendicular to the beams, was deformed welded wire reinforcing D3.0xD7.5[3]. Top mat reinforcing steel was grade 60 and bar size varied from #3 to #5.

The panel concrete had to be placed in two stages, a bottom half and top half. The two stage placement of concrete was required because the bottom half of the panel was prestressed and the top half was not. If the concrete had been placed in a single pour with only the bottom half prestressed, camber would have occurred, resulting in difficulties grading the bridge deck and a wavy final finish to the deck with poor ride quality. Shear pockets were left open, so after the placement of deck concrete, the panel and outer beam may become integral. (See Figure 2.)

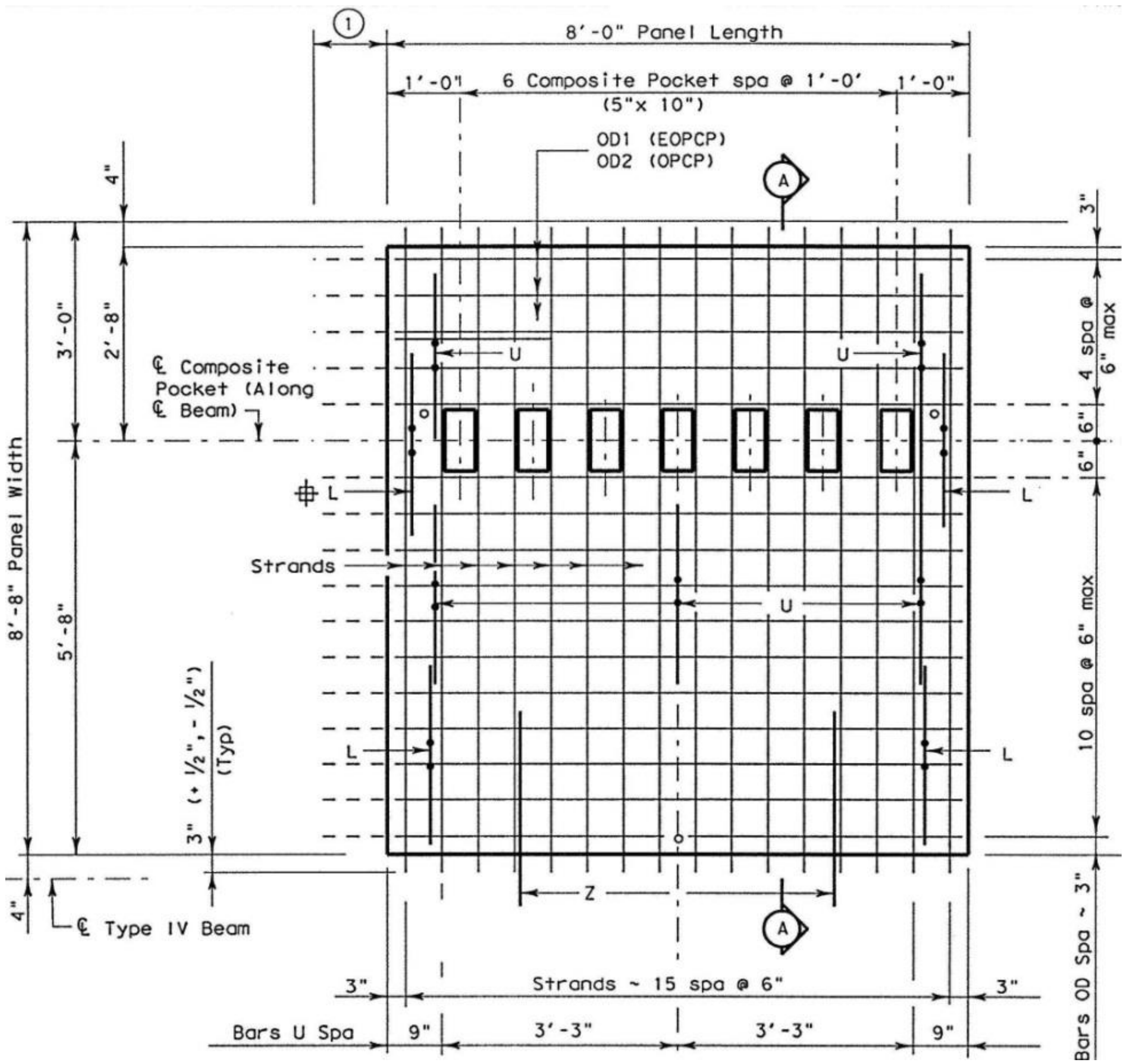

Figure 2. Bottom Mat Reinforcing Steel of First Generation BDOP[2]

PLACEMENT

Minimal overhang brackets or formwork were needed in the placement of deck concrete. (See Figure 1.) This greatly accelerated the construction of the bridge deck.

The beam shear reinforcement bars, Bars "R", are normally extended into the deck but were shortened for the fascia beams to not conflict with the overhang panels. To provide composite action, threaded rods that extended from the top of the outer beams into the panel pockets were installed in the field. This was done for two purposes: (1) it would have been too difficult to place the "R" bars in the outer beams without knowing exactly where the panels would be placed on the beam, and (2) the panel needs to be integrated with the outer beam after deck concrete placement.

Before overhang panels were placed, low density gray polyethylene 1.0 lb. density foam was bonded to the top of the outer beams, as shown in Figure 3, and the outer edge of the first inner beam[2], which was to act as a dam during deck concrete placement. The foam was bonded to the beam and only to the first few panels using a synthetic elastomer liquid adhesive[2]. The foam was only bonded to the first few panels because the inspector reported difficulties when trying to readjust the panels. It was determined that the self-weight of the panels was sufficient to keep the foam in place. Through research, this foam/adhesive combination was found to be the best combination to resist lateral pressure from the placement of concrete[4].

Figure 3. Beam/Overhang Panel Interface

It was apparent that the panels, which were placed using a crane, were not square after several had been placed, because alignment with the finished deck edge could not be maintained. The panels, therefore, had to be trimmed square to keep alignment with the finished deck edge. After panel placement, a temporary safety railing was installed on the outer edge of the overhang panel. (See Figure 4.) They were brought to the proper grade height using a coil bolt/insert system[2] shown in Figure 5. After proper grade height was reached, the panels' "Z" bars were welded to the first interior beams' "R" bars for stability of the panels during deck concrete placement[2]. (See Figure 6.) After the panels were placed, stabilized, and a temporary safety rail installed, a safe and convenient work platform was created.

Figure 4. Overhang Panels after Placement

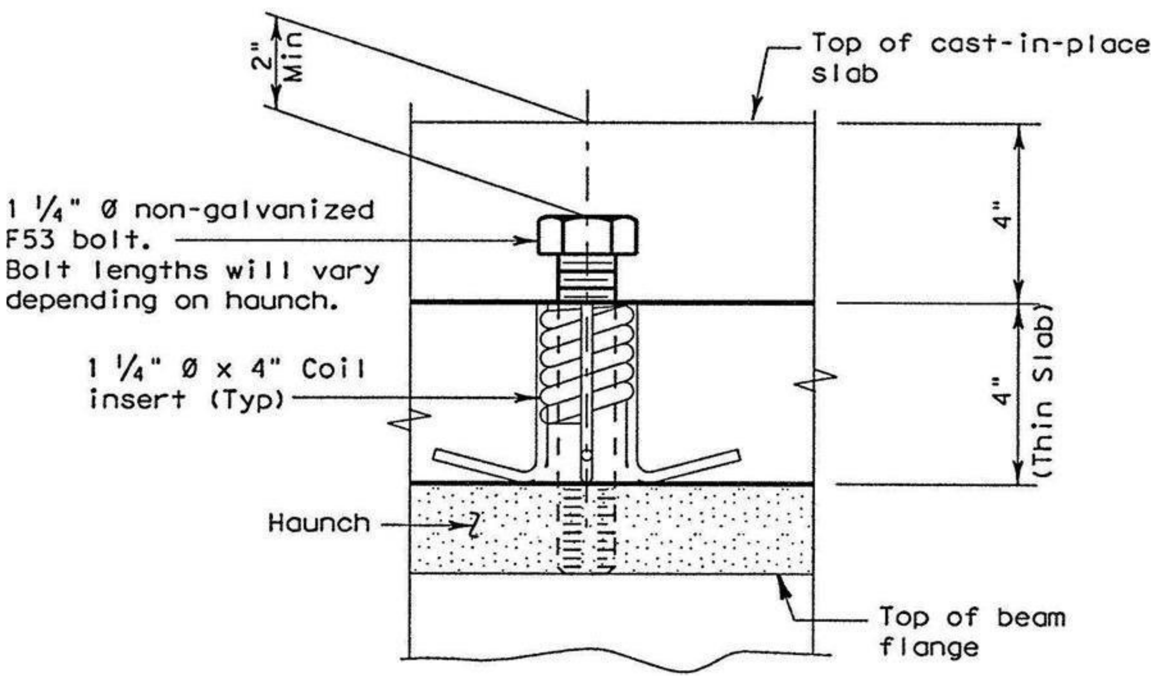

Figure 5. Coil Bolt/Insert for Setting Proper Grading Height[2]

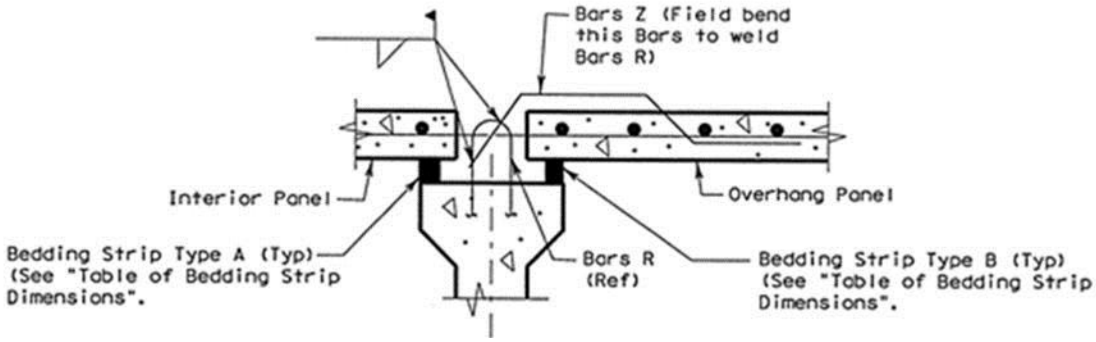

Figure 6. "Z" Bar Weld to "R" Bar[2]

The rest of the deck reinforcing was placed and tied to the exposed overhang panel reinforcing. The screed rail was placed on the panel, as shown in Figure 4. The majority of the deck concrete was placed with a mobile screed, but the concrete placed in the ledge area and the panel shear pockets had to be placed and finished by hand.

Panels were not placed at each end of the bridge because Texas Department of Transportation (TxDOT) requires the bridge ends and/or span unit to have a thickened end region, which projects approximately 3.5 feet into the span. (See Figures 1 and 7.) Therefore, overhang brackets and formwork had to be erected and wrecked in these regions.

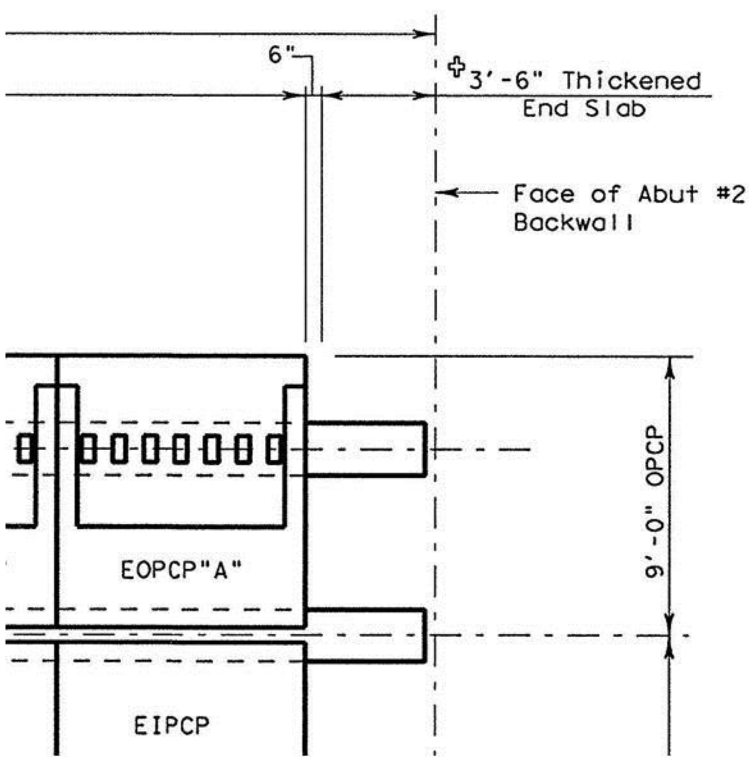

Figure 7. Thickened End Region[2]

CURRENT CONDITION

The last inspection, performed in February 2012, rated the deck at an 8 (out of a scale of 0-9, where 0 means the bridge is closed and beyond repair, and 9 means the bridge is in excellent condition[5].) An unofficial condition survey was performed on the structure on April 3, 2014. Overall, the condition of the deck was very good. (See Figure 8). Figure 9 shows very narrow cracks at the cold joint where the panel concrete met the deck concrete, which was expected because of differential shrinkage between the older panel concrete and the newer deck concrete. No concrete blowouts were apparent at the interface of the overhang panel and the outer or first inner beam. As expected, some cement paste leakage was visible at the beam/panel interface, signifying that air was allowed to escape from under the panel and, therefore, the chance of a void under the panel was diminished.

Figure 8. Current Picture of Rock Creek Bridge Deck, FM 1885

Figure 9. Cold Joint Crack

SECOND GENERATION BDOP

The second generation BDOP (SBDOP) was designed in 2014 to rectify identified issues with the FBDOP. During the design phase many meetings were held with contractors and precast concrete fabricators to address these issues and any other issues that they foresaw.

Tx Girders, mentioned throughout this section, were developed by TxDOT as a variation on AASHTO prestressed concrete beams, and are wider than the AASHTO shapes.

The SBDOP length varies from 6 to 13.5 feet based on the girder spacing and the overhang length, and its width varies from 6 to 8 feet based on the ledge width of 1.5 feet. Panels less than 6 feet would have insufficient embedment length to develop the #4 bars running parallel to the girders. The maximum width of 8 feet is based on transportation restrictions. The maximum girder spacing that TxDOT allows for its Tx Girders is 10 feet and the overhang varies from 3 to 4 feet, depending on girder type. Therefore, the panel length can range from 6 feet to 13.5 feet. The thickness of the panel is 8.5 inches.

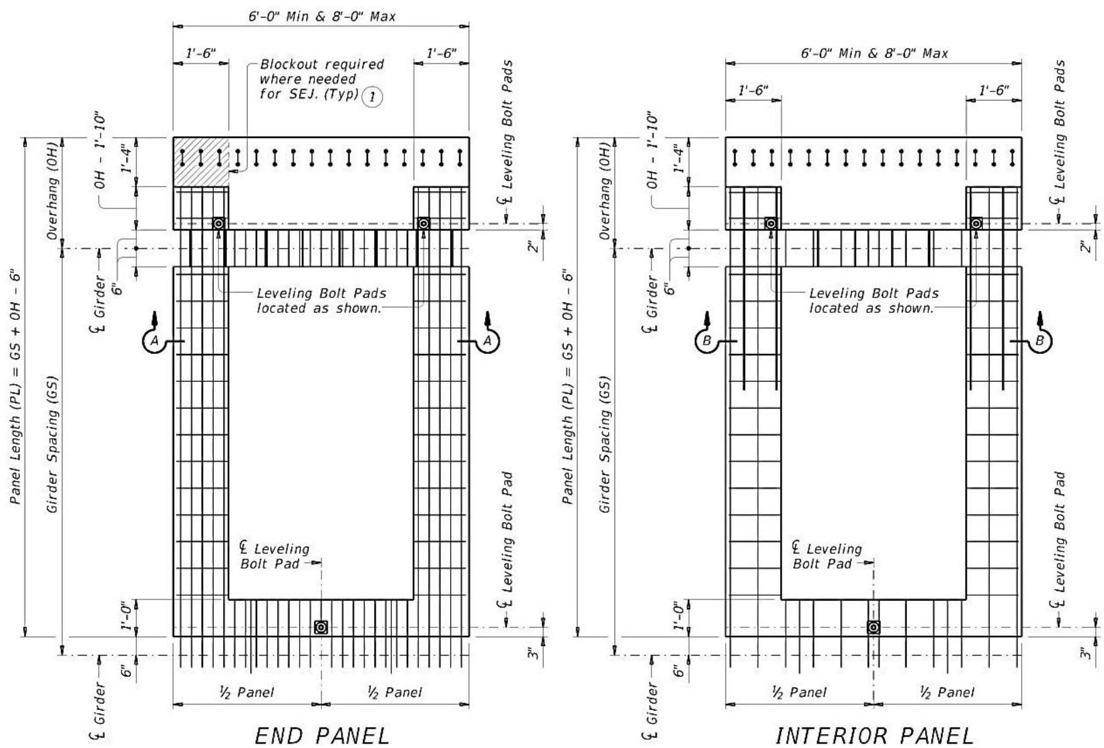

Figure 10. End and Interior SBDOP[6]

The SBDOPs are currently only designed to be used with Tx Girders (because Tx Girders are TxDOT's main bridge support system) and no skew. With a few modifications, the SBDOPs can be used with other beam types such as steel beams, U-Beams, etc., once the need arises. The panels can be used on skewed bridges, but the end panels will be excluded and the end regions will be constructed in the traditional method using overhang brackets and formwork.

ISSUES

All fabrication and panel placement details come from References 6 and 7, respectively.

As mentioned previously, the FBDOP concrete was placed in two stages, because only the bottom mat of reinforcing had prestressing strands[2]. This two-stage process increased the fabrication time of the FBDOP and, therefore, the cost. To decrease the fabrication time and cost, the SBDOP only uses conventional reinforcing steel. (See Figure 10.) Deformed weld wire may be used as an option. Since the SBDOP does not use any type of prestressing, the panel concrete can be placed in a single placement.

To eliminate the need for any type of formwork and overhang brackets, an end panel was designed. TxDOT requires a densification of reinforcing steel in the thickened end region. The end panel, therefore, has the same shape as the interior panel, but has closer spacing on the reinforcing bars running perpendicular to the girders. (See Figure 11 and Figure 12.) The spacing of the steel reinforcing running parallel to the girders is the same for both panel types. Table 1 lists the bar names, bar sizes, and maximum bar spacing used in the SBDOPs.

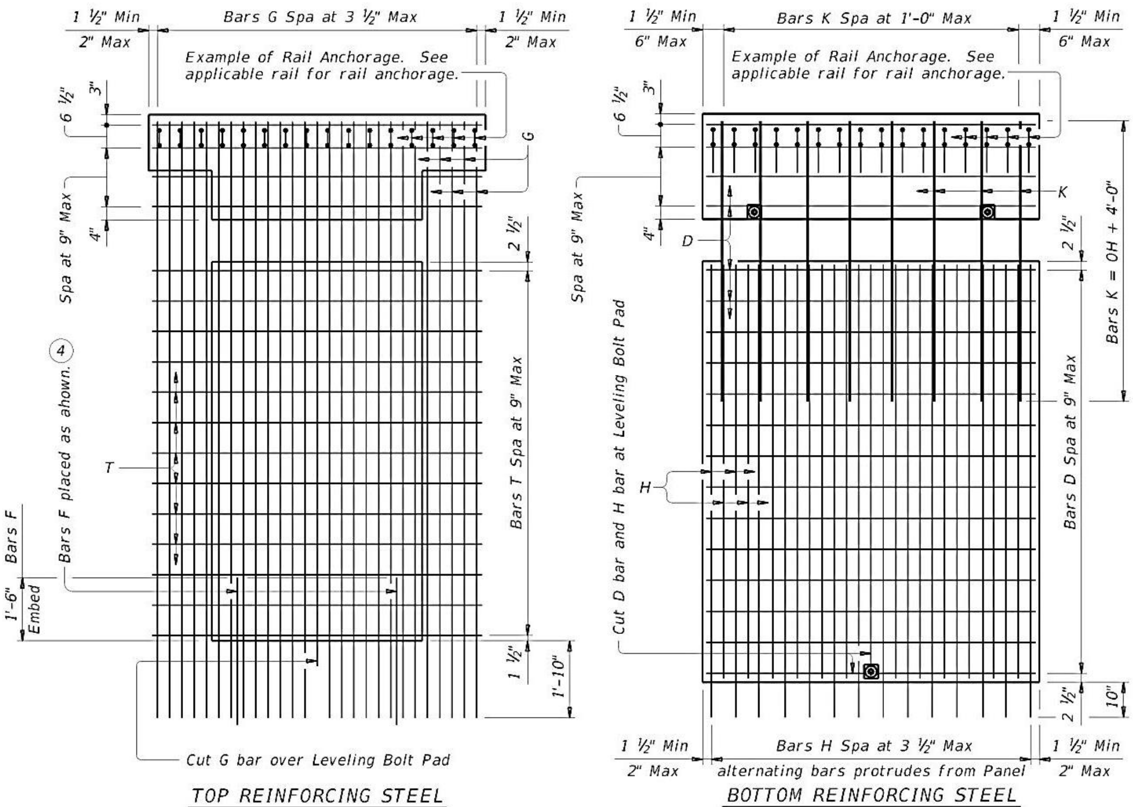

Figure 11. End Panel Reinforcing[6]

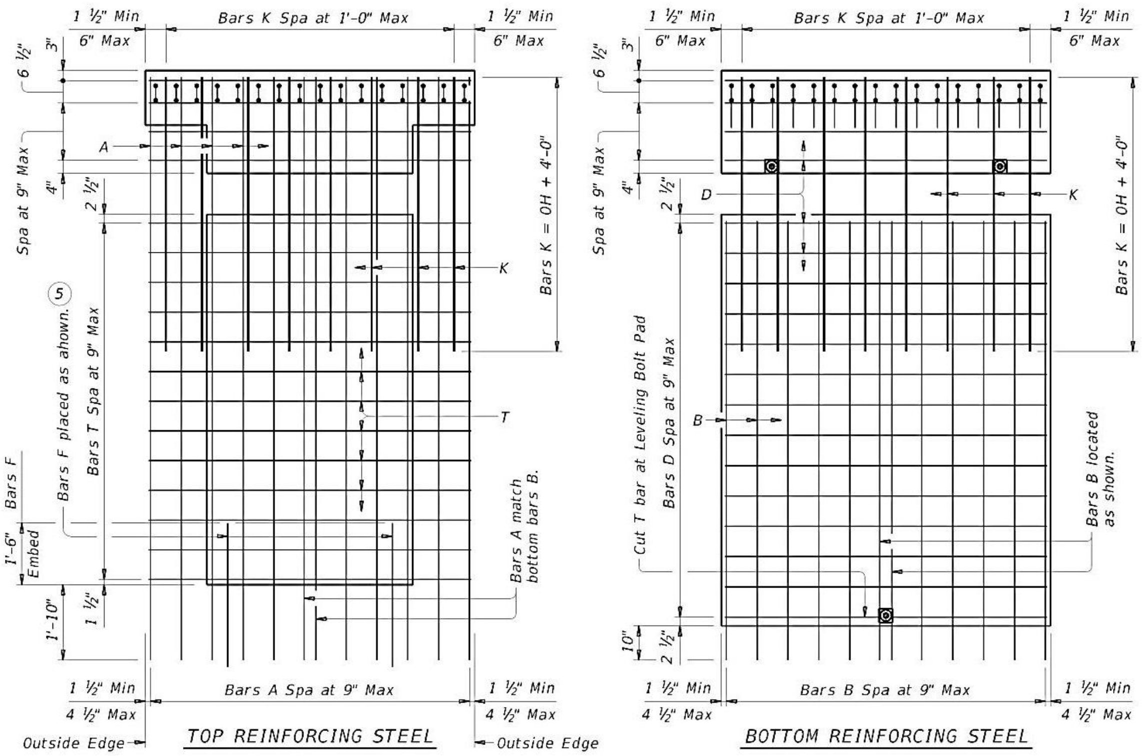

Figure 12. Interior Panel Reinforcing[6]

Table 1. SBDOP Bar Names and Sizes[6]

Bar Name	Bar Size	Max Spacing
A	#4	9”
B	#4	9”
D	#4	9”
F	#3	Varies
G	#4	3 ½”
H	#4	3 ½”
K	#8	12”
T	#4	9”

As mentioned previously, the “R” bars of the outer beams of the bridge on FM 1885 at Rock Creek were shorter, so they could be completely embedded in the exterior beams. The installation of the threaded rods in the outer beams before placing the FBDOP was time consuming. Therefore, the shear pockets were replaced with a gap the entire width of the panel to eliminate this step. Use of an entire panel-width gap instead of discrete pockets originated with the NUDECK system[8]. This gap was initially design to 8 inches, but after further discussions with fellow engineers a 12-inch gap was decided upon. A 12 inch gap would allow the deck concrete to be more easily consolidated within the gap and under the panels. To stabilize the gap during handling and/or deck concrete placement, the panels have supplemental reinforcing “K” bars placed in the top mat across the gap of the interior panel and only “K” bars in the bottom mat. The use of only “K” Bars in the bottom mat was to minimize the chance of conflict with the “R” bars of the outer beams during panel placement. The reinforcing across the gap was analyzed extensively to size the “K” bars and ensure they would be stable during handling and deck concrete placement. Additional “K” bars in the top mat of the end panel were not needed because it was determined that the bars already in place would be sufficient to keep the gap stable during handling and deck concrete placement. Adding supplementary bars to this already crowded area would have caused concrete consolidation issues during panel concrete placement. The top mat “K” bars will also supplement the “A” bars for the negative flexure of the overhang during normal bridge operation.

Like the FBDOP, the SBDOP uses a “Z” bar to stabilize the panel after placement by welding the “Z” bars to the “R” bars of the first interior Tx Girder. This bar is ductile enough to allow sufficient movement to grade the panel to the proper level after it has been welded off.

Initially, the same coil/bolt assembly that was used to grade the FBDOP was going to be used for the SBDOP, but after analysis it was determined that this type of assembly would not work for the full range of girder spacing, overhang length combinations, and would require additional robustness for future larger loading conditions. The use of 100 psi polystyrene to bring the panels to final grade was proposed and analyzed. It was determined this option was not the best choice for grading, because the panels are full depth and required final grade positioning, while anticipating a slight cantilever uplift of the overhang system during placement. The rigid polystyrene system could potentially breach during panel uplift causing haunch placement blowouts and failure. After the polystyrene system was deemed unsuitable, and the FBDOP coil/bolt assembly potentially under sized, a new grading system was designed, shown in Figure 13. It consisted of a 1 inch hex head coil nut, 1 inch diameter coil rod or bolt, HSS 3.5 x 0.216, and 4 inch x 4 inch x 3/8 inch plate. After grading, the contractor will need to provide support to the panel before deck concrete placement. This can be done any number of ways, such as welding the “K” bars, the “B” bars, and the “H” bars to the “R” bars or a grout pad at the grade bolt locations. After the panel is properly supported, the contractor may remove or leave in place the grade bolts as long as a 2.5 inch cover from the top of the bolt to the final grade is maintained.

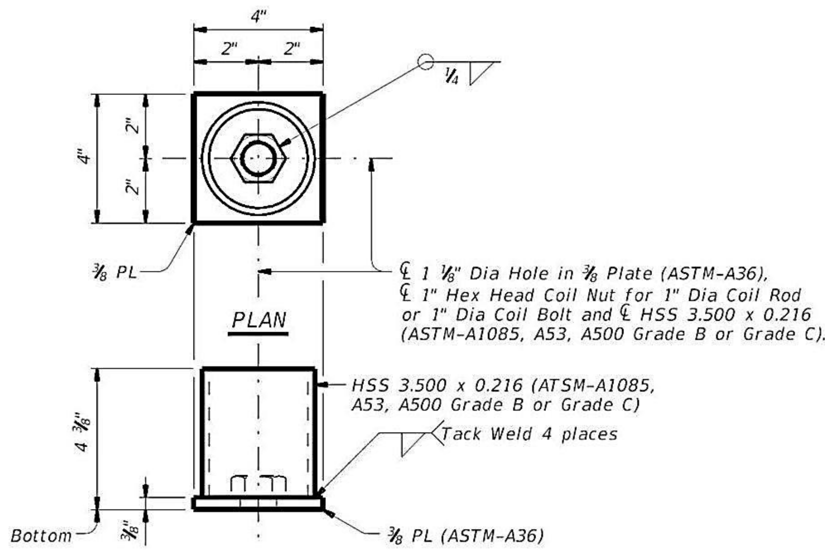

Figure 13. SBDOP Grading System[6]

Similar to FBDOP, the SBDOP uses low density polyethylene foam (1lb density) as a sealing strip to contain the deck concrete under the panel during placement. This foam is pliable enough that it should be cut 1 inch higher than the anticipated haunch thickness. The seal strip will be bonded to the Tx Girder and panel using synthetic elastomer liquid adhesive[7]. See Figure 14 for a typical transverse section of the panel at panel placement.

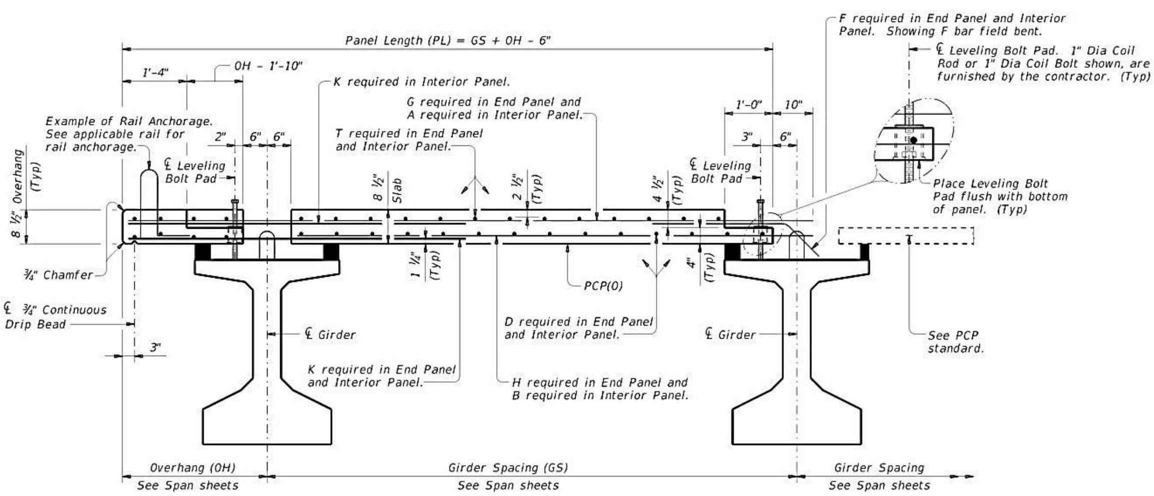

Figure 14. Placed Typical Transverse Panel Section[6]

CONCLUSION

With the United States' aging bridge infrastructure and the general public calling for quicker and more economical construction; government agencies, consultants, and contractors are looking for innovative ways to design and build bridges quickly and economically. Economically, it is a sound decision to replace functionally deficient and obsolete bridges, because they negatively impact commerce by transportation delays, decreased worker productivity, and a multitude of other factors. TxDOT is taking innovative steps to quicken the construction process. One of these steps is the development of the BDOP. The FBDOP was the first attempt, and to overcome problems encountered during the fabrication and placement of the FBDOP, the SBDOP was designed. BDOPs eliminate the need for formwork erection and wrecking, simplify grading, and require a minimal amount of cast-in-place concrete in the overhang region. Just eliminating the need for formwork should significantly decrease the construction time of the bridge deck. The current condition of the Rock Creek Bridge on FM 1885 shows that the use of BDOPs is a viable option to decrease the construction time of bridges. Unlike the current way in which the overhang region is constructed, the FBDOP allows for a convenient and safe work platform that does not need to be wrecked. Not having to wreck overhang brackets makes BDOPs safer than the current method of overhang construction. The traveling public will benefit from the use of BDOPs by decreasing the time a construction zone is present. Shortening the time of construction will reduce number of traffic delays experienced by the traveling public and improve the safety of the traveling public by lowering the potential of accidents occurring in the construction zone. As well as benefiting the traveling public, the owner and contract would benefit from the use of BDOPs by a safer work zone and reduction in construction time. The use of BDOPs will be a giant step forward in accelerated bridge construction.

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