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Please stand by. Your webinar will begin shortly.

Ladies and gentlemen welcome to the FHWA UHPC connections webinar series. At this time all participants are in a listen only mode. Later we will conduct a question-and-answer session and I will give you instructions at that time on how to signal. Should you require assistance during the call please press star zero. Now I want to turn the conference over to Michael McDonough. Please go ahead.

Thank you, Sharon. Once again I would like to welcome everyone to the Federal Highways webinar series on ultrahigh performance concrete for precast concrete element series which is an Every Day Counts focus innovation. As you heard I am Michael McDonagh I am with WSP and I will be the moderator for the session. I will also be resenting an overview of today's topic which is construction, inspection, and quality insurance of the UHPC connections. With me is Eric Perry he is my cohost working with Leidos.

Today's webinar is the fourth in the series of webinars that Federal Highways is conducting between March and August of this year. The purpose of these webinars is to provide interested to agencies and private entities with information for using UHPC for connecting precast bridge elements as well as providing information on benefits and lessons learned. Before I go further I want to mention that if you would like to obtain a certificate for professional development hours, a PDH, we will provide an opportunity at the end for each person to type in their name and email address into a PDH registration pod. That pod will be left open for a few moments after the webinar closing to allow you time to enter your name and email address. We will use the information to send out certificates after the webinar is completed. At this time, we will administer a quick audience poll to capture the demographic makeup of the target audience.

If you would answer the two questions on the screen that will help give us a good idea of who is calling in. It looks like we registered most responses. I will give you 10 more seconds. I will end the pole at this time.

The focus of today's webinar is entitled Construction, Inspection, and Quality Assurance of Ultrahigh Performance Concrete Connections. This will cover specific issues related to construction using the ultrahigh performance concrete. The connection surface preparation mixing of the UHPC and testing of the UHPC are among topics that will be covered. In addition, to the instructive material we will also have several speakers giving a presentation on a case study of the bridge using UHPC connections as well as the contractor's perspective on that project. Today's webinar will last 90 minutes. The first 60 minutes are allocated to the speakers and the last 30 minutes will be fore questions. If during the presentation you have a question type it into the chat area on the left-hand side of your screen. At the end of all the presentations the speakers will answer as many questions as time allows. I will turn and check all the questions and answer them at the end of the presentation. The presentation will be available online in a few weeks including a recording and a transcript. We will notify all attendees when the documents will be available through email.

Turning to the presentation team, it includes me, Michael McDonagh, Mathew Royce, and Jeff Hanlon. I am a senior technical principal at WSP. Until recently known as WP Parsons Brinkerhoff. I have 20 years' experience in bridge design and I have been most recently working on the rehabilitation of the three and a half-mile long Pulaski Skyway, since 2012 in fact, where we have been using ultra high performance concrete for precast connections for the majority of the 3 1/2 mile structure. Prior to joining WSP I spent five years working in Paris France where I first encountered UHPC and had the opportunity to design several unique ridges around the world with UHPC. I am also a member of the organized committee of the US-based interactive international symposium on UHPC which was first held July of last year, and I am currently assisting Federal Highways through their Every Day Counts program to educate and encourage the states in the use of UHPC for precast bridge element connections.

Our second speaker will be Mathew Royce. The director of the New York State DOT structures design quality assurance Bureau. The Bureau is responsible for the development of the policy structures as well is the introduction and standardization of innovative technologies such as UHPC. Mathew has been working in the office since 1988 and prior to his current assignment he was the director of the design Bureau. Mathew is a licensed professional engineer in York.

Our third speaker is Jeff Hanlon who worked in the highway construction industry since 1977 and a registered professional engineer in New York. He has served as the president of State Hill Constructors when he started the company. Mr. Hanlon oversees a variety of projects including design build and accelerated construction including the use of UHPC for bridge connections. He will present today on the contractor's perspective on the recent project and Interstate 81 in New York where UHPC connections were used.

Before we begin we will do one more audience poll. We would like you to tell us a little about your experience and expertise, especially with regard to UHPC. This will help us learn more about you.

As we wrap up the poll I will remind everyone if you have questions please type them into the chat pod. Finally, if you need PDH remember to stick around to the end where we will have a separate pod where you can enter your name and email. We will end the poll now and go into the first presentation.

I am the first presenter, and I will give a brief overview of construction, inspection, and quality assurance of UHPC connections. We are going to dive right in. If anyone has been following along in the webinar series you would have already received the introduction in webinar one why we are using UHPC for connections as well as design information in webinar three. We will not rehash that today. You can go back and view the webinars if you need to. However, if there's anyone new here I want to mention what is ultrahigh performance concrete. It's a cement material. It can achieve compressive strength between 18 and 35 KSI. It has tensile capacity between .9 and 1.5 KSI. It bonds extremely well to the conventional concrete with about 600 psi bond strength and has extremely low permeability from about 360 coulombs down to as little as 20 coulombs. These are the reasons why it's a great material for connecting precast bridge elements. Today we will talk about preparing your interface of your precast concrete in preparation of connecting it with UHPC. We will be talking about formwork requirements and pre-wetting requirements. We will be going over the mixing and casting of UHPC and discussing overfill and top forming of UHPC connections, and then we will discuss field testing of UHPC for fresh properties prior to placement. Finally, we will talk about lab testing of UHPC for its hardened properties.

So, if you have a UHPC connection project, before you start messing around with UHPC, you need to make sure your precast has been properly prepared to be connected with UPC. That is an important concept. The main aspect is you need sufficient roughness and need to expose the aggregate. The most common way to do that is to do an exposed aggregate finish. The amplitude of the finish is not so important. As you see on the slide we have four different amplitudes of surface roughness from none to low, medium, and high. The none category would not give you a good bond to UHPC. However the low, medium, high will all give you a good quality bonded. How that is typically achieved is to apply a set retarder in the precast form and then, after you have stripped the forms, you would hydro blast the edges where the set retarder was applied and remove the surface paste and expose the aggregate.

Here's an example which I believe you will see later as well. This is precast deck panels with a good exposed aggregate finish. While we look at this picture we can talk about a few other things such as formwork. In this case in the foreground we see a stringer and there is a haunch angle form, and you see the gap and there is a piece of foam insulation. That is sealing the form between the panel and the stringer below. You can see we have shear below the bottom rebar. You can also see there are very short rebar connections with no hooks, which is typical for UHPC connections. On the subject of formwork, it's very important your formwork is watertight. UHPC flows really well, almost as well as what it is. If your forms are not tight it will find a whole and it will leak out. This is a key difference between the placement process for UHPC versus conventional concrete. UHPC does not have course aggregate that will plug up any small holes. You can see the background there's a bulkhead used to break up the joint between separate pores you notice the spray foam around the bulkhead which is another method, an indicator of the need to have a watertight form.

Once you have your connection interface properly roughened and your forms are in place, you need to get ready for pouring the UHPC. Before you pour, you need to make sure your connection interfaces have a saturated surface dry condition. The reason for that is UHPC has very low water content, a very low water to cement ratio. Consequently if you pour UHPC up against dry concrete, the dry concrete will suck the moisture out of the UHPC, and that will degrade not only the quality of the UHPC but also the quality of the interface and the bond. A good way to achieve that is to soak the connection interfaces and then put burlap in those joints and keep the burlap wet for a period of 24 hours prior to the pour.

Once your joints have reached saturated surface dry conditions, now it’s time to start mixing the UHPC. This would be a typical UHPC mixing scene. We have 2 one-half cubic meter vertical-axis high-shear mixers, and you can see the forklift is dropping a super sack of UHPC into a mixer. That sack also has a volume of one-half of a cubic meter, or about .65 cubic yards. It's always a good idea to have a minimum of two mixers. If one mixer breaks down you can continue operating. Also, the mixing time can take up to 15 minutes, maybe longer, so if you have multiple mixers you can stagger them and get a faster rate of production. As this photo shows you insert the dry ingredients in the mixer and that dry ingredients sack can make everything you need for UHPC with the exception of liquid ingredients and the steel fibers. The next step would be to input the liquid ingredients into the mixers and that is typically done by measuring out the liquid on-site which consists typically of water and super plasticizer. You also see in the photo to the right there buckets of ice. Depending on the ambient temperature, sometimes some of the water needs to be replaced with ice to prevent the mixed UHPC from getting too hot and losing workability. The UHPC technicians on site will typically control that and monitor that.

Once the dry and wet ingredients are mixed, the last step is to mix in the steel fibers. What you see here is two workers are raking steel fibers into the mixer because there will typically be a screen which prevents the fibers from going in in a big lump. It facilitates the uniform mixing of the fibers into the UHPC. Those bags stacked in the background are bags of fibers. Typically depending on the percentage of fiber in your mix, you would add 2 to 4 bags, possibly more, per batch of UH PC.

At this point your UHPC is ready to go…or not, but you think it may be ready. The next step to confirm whether your UHPC is ready to be placed is to do a flow test. Because ultrahigh performance concrete flows and is self-consolidating, you can't do a conventional slump test as you would a typical concrete. Instead you do a flow test. For this test you put your UHPC in the brass cone, you lift the cone off, you wait two minutes, and you see how far has it spread. If the mix is ready to go it will spread about nine inches or at least between eight and ten. That is a key indicator your mix has been mixed properly and is ready to be placed.

Once you achieve that it's time to place the UHPC. There's a couple ways you can move it from the mixer to the pour location. In this location here, they are using a motorized buggy, that's a common way. You'll notice they built a plywood trough that helps them get the UHPC into the precast deck panel joint with minimal mess and waste. The trough is not mandatory. Alternatively, for smaller jobs, you can simply use a wheelbarrow, which is what is done in this photograph. You can see they are not using a trough and there's some spillage there, but they can scoop it up and throw it in the joint.

During the pouring of the UHPC, because most decks are not level—you either have cross slope or longitudinal profile dips and rises or probably both—because of that lack of levelness and the fact that UHPC is self-consolidating and thereby self-leveling, it will be necessary to top form a precast deck project in order to completely fill the joints with the UHPC. That's what you see happening in this photo. The one problem was top forming is you get air bubbles trapped underneath the form. You may have noticed in previous slides there were little strips of wood mounted on the panel around the slide of the joint. The reason for that is to overfill the joint, typically you go an eighth to a quarter of an inch, that way any air bubbles that get trapped on the bottom are above the level of the deck and they don't enter into the typical cross-sectional depth of your deck section. What that means is, when the project is nearing completion, grinding will need to be done to grind down the overfill UHPC to the level of the precast deck panels. In some cases, New York State being one example, they will mill the entire deck from curb to curb, and they can do it in one continuous operation and they don't need to grind the UHPC first and come back and do other milling. If you're just placing an overlay, you may want to go ahead and grind the UHPC before you put down the overlay. That is what is being done on the Pulaski Skyway.

Finally you need to test the UHPC in the lab for the hardness properties to make sure you are getting what you expect to get in terms of compressive strength in the field. You can do that using a cylinder or a cube, although a cube is less common, of course. A couple words of caution: if you try to test a typical 6-inch diameter, 12-inch tall concrete cylinder, not a lot of labs will be able to test it to failure because of the high compressive strength of UHPC. Typically we will do smaller cylinders—3-inch diameter, 6-inch height. Those agencies that do a cube typically would use a 2-inch cube. One final word of caution with the cylinders or the cubes, you have to have the ends grinded to almost exact parallelness and plainness in order to get an accurate reading of the

compressive strength. Using neoprene end caps or things of that nature that are done for conventional concrete cylinders will not give you accurate results with UHPC testing.

That is the end of the overview. Hopefully it provided some useful information at this point I will hand the presentation over to Mathew Royce, who will begin his presentation on the Interstate 81 projects in Syracuse, New York.

Thank you. I'm happy to talk about the I-81 project we completed a few years ago and share some of our experience and thoughts on that and some of the lessons learned at the end of the presentation. In general, the project is a deck replacement project that is part of a large-scale bridge replacement program that we had at that time. There were a number of projects, and a number of bridges were being combined on different projects and contracts and then completed during that time. Many of them were conventional construction also. For this one project I am talking about, I-81, there were two crossings, and each featured two three-span structures. Each deck replacement was constructed and completed in 10 days per bound. This used precast deck UHPC joints. We had some experience with the joints prior to that. We were fairly familiar at that time, enough to bring it mainstream. It also used hidden haunches with non-shrink grout in the haunches. One of the main reasons for that is that at that time there was no way to get the we fiber we needed, it was not being produced in the country. So we were limited for the quantity we could use to stay within the limits of the Buy America provisions. We used emulative design; we defined it as a deck and let the contractor come up with the precast solution. You'll see details about that later on. We used no overlay. We used diamond grinding. We diamond ground it down to the appropriate profile and smoothness to give us a good read. These projects were completed in 2013. I will get into a little more detail about each one.

The first one is I-81 over East Castle Street. The bridge length is about 157 feet with three spans and seven steel girders. Each bound was done as one construction sequence and then the other side was done afterwards. Each side was completed within the 10 day time period. We used the precast concrete with UHPC joints. The other one is the East Calthrop Avenue. The project was similar, but had a slightly different span length.

We have some experience with precast; we have done different varieties of precast. The latest ones we did mainly were precast panels with post tensioning. The earliest ones didn't have post tensioning, and the panel to panel connections were always problematic; they cracked and leaked even with an overlay. Then we moved on to post tensioning to improve durability, and the issue with that is it's a pretty complex operation. You have to spend time grouting and putting in overlay, and the installation is fairly complex. Also there is tight tolerance required for each duct to line up, and you have to splice them and make sure they are not leaking when you put grout in the joints. We all went through that, we experienced those issues in late 90s to early 2000s. We were looking for solutions outside of that. Generally we know that even if you go with the post tension decks, there's a lot of additional work that needs to be done. That's why we are interested in avoiding the overlay, and putting the diamond grinding to complete the surface which gives us more freedom to complete the project. Cost is also an issue.

Limited experience in connection design and details was an issue, even with post tensioning. A limited number of contractors had experience with it, and a lot of the owners were not really excited about specifying it, they didn't see a need for it. One of the main differences is if we are doing a post tensioning deck system, you have to decide that early in the design stage. You cannot change that

later on because of the need for accounting for the post tensioning and the long-term effects of that on the structure, whereas in the case of UHPC you are not changing much. It's a similar design only we have to introduce joints that are standardized in the UHPC joint detail provided to the contractor.

As I said, grouted joints post tensioning with overlay have been used with limited success. I have to say many of them work okay and some of them showed leakage even when you post tension. We still had some issues with the concrete overlay. It's not a total success, but it's better than no post tensioning, but time was an issue.

Now we moved onto UHPC joints in 2008 and 2009. We had some connection designs we wanted to test and we worked with FHWA and Ben Graybeal. They did test the joints for us and we put that into some small projects for deck replacement where we used the grout in the haunches and stud pockets. So only the joints were UHPC, the stud pockets were the non-shrink grout, which needed an overlay to protect them.

We decided to move towards UHPC both in joints and haunches. Eventually we came to the realization that we may not be able to proceed that way because of limitations on the quantity of UHPC we could use in the project. We worked with the Feds again, and came up with other details where we could use hidden pockets. Some of them used UHPC when shorter studs were not sufficient because the UHPC could carry the shear through the haunch without any problem. Another use was the non-shrink grout completely filling the haunches. In that case, the studs would have to penetrate into the deck and come up above the bottom level of reinforcement. We tested them both, and both worked. In the case of I-81 we used the longer stud with non-shrink grout to limit the quantity of UHPC.

So this is a hidden pocket detail where the top layer has the non-shrink grout and the bottom has UHPC, where the steps are shorter. The benefit of that is you can speed up construction because there is no interference issue. In the top one, you have to be precise where you locate the stud, and make sure the transfer rebar is not hitting the studs. If it comes to rest on it, it might cause damage to the panel. It is a little tricky, but the quality of the UHPC is very high in the haunches, and right now we generally give the contractor the option for which they use. In the case of I-81 we mandated the use of non-shrink grout, which reduced the quantity of the UHPC in the total project.

If you have to have a longitudinal joint, we would like to have a joint on top of a girder. That is beneficial in many ways. You can accomplish both the haunch fill as well as the joint fill in one single application. When you have a joint like this, where have rebar coming from both sides into that joint and crowding it, if you start to penetrate into the upper bound of the bottom layer, that could cause a lot of interference.

We have used this for I-81. This is a transverse joint. We allow the contractor to pick and choose where they want to locate it. I just wanted to show you a layout. Like I said it was an emulative design that we gave to the contractor, and we said, this is the amount of steel we need, this is the thickness of this slab, it has to be conventional cast in place, and it also has a concrete barrier. We said, you have the option of casting the concrete barrier along with the panel as one, or come up with a different solution. You have to meet the deadline.

The contractor decided to cast it in one monolithic pour upside-down. We did not give this layout to the contractor, they came up with it. The importance of this is that the contractor can work with the UHPC supplier so they can determine the joint location and how everything needs to be placed and maintained during the construction operation. The contractor can think through it and fine-tune it to their capacities. We don't really care about locations as long as they use the right UHPC joint, because the UHPC joints are stronger.

The first few projects we did we did not use exposed aggregate finish, and we had issues with leakage. We took care of it afterwards, but we moved on to exposed aggregate finish. Also, we used the accelerated cure because in some cases we needed to get the strength of this to about 12 to 14 KSI within 12 hours. In those cases, the strengths were computed using a maturity method, where we measured the inside temperature of the UHPC joints. We have maturity curves from the UHPC suppliers, so we knew after a certain number of hours based on the temperature and the time curve what the strengths were. Eventually we do the cylinder test, to confirm what we have. We do that later to confirm what we have at 24 or 48 hours. That is how we accomplish the testing for strength when you are waiting for the structure to be opened after 12 hours of cure.

So this is the deck placement operation. You can see the steps are longer. This is a picture of a panel with integral barrier, which also has a UHPC joint for this project. Everything lined up pretty well and the end result was very satisfactory. This is the placement of that barrier combination. It was a bit of a tight space, but they came through it. In this situation there is a significant benefit because you can actually adjust the location of the panel much easier if you have no interference at all.

This is the haunch where the struts are sticking above the transverse rebar. This is filled with non-shrink grout. This is the placement of the UHPC. It went very smooth. We were able to open all of the structures on time. We also did some of the projects with weekend closures. In these cases we may not be able to complete the whole diamond grinding of the deck at that time. In those situations, we would just grind the joints and put traffic on it and take another weekend and come back and diamond grind the deck lane by lane.

Another benefit to that is if you have multiple bridges, they can do diamond grinding lane by lane and cross only one lane, or make multiple crossings at the same time. That's basically what we did.

A conclusion I want to share with you based on what we have done is that precast decks with UHPC joints are well-suited for accelerated deck construction. We have multiple bridges, and more than 35 decks have been completed—some large and some small—and it works well.

UHPC is a good value for the owner when significant reduction in time is essential. Otherwise it is not. We have circumstances where we are not sure which way to go. If we want shortening of construction time but we don't know whether it is short enough that a conventional cast-in-place is not feasible at all, we will give it out to the contractor. We say, this is how much time we have to finish the deck. You tell us if you want to do cast-in-place or precast for the joint. We have multiple projects that worked that way, and in some cases it went in the direction of cast-in-place, sometimes it went in the direction of precast.

That proves the fact that it actually is market ready and is proven from an economic point of view when compression of the construction schedule is needed. It seems to be highly durable. We haven't seen any issues. Some of the bridges were done in 2012 and even before that in 2009. They are all

performing well. We don't have any major issues with them. We are very comfortable using UHPC joints for precast decks. We are currently working on standardization of this system. It takes a little bit of an effort to go through and fine-tune everything.

We're also working with the Feds to come up with a better girder-to-panel connection where we could utilize some of the new thinking and new designs where the quantity of the UHPC could be reduced and make it even easier to install and place the material and walk away from it. Once everything is set we will standardize the details. I am expecting everything to be completed by the end of the year.

Thank you all. That's all I have. I am passing it on to Mike.

Thank you, Mathew. Next up we will have Jeff Hanlon with Slate Hill Constructors. He will talk about the same project that Mathew was talking about only from the contractor's perspective since he was the contractor for those projects.

Thank you. As Matthew said, this project was two decks on I-81 northbound and southbound. It was actually East Calthrop and Castle Street. We did the two northbound spans in 10 days and the two on the southbound bridge in 10 days. We started off with demolition, and when we first started the projects we under decked the bottom. We will talk about that, the demolition, installation of studs and angles, the panels, and then the forming for the UHPC, placing the UHPC, and the grinding. That is the outline.

The first slide shows how we prepped the decks for demolition. We put the decking throughout and the next slide will show you how we removed the deck using demolition. The next slide shows the blankets picking them off. Because this was an accelerated project, after the first few bridges we switched to a new method. The next page shows us preparing the roadway underneath and protecting it with sand. The next slide shows how we hammered the deck right down through onto the ground. This enabled us to continue working on the superstructure while cleaning the debris below.

The next slide shows us starting to remove the studs from the old structure so we can start with a new slate for the layout. We had to remove all the studs on there. This slide shows us doing the survey to determine the location and size of the studs throughout the steel beams.

The next slide shows how we worked around weather. Even when it rained we had to keep going, so we used tents to try to protect it as best we could. The next slide shows us installing the studs and the angles. Now, the angles were the grade for the bottom of the precast slab. Once we had the angles put on the beams, you could see what height the studs should be at. The next slide shows the typical haunch grade of .40, and then we weld the angles on and then that now is our grade. It made it pretty easy. Once we got that done we knew where we were going. The next slide shows us handling the panels to install them. Each of these were an eight point pick. They were about 7 and a half wide, and they range up to 30 feet long. The next slide shows us setting them on the deck.

The next slide shows the angles, the foam, and the shims that the panels stick on, but they set real nice on the angle. The next slide shows the studs that have to come up through to catch that haunch pocket underneath. Where we can eliminate this we try to, but quite frankly the cost of the UHPC is a lot higher than that of the non-shrink grout.

The next slide shows a typical pocket underneath. Mathew had one that showed the exposed aggregate finish which we moved to. The next slide shows the exposed aggregate finish that we - - I think we did some samples in the pre-caster's yard, and then we installed it in all the panels.

The next slide shows an up-close look at that. The next slide shows the amount of rebar required on some of the connections along with the studs. As you can see the layout of the stud and the panels are very tight. We did have to use some sledgehammers to bend some studs around a little bit, but everything fit eventually. The next slide is an up-close shot of the angle, the shims we used to hold the precast in place, and also the angle where it met the beam. The next slide shows we had to put a bead of silicone were the angle met the beam. We had leakage in that area also. When they talk about being sealed up, it is important to try to plan to fill all the holes, especially when you have an old beam.

The next slide shows the completed deck after it's been set. Now you are ready to lay out your forms for the panels. And the next slide shows the pre-wetting. We wet the inside and covered it over. I think sticking it down in would've worked well too. The next slide is part of the forming up of the outside. We had the form on the outside overhang. The next slide shows the deck , the chimneys— you have to have positive pressure at all times because little by little the stuff creeps, so by having the chimneys we made sure all the voids got filled. The next slide shows where the bulkheads are. We started using Plexiglas bulkheads that we caulked around, and we tried to leave them in place. We ended up going back to the plywood and doing the removable forms. It's time-consuming.

The next slide shows another picture of us mixing the stuff, which Matthew showed. The next slide is our ice machine that was used not just for ice for the mix, but also to keep the water cold for the guys. The next slide shows the installation of the UHPC. We used plywood to drive over the one panel to the next. The chimney is there. The bulkheads—you only have the bulkhead every so often. You want to make sure you keep each void filled. The other important thing is if you have a blowout, you don't lose everything on the bridge because it's hard to stop once you start if you do get a blowout.

The next slide shows the guys finishing it off, and then the next slide shows how we put the cover over top so it doesn't spill out. You will note the plywood is covered with plastic so you get a much better finish. The panels are easier to remove.

The next slide will show where, Matthew mentioned 12 hours, we had to keep it at 120 degrees for 12 hours to get the strength. So the thermal coupler is right inside the joint. The next picture shows the reader where we kept track of the temperatures to get the strength as we predicted.

The next slide is after we start stripping the chimney made out of plywood. It proved quite hard to remove so we switched to the buckets. They were easier. The next slide shows the heating enclosure. We initially heated it from the bottom up through, thinking it would be better. Later on we did heat from the top with heated blankets, coils. The reason here is if you don't get the heat started soon enough, the steel could be expanding along with the heating process. In the next slide we took a core. Matthew mentioned how he had some leakage early on, but between the different way of heating and the new exposed aggregate joints we cured this quickly.

The next slide shows the precast panels with the extra weight on the outside. Notice the waler with the tie rod holding that panel down in place. It was very close to tipping. If you ended up putting stuff on that outside or a bunch of guys get out there on the outside, you would end up losing that panel if we didn't have that bolted down. You see the panel up underneath there— it was easy to form up with the joints with the decking underneath.

This slide shows us profiling and grinding the finished deck. Under traffic, where we could switch traffic from side to side to do this deck, and go right down the road to the next deck. That does give a very nice ride once we got done.

The lessons learned I wrote up on the next slide, we completed three different contracts. The first one had five single span decks, and had four three span decks, so the first contract had a total of nine span decks, and the second contract was an inverset, where we had the beams and the deck together. These were very heavy units, 100 tons, 200,000 pounds. Then we put five of them together and made them a single span deck. We used UHPC to join the inversets and the back wall connection also. Our third contract where we used UHPC was on a design build contract where we had options and we went with this because it fit in with the local needs of getting in and out quickly.

The productivity on these contracts —in the first five decks we did there were all single spans, so by the time we got to the last one, which was twice the size of the first one, we were able to do it in less time. The productivity really increased once everyone knew what they had to do. The next slide shows some of the details I think are important in using UHPC. We did have blowouts. I think everyone is going to have those the first time they try this. So you need to minimize them by using the bulkheads and using the caulking and taking time to form everything right.

The survey is also very important, especially if you are rehabbing the deck trying to determine the flexure you'll have and how much you should survey the beam before you take off the deck, and then you have to do some analysis to determine how much flexure you think you have. All in all it worked out well. One of the things I think we would changes on the panel supports is if we could beef up the angles and be assured we could come up with an angle that would support the panel by themselves without using the shims. That might be something we would look into on the next project.

Again heating from the top worked better than heating from the bottom. The steel will expand, but if you put it on too soon, you you're not going to be working too much with 120 degree temperature going on. In the future I see there's going to be more and more of this type of construction. Labor costs are going up but material costs are not, so the amount of time it takes to do the project will become more and more valuable, keeping lanes open as much as we can.

I think that's all I have. I welcome any questions.

Thank you, Jeff. I would like to throw in before we move on just to clarify that the heating that was used was specifically because this was an accelerated project. If you are using UHPC and you are not under a strict timeline, there would normally be no need to heat the UHPC. That is only if you are trying to put the UHPC joints in service in as little as 12 hours.

Before you move into the full Q&A section, I would like to do one more audience poll. This poll is designed to help us understand what types of guidance you our audience would find helpful on the

subject of construction, inspection, and Q&A of UHPC connections. It's an open-ended poll. Take a moment or so to type in whatever you believe would be helpful and additional guidance on today's subject matter. Simply stated, what guidance would you like to see FHWA provide to assist you in implementing UHPC connection project.

It looks like the results are slowing down. We will give a few more seconds before we move on.

We are going to move into a Q&A session now. In addition to today's speakers, myself, Jeff Hanlon and Mathew Royce, joining us today to answer questions will be Ben Graybeal. Ben is a team leader for bridge engineering research in the Federal Highways Office of Infrastructure Research. He's one of the Nation's most prolific UHPC researchers and program directors. He has a lot of experience with UHPC, he has been a leader in the UHPC community since Federal Highways began research on UHPC in 2001. We are going to go through the questions in the chat pod pretty much in sequential order.

It looks like the first question we have here is whether we need a special mixer for UHPC or if a conventional concrete or cement mixer can be used? I will take a stab at this answer and if anyone else wants to jump in and correct or amend what I have to say feel free. On most typical UHPC jobs you will want to use a special high-shear mixer that provides you the best performance and the fastest mixing time. You can use other mixers, some other mixers, for instance a ready mix truck has been used multiple times, but it takes a lot more time to completely mix the product. I think, from what I understand, some grout mixers can successfully mix it. But there are also some low powered concrete mixers that would not be suitable for UHPC. I don't know if Ben or others want to add to that answer?

I will add to that. Basically you are correct, Michael. There's a certain amount of energy you need to put in to disperse the liquids and turn it into a flowable material so you can place it into the connections. Most mixers will work. With some of them, it will take so much time your mix may get hot or start losing water and get stiff. If you are using a lower-end mixer you can run into some other challenges.

Thank you, Ben.

The next question is how was the construction phased? I'm sure this is in reference to the I-81 project. How did you remove the existing deck and did you reuse the girders. Jeff would you like to answer this?

We closed the road completely. We did the whole deck at once. There was no phasing of the bridge. Then - - what was the second part?

How did you remove the existing deck and how did you remove the existing girders?

The girders stayed in place. Initially we tried to cut and pick the deck and get small stuff, but the much faster way was to close the road underneath and drop the deck through the girders and then we decked it to work off of. The faster method was to program the deck right through—without hitting the beams, of course. Then we saved the beams and cleaned them and cut off the old studs and took survey shots and went from there.

The next question is what are the UHPC material properties required by New York State DOT?

We have a set of criteria that we listed that is for qualification testing. I don't remember the numbers. There's a strength-related performance requirement, a minimum steel fiber requirement, and also a timeframe for accurate construction. And as I said, where we have strength requirements to total 14 KSI in around 12 hours timeframe, we can go in and start the grinding and open the bridge to traffic. We asked them to double up the temperature time curve for maturity method so we can use the information to assess the strength of material. Basically they have some existing data on bridge properties that need to be evaluated. I think we have a copy of our specs available at the website. If someone wants to take a look at that, it lists all the properties we need met. During the actual construction, we go through the strength test and things like that to evaluate the mix. And also by maturity method or by the testing of the cylinder. That's a general outline of what we do.

Thank you, Matthew. On that note I would point out that in the file share box there are a number of documents that you can download, and one of them, in the third line, is the FHWA Design and Construction of UHPC Connections Technote. That's available to everyone, as the name suggests. One of the other things it contains is specific material properties of UHPC, which would be required on most projects certainly if you are using this guideline. That would align well with the New York State requirements as well.

Next question: were residual stresses considered for the steel girders due to welding of the shear studs?

Matthew can you address that?

That's the standard practice that we have. We use the stud shear connectors all the time, so there is a certain standard we follow. We are not looking at the residual stresses as part of our design calculations.

Thank you. What is the minimum spacing within reinforcing steel? I assume this means within the UHPC, and I can answer that. This comes directly out of the Design and Construction of UHPC Connection Technote, which gives a guideline of minimum clear spacing of one and half times the length of the longest fiber in the UHPC. The most common UHPC in use has fibers that are one-half-inch long, so in that case the requirement would be to .75, or three quarters of an inch of a minimum spacing between steel rebar or other objects that was in the UHPC.

The next question is, what is the set time for UHPC?

This is Ben. It varies. UHPC is a Portland-cement based material, so just like with conventional concrete you can have lots of different set times. You can control that, you can use accelerators or use a retarder, although I don't know of that being done. So the set time varies. It also varies depending on your environment. In a warmer environment, you will have that chemical reaction happen more quickly—the hydration reaction that produces the durability properties of the concrete. It varies. I'll bet the questioner is asking how fast I can make it set, because we are talking about accelerated bridge construction in a lot of cases. You can make it set fast enough that you can complete a project in a weekend. A certain amount of that weekend will be set aside for the strength gain of your field-cast grout. So it will take a number of hours to get the UHPC to gain the strength. You really can't make a UHPC gain strength within one or two hours, so you can move onto the

next construction operation. If your project requires that speed, you need to use some other material. It's probably not going to be a Portland cement-based material but, it's probably a different chemical reaction that will deliver that strength that quickly. Obviously when you use those materials you run into other challenges. UHPC is different. You can gain strength quickly if you set it up right in the right conditions. In 12 hours you could be easily onto the next construction step, but if you are doing cold-weather concreting under more adverse conditions, it will take longer because, again, Portland-cement chemical reactions.

Thank you, Ben. Next question is what is the best noninvasive top-forming methods used? I will take a stab at that. I would say the most common top-performing method would be to use either coded plywood or possibly plastic or vinyl products which would then be screwed into the concrete using concrete screws or Tapcon screws. I suspect the questioner may be interested in ways of not touching the pre-cast concrete and that's noninvasive. The only way I am aware of doing that which has been done is when you set your top form you put heavyweights on the top to hold in place. I don't know if Ben , Matt, or Jeff have you seen other methods used?

We started off using a lot of sandbags on the forms. We did quickly switch to the Tapcon because we found the sandbags were not as good as the tapcons.

The one thing I have seen elsewhere is using some sort of a whaler or strong back to tie the top form down relative to the underside of the deck, so then you would have a threaded rod that would pass through your connection. I've seen that done but you end up with a lot of those braces, and it restricts your ability on top of the deck to move around your equipment. You will have some sort of wheelbarrow or buggy transporting the UHPC on the deck, so if you have all these tie downs coming back at every connection it restricts your ability to move.

I want to add something to that. Right now our methodology is not to use a separate overlay. So our decks are usually thickened by half an inch, maybe it will be close to three-quarters of an inch, which is then being diamond ground off. So by controlling the depth of penetration of those tapcon screws, we are reducing the damage to the deck. In addition to that, we generally require the interfaces to be sealed with methacrylate just in case they have some sort of separation and leakage. That's one way of making sure the deck system is leak resistant after joint placement. And along with that, we require them to place that methacrylate along those screw parts so that they also get filled if there is any faults left behind. That's where they are approaching it. Generally speaking it looks okay. After a certain number of years we haven't seen any problems, so it is performing well.

Thank you, everyone.

The next question is for Matt. Is New York State DOT using UHPC in precast approach slabs?

Yes. We allow the slab to be made in different pieces and combined together in the field with UHPC joints. There's a standard detail that we show in our plans. And also we use that to connect the approach ramp to the deck. Usually in multiple bridges we try to avoid joints. One way of doing that is using a slide-over slab. We placed the UHPC on top of the back wall of the connection between the approach slab and the deck slab. We have a bond breaker beneath the UHPC to allow the movement from temperature-related effects. We do allow the use of UHPC for the approach slab connection.

Next question: were the support angle to girder flange welds continuous or intermittent? What testing was performed on those welds, and how did it impact the construction schedule?

The welds were intermittent, similarly as you would do angles and pans for a board in place deck. Again we had to caulk along the entire interface between the existing beam and the new angle because the weld did leave a gap. And then we relied on the solid 2 x 2 steel shims to hold the precast in place. I think in the future if we could come up with an angle that would support it, we would look for a solution there. It would be better to eliminate the shim. We actually couldn't come up with the way of doing it for this project so we stayed with the shim.

Was there any testing done on those welds?

No. We had trouble with people wanting to take the liability that this would work design wise, so that's why we ended up with the shims. I think in the future if he had more time we would try to get something that would be approved. It might have to be a channel or something, we're not sure. We couldn't come up with something we knew would handle panels themselves, that's why we had to keep with the actual shims. There was no testing done.

How do you assure the quality of the haunch connection? I'm assuming in this case they are referring to the hidden haunch pocket style connection. I can take a stab at the answer to that. Basically, along the length of a hidden shear pocket, there will be vent holes that vent to the top deck surface. You use those vent holes to assure yourself that the haunch has been completely filled with UHPC, because once it's filled it will come out of those vent holes. Then lastly, if you still have any lingering doubts that your hidden haunch is not completely filled with UHPC after the material sets up, you can go underneath the bridge and tap on the haunch angle forms to search for any hollow spots. If you have any doubts you can go so far to remove the forms to visually inspect. Does anybody have anything else to add?

In the same way we had a chimney for the UHPC, we would do a similar type funnel for the vent holes to make sure we had positive pressure and completely fill the gaps.

Thank you, Jeff.

The next question is, has UHPC been used as an overlay or inlay rather than in the joint only? Ben would you like to take a stab.

That's an emerging use of the UHPC. The first deployment of UHPC as a bridge deck overlay, sort of a rehabilitation overlay, occurred in Iowa in 2016. It's coming up on one-year-old. That's the first deployment of UHPC in that case. It's about a two-inch thick layer of UHPC that was put down on a bridge deck that was showing potholes and deterioration. In Europe, it's more prevalent. There's around 50 different bridges that have used this concept to rehabilitate deteriorated bridge decks in Europe. Switzerland is the leader in this technology. They went so far as to rehabilitate probably about a two-kilometer-long segmental structure that was starting to show deterioration. In that case they milled off the concrete cover on the bridge deck and replaced that cover with an equal thickness of UHPC. It is a promising concept to use UHPC to fix bridge decks that are showing some real deterioration, if for whatever reason you are not ready to invest the time and money in removing and replacing the deck.

The next question is, what is the UHPC cost premium versus conventional grout usage? I will take a stab at that. The question is a little bit complicated. It depends on how you are using UHPC. First of all, if you are referring to epoxy grout, the cost could be similar. If you are talking conventional cementitious grouts or simply concrete, it depends upon the use. In other words during the presentation you heard Matt talk about whether they use non-shrink grout in the haunch versus UHPC. In that case, you had a predefined volume being filled with one product or the other. In that case, UHPC was more expensive. From looking at using UHPC to make a joint between two panels, now you have to take into account the fact that with UHPC, because of its exceptionally high compressive strength and other properties, it allows you to drastically reduce the rebar lap splice length versus using conventional products. As a result you end up with being able to use much less volume of material, and if you compare the volume of material with the cost of the UHPC to conventional grout, you could possibly see a cost savings for UHPC. Ben would you like to add anything?

I guess I would say, when you think about this, think big picture. Think about the project and what you're trying to do. If you are replacing a bridge deck, and we focus a lot of bridge decks, what will be the cost per square foot to replace it? There are different ways to do that, and you have to add up the costs of all the different components of whatever construction methodology you will use to look at your finished product. If you break it down into bid line items and your line item goes so fine as to say what is the cost per cubic yard of my UHPC, then you might have some sticker shock. But, if you look at it as a whole and say my finished solution will give me this many years of life and cost me this much per square foot, it's going to be a reasonable price.

I would concur with all of that. If the guy is looking for numbers, you're probably looking at it could be a factor of 10 UHPC to normal grout.

On a purely volumetric basis, right?

Right. So it's a lot. I do agree, you have to look at the whole project. We tried to—on a job where we had non-shrink grout required, we tried to get a better price for the ultra-high performance concrete so we could do it all in one shot rather than to different types of grout. I was surprised there wasn't much budging on the price. It paid to do the two types of grout. I'm hoping down the road we can simplify it by using the one grout.

One thing I did see is the price of UHPC, the all-inclusive price: the forming, the mixing and the mixers, the manufacturer's representative (which is typically required for a UHPC job), the total cost of the UHPC does go down significantly as your project gets bigger and bigger simply because that overhead portion of your cost becomes much smaller as your total quantity increases. I have seen price fluctuation of greater than three times for the price of UHPC on a small job versus a large job.

From a New York perspective, I want to add one more thing. If it is not for the UHPC at the joints, forget about the haunches, just at the joints, we will not leave that without an overlay. So basically by using UHPC you eliminate the need for overlay. If you are eliminating the overlay and considering the time savings, this is what we will offer against the additional cost of UHPC. On top of that, if you use an overlay, you will need to replace the overlay at some point in time. That will probably not be needed if you're using the UHPC. Altogether, with everything combined, I think the value is one of the reasons it's good for the owner even if the quantity cost is higher in many cases.

The next question is what was the criteria for welding the steel angles to the top flanges?

In our case it acted as a form, number one, and it also gave us grade for the bottom of the deck. Those are the two major reasons for it. It helped out with supporting the panel, but we didn't rely on it 100 percent.

I suspect the question might be dealing with the fatigue concerns that could come up from welding onto the flange. In these cases I think they were all simply supported spans, am I correct?

That is correct. We have done some of them with multi-span steel girders, and there is details we've used with a kind of a soft plate in between to hold that angle in place in the moment zone. So alternate details can be used for the welding.

Right, very similar to stay-in-place forms.

Exactly.

That's a common practice regardless of precast or cast-in-place.

We have time for one more question. Are there any concerns with shrinkage cracking in the UHPC closure strip? If so, how do you prevent that?

UHPC is a Portland-cement material and it does shrink, but if designed appropriately it doesn't shrink that much. In fact it can shrink less than you would see for a well-designed bridge deck. These connections are very narrow, if you are talking about bridge deck level connection. There's not a lot of shrinkage to be had. So it's a material that doesn't shrink much and the connections are narrow. We don't tend to see shrinkage cracks in these deck level connections. They don't pull away from the interface. We tend to get pretty good bonds.

Actually that - - you are right. By controlling the size of the joint, the total shrinkage is very manageable. Also with the addition of the exposed aggregate, the bond between the conventional concrete and the UHPC will get better. Some of this strain gets distributed within the joint, and if there's any separation we would rather use something like methacrylate to fill the gap. Whatever shrinkage happens early, so by filling that gap, fixing that separation is achieved early. We have done that and basically we have seen much better performance with that. One of the issues is we have a lot of we have a lot of small [Indiscernible] cracks, and in the UHPC connections we have not seen that. I think the fiber itself is capable of controlling it because there's a limited amount of shrinkage. The fiber is able to assist it and keep it together. That is my thought. From a practical point of view it's more a non-issue when the joints are smaller.

Thank you Matthew and Ben. We have to wrap up the Q&A and the webinar here. Before we do that, I want to point out a number of resources that are available. There is Federal Highways HRT-13-060 UHPC State-of-the-Art Report from June 2013. This gives you guidance on mixed designs and material properties and design guidelines. That is available through the file share box as well as the Federal Highway website. Also, the design and construction that I referenced earlier that is a useful guideline for design engineers as well as people constructing with UHPC. There's also a handout of the presentation that can be downloaded as well.

I also want to point out the Federal Highways website, the addresses is here on the screen. Sometimes a quicker way to get there is to enter the terms FHWA UHPC into your web browser and you will see either this Federal Highway research page as your first result or possibly the Federal Highway Every Day Counts page for UHPC. Both contain a lot of useful information and links and downloads for additional information.

As a reminder we will leave the room open after we close which will be a minute from now. For those that want to enter their information so they can receive a PDH certificate. Please enter your name and address. Before you go, we would like to do one quick final poll. To get some feedback from you and tell us how we did today. Hopefully we can use that to improve future webinars. If you won't mind clicking on question number six on your screen about whether your expectations were met or not.

It's nice to see we have a largely favorable response. Here's some information about the upcoming webinars. This is number four in a series of six webinars. Next month we will be doing a webinar on UHPC implementation stories, and this will be on July 11. We will have representatives from Georgia DOT and Delaware DOT, who will give their experiences implementing UHPC on multiple projects within their states. Finally, about two months from now on August 15, we will give an owners' perspective of the use of UHPC on the Pulaski Skyway. As I mentioned earlier that's a 3 1/2 mile historic elevated viaduct that is being completely re-ducted with precast panels using UHPC connections.

You can sign up for all of these as well as view recordings of the past webinars by going to the address on the bottom of your screen. This is accessible from the Federal Highways website, for any further requests for information or support through the every day counts program about UHPC. Your two main contacts are Mark Leonard with the Federal Highways Resource Center and then Dr. Ben Graybeal at Federal Highways Turner Fairbank Highway Research Lab. He was one of our Q&A presenters today. Their contact information is on the screen. With that, we are concluding the webinar. We will bring up the PDH chat pod in one moment. Those of you that do not need a PDH certificate you are welcome to disconnect. I thank you for your attendance.

Ladies and gentlemen, thank you for your participation. Thank you for using AT&T teleconference service. This does conclude today's presentation. You may now disconnect.

[Event Concluded]