IOWA HIGHWAY 1 BRIDGE OVER CAMP CREEK LATERAL SLIDE

James S. Nelson, PE, Iowa Department of Transportation, Ames, IA

ABSTRACT

The Iowa Department of Transportation (DOT) is preparing to construct its second ever lateral bridge slide project. The project consists of a single span 120’ x 44’ Pretensioned Prestressed Concrete Beam (PPCB) bridge utilizing 45-inch deep bulb tee beams. The bridge superstructure will be constructed adjacent to the existing bridge on falsework and laterally moved into position following the demolition of the existing bridge and construction of new substructure. Additionally, the project utilizes precast concrete abutment footings and precast concrete wingwalls.

The Iowa DOT's first lateral bridge slide project allowed for improvement opportunities to be identified. This paper documents the development of the new project and the design adaptations that are being made for the implementation of the improvement opportunities. One major innovation for the new project will be the design and construction of an integral abutment connection using Ultra-High Performance Concrete (UHPC).

Keywords: Accelerated Bridge Construction, Ultra-High Performance Concrete, Precast Concrete, Precast Substructure, Connections

INTRODUCTION

The Iowa Department of Transportation (DOT) is preparing to construct its second ever lateral bridge slide project. The project consists of a single span 120’ x 44’ Pretensioned Prestressed Concrete Beam (PPCB) bridge utilizing 45-inch deep bulb tee beams. The bridge superstructure will be constructed adjacent to the existing bridge on falsework and laterally moved into position following the demolition of the existing bridge and construction of new substructure. Additionally, the project utilizes precast concrete abutment footings and precast concrete wingwalls.

The Iowa DOT's first lateral bridge slide project, constructed in 2013, near the city of Massena allowed for improvement opportunities to be identified. This paper documents the development of the new project and the design adaptations that are being made for the implementation of the improvement opportunities. One major innovation for the new project will be the design and construction of an integral abutment connection using Ultra-High Performance Concrete (UHPC).

PREVIOUS EXPERIENCE AND POST CONSTRUCTION REVIEW

In 2013, the Iowa DOT constructed an Accelerated Bridge Construction (ABC) project using the lateral slide construction methodology. The Iowa DOT has utilized ABC methods multiple times in the past typically using precast components and modular units. However, the lateral slide method was a new tool. The first lateral slide project was the IA 92 Bridge over a small stream adjacent to the city of Massena, IA. The project was considered highly successful at replacing a deteriorated and posted bridge in a 9-day critical closure. While the entire construction period was several months, the mobility impact when the road was closed and traffic detoured was only 9 days. A detailed account of this project can be found in the 2014 PCI/NBC proceedings in a paper titled Iowa Accelerated Bridge Construction History[1].

In an effort for continuous improvement, the Iowa DOT held a post-construction review of the project to document lessons learned and sought to improve future projects. The post construction review was held on November 14, 2013 in Ankeny, IA. The post construction review was held in two parts. The first part of the meeting was termed an internal discussion with Iowa DOT bridge design staff, construction field staff and Iowa Division Federal Highway Administration (FHWA) staff. The project was funded in part by a Federal Highways for Life grant generating the FHWA interest and oversight of the project. The second part of the meeting added the bridge construction contractor and the consulting engineer hired for design of the project temporary works and lateral slide system to discuss and document the lessons learned from the project. Complete documentation of the post-construction review meetings can be found on the Iowa DOT’s dedicated website to the Massena project[2].

The significant lessons learned in the project that have been identified to implement and/or further develop in the IA 1 over Camp Creek lateral bridge slide project include the following:

1. Let ABC projects in the fall similar to steel bridges to allow for the submittals to be worked out over the winter and be ready for spring bridge construction. During the Massena project, the final submittal regarding the bridge lateral slide process was approved “just-in-time” and came too close to being on the critical path of the project schedule.

2. Utilize an electronic construction collaboration system to electronically process and track contractor submittals.

3. Add temporary barrier rail to the project to shield the adjacent bridge superstructure construction area if the existing bridge guardrail is not long enough.

4. Specify bridge superstructure falsework construction acceptance by the design engineer rather than the DOT. For the Massena project, the contractor submitted a falsework design that was reviewed and approved by the DOT. The falsework was then constructed with some minor modifications coordinated between the contractor and their design engineer unbeknownst to the DOT. This caused some project delay as the DOT would not accept falsework that was not in accordance with the approved falsework plan. Since the falsework is not a permanent structure for the DOT and was not located over live traffic, acceptance of the falsework may be by certification of the design engineer. Removing DOT acceptance of falsework from the project critical path helps all parties on the contract.

5. Include a plan note to allow prorating the critical closure Incentive/Disincentive to a unit less than one day. The DOT standard incentive and disincentive unit of measurement is per day. For the very short ABC projects when each hour of closure is significant it makes sense to use the unit of measurement to the nearest hour rounded up for awarding an incentive or disincentive.

6. Include alternate designs for the abutment footing, one a precast option and one a cast-in-place footing option. Only a precast footing alternate was designed in the Massena project however the contractor chose to cast-in-place the entire abutment footing. The contractor’s preference was driven by the larger volume of concrete on the critical path that raised the heat of hydration temperature effect and sped up the curing when compared to the smaller pile pocket concrete cast. For the full cast-in-place footing the reinforcing used was the precast design reinforcing. However, the controlling load case for the precast was the precast pick and a cast-in-place option could have a lighter and more economical reinforcing design.

7. Change Iowa DOT pile driving acceptance criteria for ABC projects such as lateral slides to design bearing using a wave equation analysis. Current DOT pile driving procedure is to install the full plan specified pile length and verify capacity has been reached. Pile driving can be terminated prior to reaching full

installation or upon reaching practical driving refusal. The standard DOT acceptance criteria for pile driving can add unnecessary construction time onto pile driving in order to install the full length of the pile or reach practical refusal.

8. Consider a slightly longer critical closure than nine days for this type of project. The nine-day critical closure was considered by the contractor to carry significant risk of being exceeded with little chance of construction being completed ahead of nine days. The contractor indicated bid prices may be better with a critical closure of approximately two weeks.

9. Increase the size of the bridge staging area to address more storage of materials and equipment. See Figure 1 – Constructing New Massena Bridge.

Figure 1 – Constructing New Massena Bridge

10. Consider a separate bid item for the temporary falsework from the prefabricated bridge superstructure move bid item. The falsework is constructed early in the project while the prefabricated bridge superstructure move happens late in the project. There is no guarantee of partial payment for the single bid item that was used on the Massena project, making this a contractor cash flow issue potentially driving up the cost of the project.

CAMP CREEK BRIDGE REPLACMENT PROJECT BACKGROUND

The second lateral bridge slide project the Iowa DOT is planning is the Iowa Highway 1 Bridge over Camp Creek. The bridge is located 3.1 miles south of the city of Kalona in eastern Iowa shown in Figure 2 – IA 1 over Camp Creek Location[3]. Highway IA 1 is an important north-south route connecting many rural Iowa communities to the Iowa City metropolitan area.

Figure 2 – IA 1 over Camp Creek Location

The existing bridge was constructed in 1955 and consists of an 83 ft. x 30 ft., 3 span slab bridge shown in Figure 3 – Existing IA 1 Bridge over Camp Creek. The bridge deck was overlaid in 1980. The existing condition of the bridge is considered fair, however significant repairs to the barrier rail, bridge deck overhang and substructure under expansion joints are needed to maintain the serviceability of the bridge. Upon evaluation, rehabilitation of the existing bridge was not considered cost effective.

Figure 3 – Existing IA 1 Bridge over Camp Creek

Three alternatives were considered for bridge replacement. The first alternative was a conventional bridge replacement project using a 26 mile off-site detour. The estimated duration of the detour for alternative one was 120 days. The second alternative considered building a diversion that included a temporary bridge to maintain two lanes of traffic. The third alternative was bridge replacement using the lateral bridge slide ABC method. The traffic would again be maintained using an off-site detour with a shorter 14 day duration for the ABC alternative. Due to the configuration and condition of the existing bridge a staged construction option maintaining one lane traffic on the existing bridge was not considered. Traffic volume at the bridge, measured in 2015 was an Annual Average Daily Traffic (AADT) of 3,130 vpd with 16% trucks. The off-site detour was not a short detour and consists of a 26-mile detour including 18 miles of out of distance travel. The significant user costs of the off-site detour motivated the Iowa DOT to select the lateral bridge slide ABC method as the alternative to proceed forward with final design.

IMPLEMENTATION OF LESSONS LEARNED

Many of the lessons learned on the Massena lateral bridge slide project were easily implemented in the preparation of the Iowa Highway 1 over Camp Creek lateral bridge slide project plans. Table 1 - Implementation of Lessons Learned summarizes the issues and resolutions that are being implemented for the IA 1 Bridge over Camp Creek lateral slide:

#	Lesson Learned	Implementation Plan
1	Let ABC projects in the fall similar to steel bridges to allow for the submittals to be worked out over the winter and be ready for spring bridge construction.	The project is currently scheduled for a December 2018 letting but will be considered to be advanced a month or two if all right-of-way, utilities and permits can be cleared.

2	Utilize an electronic construction collaboration system to electronically process and track contractor submittals.	The Iowa DOT has implemented an electronic submittal and processing system that is used on all primary system projects for the electronic tracking and processing of submittals.
3	Add temporary barrier rail to the project to shield the adjacent bridge superstructure construction area if the existing bridge barrier rail is not long enough.	Existing guardrail is long enough to shield the construction staging area.
4	Specify bridge superstructure falsework construction acceptance by the design engineer rather than the DOT.	Falsework construction acceptance will be made by an inspection and certification from the design engineer.
5	Include a plan note to allow prorating the critical closure incentive/disincentive to a unit less than one day.	The critical closure duration will be calculated and rounded up to the nearest whole hour. The incentive/disincentive will be prorated by the hour.
6	Include alternate designs for the abutment footing, one a precast option and one a cast-in-place footing option.	A designed alternate will be included for bid for either a precast footing or cast-in-place footing.
7	Iowa DOT pile driving acceptance criteria should be revised for ABC projects to design bearing using a wave equation analysis rather than installing the full pile and checking capacity or reaching practical driving refusal.	The specifications will be changed for the project to allow for pile driving to stop at design bearing capacity.
8	The nine-day critical closure was considered to carry significant risk of being exceeded with little chance of being beat on the project.	The critical closure duration will be increased to 14 days for the project.
9	The bridge staging area could have been larger to address more storage of materials and equipment.	The bridge staging area specified was doubled to better accommodate materials and equipment.
10	Consider a separate bid item for the temporary falsework from the prefabricated bridge superstructure move bid item.	Separate bid items will be used for the temporary falsework and the prefabricated bridge superstructure move.

Table 1 – Implementation of Lessons Learned

Implementation of the applicable lessons learned from the Massena project are anticipated to improve the constructability of the project. Additionally, the price bid by contractors on the project is anticipated to improve as project risk is reduced. Repeated use of the lateral bridge slide ABC method will also tend to improve the price bid on this type of project as contractors become more experienced and accustomed to the lateral bridge slide construction method.

INTEGRAL ABUTMENT CONNECTION WITH UHPC

The original design intent of the Massena lateral bridge slide project was to develop an integral abutment connection at each abutment. Iowa DOT prefers integral abutment bridges due to their ease of construction and longtime durability. A standard integral abutment detail for a Bulb Tee C beam is shown in Figure 4 – Iowa DOT Standard Integral Abutment Details.

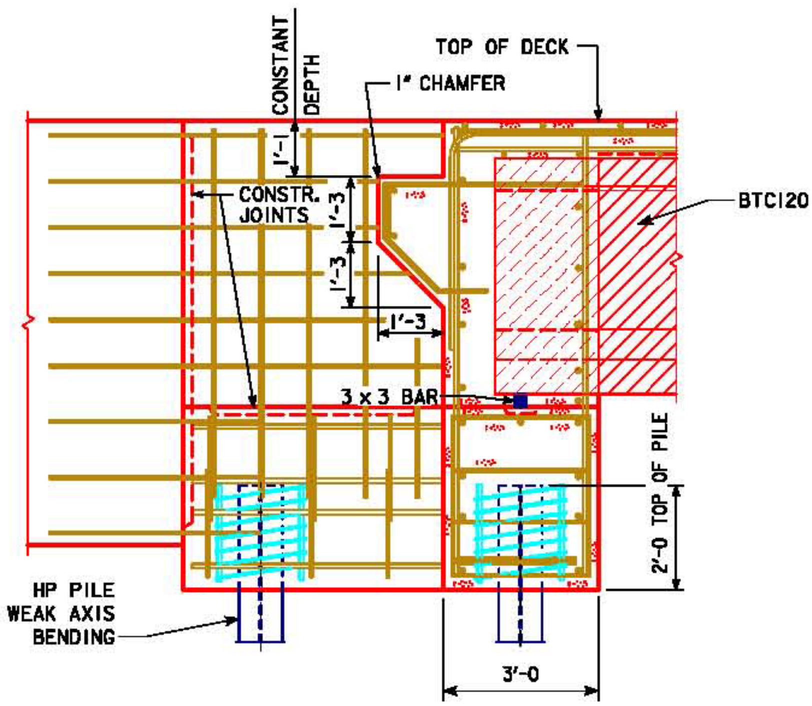

Figure 4 – Iowa DOT Standard Integral Abutment Details

During the design phase of the Massena bridge several integral abutment design concepts were considered that ultimately were rejected mainly due to constructability concerns.

One concept considered mechanically spliced reinforcement projecting from the footing with significant areas of the concrete diaphragm left void. After the bridge was moved into position, the mechanically spliced reinforcement would be installed and concrete cast in the void areas to make the connection between the bridge superstructure and substructure. The main drawback to this design concept was the large areas of the diaphragm that had to be left void to develop the reinforcing connection. This was anticipated to be difficult to construct and did not leave a substantially solid diaphragm to utilize in the slide operation as a jacking point shown in Figure 5 – Massena Solid

Diaphragm Jacking Reaction Point. A secondary drawback was that the cast in place concrete connection would be on the critical path of the construction.

Figure 5 – Massena Solid Diaphragm Jacking Reaction Point

A second concept considered to develop an integral abutment connection on the Massena project was to cast the abutment pile footing integral with the superstructure and diaphragm with pile pocket voids to be later connected to the piling. The entire bridge then would be moved over the top of the pile foundation and lowered down over the piling to make a connection with a special high early strength cast in place concrete mix. This method was considered a highly durable design but again had significant constructability concerns. The biggest concern is the risk of the pile pockets not lining up with the piling when the bridge was lowered onto the piling. The pile driving tolerance with the given pile pockets was ±3 inches in any direction. Should the pile pockets not lineup with the piling, the repair correction would require concrete removal underneath the footing that seemed extremely difficult.

A final concept considered to develop an integral abutment connection on the Massena project was to cast small diameter voids in the diaphragm and footing and to use drop in high strength reinforcing grouted in place to make the connection. This concept was also a constructability concern with the large number of reinforcing connections all needing to be aligned between the footing and diaphragm to drop the high strength reinforcing in to be grouted to make the integral connection. Consideration was also given to drilling the voids after the lateral slide. While the drilling option solved the constructability alignment concerns it was seen as impractical due to the significant depth that the hole would need to be drilled. Even if the holes could be drilled to that depth, it would be very time consuming for an ABC project.

Ultimately due to project development time constraints, and the lack of a feasible integral abutment connection concept, the final design detail selected was a semi-integral abutment detail shown in Figure 6 – Massena Semi-Integral Abutment Section. The semi-integral abutment was easily constructed and accommodates the necessary thermal expansion and contraction of the bridge with laminated neoprene bearings. The bridge is retained by a concrete keeper block cast around the base of the superstructure diaphragm.

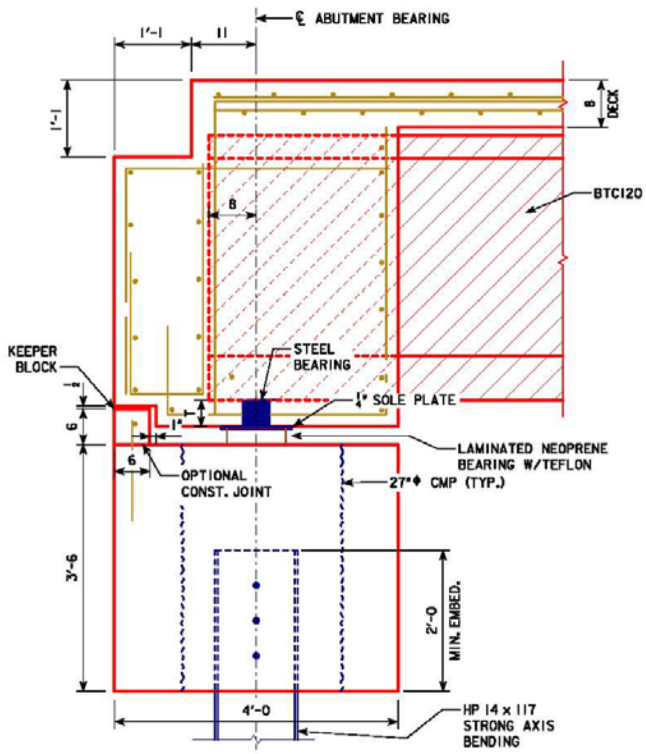

Figure 6 - Massena Semi-Integral Abutment Section

While the semi-integral abutment detail was very effective on the Massena lateral slide project there was still a desire to develop an integral abutment connection for future lateral slide projects. The Iowa DOT was aware of ABC integral abutment research being conducted by the Bridge Engineering Center, part of the Institute for Transportation at Iowa State University. The research is documented in a technical report by Hosteng, Phares & Redd, 2015[4]. Phase one of that research project explored two concepts for making the integral abutment connection. The first research concept used embedded grouted splice couplers embedded in the diaphragm and reinforcing projecting from the footing to make the connection following the slide. The research demonstrated with full size test specimens that this connection was highly durable and effective from a strength standpoint. However, the details were lacking from a constructability standpoint due to the large number of connections that needed to be aligned using very tight tolerances to make the connection.

The second research team concept was very innovative and used a stub H-pile section internal to the abutment diaphragm and a void in the pile foundation footing. Following the bridge superstructure slide, the H-pile section was released inside the diaphragm to drop down with a portion embedded in the footing and a portion embedded in the diaphragm. The H-pile was then grouted in place to solidify the connection between the superstructure diaphragm and the footing. The detail was considered highly constructable, but the subsequent full scale load testing indicated it lacked the necessary strength and durability failing nearly immediately as load was applied. The failure opened a large gap between the footing and superstructure diaphragm on the rear side.

The Iowa DOT has partnered with the Bridge Engineering Center for an extension of the initial integral abutments for ABC research to develop a connection utilizing UHPC. This research will be an adaptation of the Massena integral abutment concept number one except the connection concrete will be UHPC. The biggest drawback from the initial Massena concept was the large area of cast in place concrete needed in order to develop the reinforcing using conventional concrete. Utilizing UHPC allows for a greatly reduced reinforcing splice development length that in turn reduces the connection closure area improving the constructability of the detail. The Iowa DOT has developed preliminary design details for testing the new connection. The design details were developed based on the research carried out by the FHWA at Turner-Fairbank Highway Research Center and documented in the Technote for Design and Construction of Field-Cast UHPC Connections[5].

The preliminary design is to utilize #7 grade 60 rebar projecting from both the footing and diaphragm with non-contact lap splices and UHPC in a closure pour. The development length utilizing UHPC in accordance with the Technote is only eight bar diameters and the non-contact lap splices overlapping 75% of the development length are designed to meet maximum and minimum reinforcing spacing requirements. Meeting all the design criteria results in a very small UHPC closure pour shown in Figure 7 – Preliminary ABC Integral Abutment Connection Detail Using UHPC.

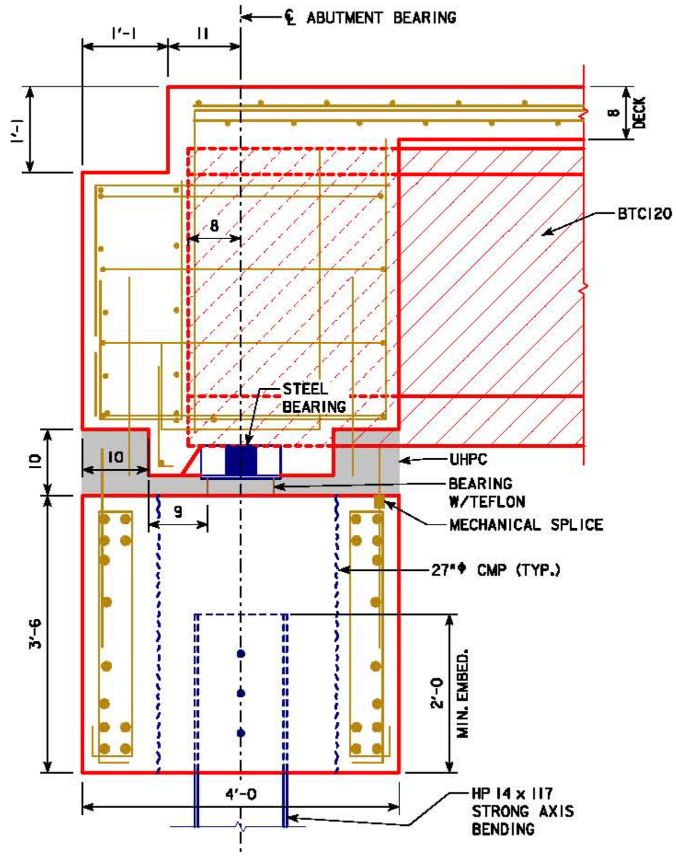

Figure 7 – Preliminary ABC Integral Abutment Connection Detail Using UHPC

Total volume of UHPC in the closure pour for the project is estimated at 2.0 cubic yards. For the Iowa Highway 1 over Camp Creek Bridge, one abutment will be an integral abutment connection and one abutment will be semi-integral like the previous Massena project in order to limit the usage of the UHPC which can be a costly material. The interfaces that the UHPC are cast against will specify an exposed aggregate roughened surface to a minimum of International Concrete Repair Institute (ICRI)[6] concrete surface profile level 7. Five angled "chimneys" will be cast in the back of the diaphragm in between each beam line in order to accommodate the UHPC casting and develop a small amount of head pressure to consolidate the UHPC in the closure pour area. High quality forming will be necessary to prevent leakage as UHPC has been shown to be a highly fluid self-consolidating material. Small vent holes will be cast in the front of the diaphragm in order to minimize entrapped air.

Full scale research specimens are intended to be constructed in order to investigate the following key design concerns:

- Strength of the connection
- Durability of the connection

- Constructability of the connection, specifically;
  - How difficult will it be to construct the exposed aggregate finish on the interface areas?
  - Will there be any conflicts with the projecting reinforcing and mechanically spliced reinforcing during or after the slide given the spacing tolerances used?
  - How difficult is it to properly install the mechanically spliced reinforcing on the front side of the diaphragm after the slide?
  - If the UHPC is cast only from the bridge approach side will consolidation throughout the joint be acceptable?
  - In some areas the UHPC will have to consolidate in an area that has a height of 2.375 inches, will good consolidation be achieved in that area?

Investigating these key design concerns ahead of the advertising of the project will allow for confidence in the design and the ability to potentially alleviate contractor concerns about constructability of the design details. The intent will be to review the results of the full scale laboratory testing ahead of the project advertising, make any necessary modifications to the design should the research identify any concerns, and share all the results with interested contractors.

CONCLUSION

Evaluation of projects to use ABC techniques has become a routine procedure in developing project concepts at the Iowa DOT. The lateral slide ABC method is considered one of the most effective ABC techniques by the Iowa DOT even though it has only been used once previously. The first Iowa DOT lateral slide project was considered highly successful; however, improvements have been identified and are being incorporated into the DOT's second lateral slide project the Iowa Highway 1 Bridge over Camp Creek.

A major innovation in the development of the Iowa Highway 1 Bridge over Camp Creek project is the design of a UHPC closure pour connection to create an integral abutment following the lateral slide. Ahead of the project letting, research is being conducted by the Bridge Engineering Center at Iowa State University to verify design assumptions related to strength and durability and investigate constructability issues. The new UHPC connection detail has the potential to become a standard practice for the Iowa DOT when using the lateral bridge slide ABC technique.

REFERENCES

1. Nelson, J., "Iowa Accelerated Bridge Construction History," 2014 PCI/NBC Proceedings.

2. https://www.iowadot.gov/MassenaBridge/

3. Google Maps. (2017). [Kalona, Iowa] [Street Map]. Retrieved from: https://www.google.com/maps/place/Kalona,+IA+52247/@41.4660051,-91.7264257,13.44z/data=!4m5!3m4!1s0x87e430e90de80fa5:0xe3cb9f05c20e5895!8m2!3d41.4830723!4d-91.7060015?hl=en

4. Hosteng, T., Phares, B., Redd, S., "Strength, Durability, and Application of Grouted Couplers for Integral Abutments in Accelerated Bridge Construction." *Accelerated Bridge Construction University Transportation Center,* December 2015.

5. Graybeal, B., "Design and Construction of Field-Cast UHPC Connections," *TechNote Federal Highway Administration, U.S. Department of Transportation,* October 2014.

6. Concrete Surface Profile Chips, International Concrete Repair Institute, Inc. St. Paul, MN.