Transcript – UHPC on the Pulaski Skyway: Owner's Perspective
August 15, 2017

Welcome to the ultra-high performance concrete on the Pulaski Skyway webinar. All participants are in a listen only mode. If anyone needs assistance during the conference please press star followed by the zero. Today's conference is being recorded. I would now like to turn the conference over to Michael McDonagh.

Hello everyone. Good afternoon. Good morning to anyone on the West Coast. And welcome everyone to the Federal Highway's webinar series on ultra-high performance concrete for prefabricated element connections, and FHWA focus innovation. My name is Michael McDonagh. I work for WSP as a senior supervising engineer and technical principle in the bridge design group. I was one of the designers of the Skyway re-decking project which you will be learning about today. I will be moderator for today's session. Tim Luttrell is my cohost. Today's webinar is the sixth and last in a series of monthly webinars that we have been conducting since March of this year. The purpose of this is to provide interested agencies with information and lessons learned. Before we go any further I want to highlight a few administrative items. I think all participants are muted. If you are not, please mute your phones. Secondly, if you wish to obtain a certificate for professional development hours, at the end of the webinar we will provide an opportunity for you to provide your name and email address in a specific registration pod. We will give you time to do that at the end. We will use that information to send out certificates to everyone who has requested it. Before we dive into the webinar, we have a quick poll that we would like you to fill out so we can learn a bit about you. I will bring that up on the screen. If you are willing, answer two questions about your employment and how many people -- employment and how many people are joining from your location. [Participants are being polled.]

Okay it looks like it looks like everyone has put in the information. 46% private consultants, 9% federal highways, over 10% with division offices, a couple of vendors. Thank you everyone for filling that out. Back to the presentation here.

As I mentioned this is the sixth series. On this slide you can see the entire series that began back in March. All of these webinars including today, are available. Today's will be available in the near future. They are available at the link you can see at the bottom. Find that by searching FHWA UHPC. You can go back in and watch these webinars if you have missed of them previously. You can find today's webinar there in the future as well. The purpose of today's webinar is to provide an overview of the Pulaski Skyway project. The benefits and challenges created on the Skyway, North America's largest implementation of UHPC to date. It will be presented by owner's representatives including project manager and resident engineer to give you a first-hand perspective.

Today's webinar will last 90 minutes. The first 60 minutes are allocated to speakers. The last 30 minutes are for questions. During the presentation if you have a question please type it into the chat area on the left side of your screen on the lower left. At the end of the presentation, speakers along with guest panelists will answer as many questions as possible as the time allows. You may type in questions at the end of the presentation as we begin the Q&A portion.

As I said earlier, the presentation will be available online, including the recording and transcript, in the few weeks. We will notify all attendees via email when available. Let me introduce today's presentation team.

In addition to myself we have three expert presenters on hand. They are Mark Leonard, Scott Thorn, and David Hawes. Mark Leonard is a structural engineer with the Federal Highway Resource Center structures technical services team. Mark provides technical assistance, training, and review service in the areas of highway structure design, bridge preservation, and inspection. He has been employed with the federal highway administration since 2012. He also has 28 years of experience with the Colorado Department of Transportation Mark is a registered professional engineer in the state of Colorado and a graduate of the University of Notre Dame with his bachelors of science in Civil Engineering. Scott Thorn is a project manager with the New Jersey Department of Transportation. His group is responsible for managing New Jersey projects which include the Pulaski Skyway rehabilitation program. He has 32 years of experience with New Jersey DOT, with the past 21 years as project manager. He received his bachelor of science from the University of Delaware. Finally, David Hawes, a resident engineer with the New Jersey DOT. He has been with them for nine years, and he has a bachelor of science in construction engineering as well as a Master of science in civil engineering from the New Jersey Institute of technology. At this point I will hand it over to Mark Leonard. He will give a brief presentation on Federal Highway’s Every Day Counts program.

Hello everyone. Today's webinar is made possible by the FHWA Every Day Counts initiative. The purpose of the every day counts initiative on ultra-high performance concrete is to promote the use of ultra-high performance concrete to improve the connections that we make with pre-fabricated bridge elements, improving the strength, simplicity, and durability of those connections. As part of the everyday Council initiative, FHWA has been tracking the use of this material on highway projects. In the U.S. currently there are about 21 agencies using ultra-high performance concrete connections. There are about 95 projects in the U.S. where UHPC has been used for connecting bridge elements. As part of the webinar we have brought the stories from some of these agencies that used UHPC. From April-July, we have heard from New York, Iowa, Minnesota, Delaware, and Georgia. Today, the last webinar of the series, we will hear from New Jersey. As Michael mentioned, if you missed any of the previous webinars, the recordings are available. If you want to revisit these you can get the recordings on the FHWA UHPC webpage. This slide shows the web address and also a good search phrase for using and finding this page. Before we go to the presentation on the Skyway I would like to bring to your attention, in June 2017, ASTM published a new document, C1856, this was a big deal for those of us using the UHPC on our project, the specification provided standard procedures for preparing and testing ultra-high performance concrete to determine material properties. The slide shows examples of the 10 material properties included in the publication. It does not present new tests for the UHPC, but gives procedures for finding existing ones. For example, at the top of the list there, you could see C39. That's what we use to determine the compression strength of concrete. C1856 tells you how to prepare these specimens and how to load them in the application of C39 to ultra-high performance concrete. So, in summary you may want to take a look at C1856 and consider incorporating these in your specifications for ultra-high performance concrete projects. With that, I will hand it back to Michael and we will begin with this presentation.

Thank you Mark. Actually before we dive into this presentation, we want to do another quick poll of the audience members. Let me bring that up here. We want to learn about your UHPC experiences. If you would, fill in these two questionnaires. As you complete this, remember to use the chat area on the left if you have questions that you would like to have answered during the Q&A session.

It looks like the responses have slowed down. 10 more seconds for the last responses. We have about 70% designers, a small mixture of materials, construction, project management. A lot of people have some knowledge but have never used UHPC. I think that knowledge may have been a direct result of the webinar series. All right back to the presentation now, and I'm handing the controls over to Scott Thorne.

Thank you Michael. Good afternoon. As Michael indicated my name is Scott Thorn. I'm one of two project managers working on the Pulaski Skyway rehabilitation program. For those of you unfamiliar with the Skyway, I will give you an overview of the structure and talk about the plans that we have for the rehabilitation. Briefly getting into some of the details on the plan. I will try to get through this portion as quickly as possible so that we can get to the lessons learned. Which, with the quantity UHPC placed on the project, has been quite extensive.

The Pulsaki Skyway is a 3 1/2 mile long structure located in the northeastern portion of New Jersey. It connects Newark New Jersey and Jersey City New Jersey, spanning over the New Jersey Turnpike and Hackensack river peninsula and a number of railroads. A narrow structure carrying two 11 foot lanes in each direction divided by an aluminum safety shape barrier. Access onto the Skyway is limited to either end of the structure, with center egress access ramps. The construction began on the Skyway in 1930. The structure was open to traffic on Thanksgiving Day 1932. This massive structure was completed in a little over two years. At the time it was the single largest highway project undertaken in the United States. The designers relied on railroad design standards for guidance. Probably one of the reasons why the Skyway has lasted so long. When opened the structure carried approximately 5500 vehicles per day. The first roadway where travel time savings were used to justify the high cost of construction which was $21 million back in 1932. The iconic structure is listed both on New Jersey state and national registers of historic places. As such all rehabilitation projects on the structure are under strict scrutiny. All rehabilitation projects are designed to mimic original design in order to minimize impacts. The structure consists of 118 spans on structure, with the exception of the two 550 foot truss main spans over the Hackensack River. The deck truss spans range from 175 feet to 350 feet in length. The low-level spans on the east and west of the Skyway consist of steel supported girders. In addition, three through truss spans located in Jersey City and spanning active railroads. Since the Skyway was opened in 1932, structures have undergone rehabilitation in the 50s and early 80s. Otherwise it remains very similar to the original structure. In 2007, DOT let a series of maintenance contracts that were nothing more than Band-Aids designed to keep the structure operational until it could get a full facelift. In 2014, the ADT on the structure is 74,000. Overall the construction is poor. The superstructure has issues due to corrosion caused by eight years of salt and runoff, and based on the 2012 bridge inspection report, the Skyway carried a rating of two.

Based on the extremely low sufficiency rating, the charge was clear, to implement an extensive rehabilitation program which will bring the Skyway into a state of repair and address functional deficiencies were possible. The main lead for the program is to maintain this vital method of transportation to Jersey City and New York City, and to improve and remove both structural and geometric deficiencies. Ready to serve the needs of the public for another 75 years.

The program that was put together consists of a number of individual contracts. The first contract is nothing more than exploratory contract which removed the concrete encasement along the east half of the Skyway. This contract exposed structural steel which had not seen the light of day since the original construction. Some holes in the web were large enough that a small child could fall through. Contracts three and four replace the existing 85-year-old deck in both directions. They also replaced existing concrete floor beams for the length of the highway and replaced the lighting from 1930 style period lighting fixtures. Contract three at this time is substantially complete. Contract four should be completed by the end of the year. Contract five, will rehabilitate and replace the Kearny ramp. The future contracts six, seven, eight, and nine will rehabilitate the southbound New York exit ramp and address the superstructure and substructure repairs and rehabilitation necessary along the main spans. This will include seismic retrofit on the entire structure. The total estimated cost of the rehabilitation program to bring the Skyway into a state of good repair, is estimated between $1.3 billion and $1.5 billion.

Let’s put the other contracts aside for now, and focus on contracts three and four where we are replacing the deck. The Skyway has over 1 million square feet of deck to be replaced. With an ADT of 740,00, NJDOT elected to incorporate a system to accelerate construction and thus minimize the duration of traffic disruption to better control the quality of the product. In order to remove and replace the existing deck, they elected to close northbound lanes on the Skyway in Jersey City and New York City for a 2+ year duration, diverting northbound traffic on the surrounding roadway network. Southbound traffic is to be maintained during both contracts. A topic for another day would be the traffic management plan that was put together.

Two types of precast deck systems were selected for the Skyway – both the through truss and haunch deck truss spans which relies on an eight inch precast deck panel with the shear pockets over stringers and floor beams. The system encompasses approximately 80% of the deck square footage on Skyway. The second system we selected used an exodermic grid deck panel used in the vicinity of the Broadway center axis egress ramp and Jersey City. When discussing the need for the project, geometric improvements were a consideration for safety, and one high crash locational was the Broadway entrance ramp onto the southbound lanes. The current entrance lacks an acceleration lane and one will be added as a cantilever section. In order to reduce the dead load in this section, we elected to go with the exodermic grid deck which reduces the depth of the concrete from eight inches on the pre-cast panels to the four inches.

The concrete used in these deck systems is the same lightweight with a design compressive strength of 6 ksi. To extend the life of the deck we elected to go with the stainless steel rebar in the full depth precast deck panels. Offsetting higher costs at the front end were potential financial savings realized by the 75 year lifespan and not having to divert traffic in the future. Galvanized bars are being used in the exodermic panels.

Topic of the day, UHPC as another means of extending the life of the new deck, DOT elected to utilize UHPC for the connections. At the time this decision was made the DOT had no experience with UHPC. With the experience shared from other states and input from the designer, the benefits of the UHPC clearly lend itself to the goals of the project including minimizing construction duration and thus the time where the northbound lane traffic was diverted. The benefits included the high-strength achieved allowing for the development of the bars greatly reduced closure pour with the fast cure time. This resulted in time savings during construction. Also the flowability of material, greatly reducing the risk of entrapped air pockets in congested joints for the exothermic panels. And also the durability of material. Joints typically tend to be the weakest section in the system. UHPC enables a full realization of the durability measures incorporated in panels. Specifically, the stainless steel bars. The closure pour detail we used on the Skyway with early detail developed with UHPC. Eight inch wide with two bars cast in the panels. The top and bottom transverse bar. After listening to five previous webinars, the accepted detail today has greatly changed, eliminating the need for the transverse bar by simply utilize straight bars. Again, however, with their lack of experience, with UHPC and this size of the project we decided to take a more conservative approach and go with the time-tested detail. The contract plans only called for UHPC in the transverse closure pours, and call for the use of a type A and B grout in the haunches and shear pockets.

Here we see the details of the closure pours. The exodermic panels. This joint was slightly wider. 10 inches compared to the eight inches from the precast deck panels. The assistance of bars projecting out of the exothermic grid panels, preparing transverse bars placed in the field. Again as research has advanced, the requirements for the joint detail have been modified, reducing width and steel requirements. As you can see from an actual in-field joint, the exodermic grid panel, the joints were extremely congested. Not only were the reinforcements steel but due to the need for anchor bolts and baseplate assemblies required, these congested areas resulted in little or no risk of air pockets forming during the pouring.

As for the contract, we provided a performance specification which truthfully was more or less a sole source specification. At the time I believe there was only one of a supplier that could meet the 5 year experience requirement in the spec. Again with zero experience during the design phase of the project, only one project utilizing a minimal amount of UHPC at the time, we began pouring on the Skyway. We wanted the expertise of the supplier to be carried on the project. We required a full-scale mockup. Not only was NJDOT’s experience limited, but so was the contractor’s experience. As such until they were more aware of UHPC, we required of full-scale mockup. We stipulated that a representative the supplier be on site during all pours and went as far as mandating that the representative oversee the batching operation to ensure a proper mix. Another important factor included the specification, straight from the suppliers placement specs and recommendations, is that the deck panels are not to receive traffic of any kind until the UHPC has reached a comprehensive strength of 11,000 psi.

Not having worked with UHPC before the contractor and the D.O.T learned valuable lessons from these full-scale mockups which saved both time and money on the operation. Not to say the project was issue free, but it was a useful exercise.

To close out this portion of the discussion, to summarize the statements on how the DOT incorporated the UHPC into the Skyway project. First, nearly all joints between the full depth precast panels and the exodermic grid deck panels were made utilizing UHPC. The contract documents called for quantity of over 3300 cubic yards. The contractor elected to use them, UHPC for the haunches and sheer pockets. More than doubling the total quantity of UHPC used on the Skyway. The next three items all speak to the project purpose. The 75 year service life. UHPC is by far the strongest part of the system. Combined with the precast deck units and the corrosion resistant bars both stainless steel in the precast deck panels and galvanized in the exodermic panels. They elected to go one step further in the end to enhance the durability of the deck system by placing a one inch PPC overlay on the entire structure, completely sealing the deck preventing infiltration of chlorides. With that brief overview I will turn it back to either Michael or to Dave.

Thank you Scott. Now, David Hawes will present his point of view as the resident engineer.

Thank you Michael. I had the pleasure to be able to administer the contract for the DOT on the Skyway. There was a lot of lessons learned. A lot of construction, and more than say a learning curve that was experienced. We had a contractor that had very little experience as Scott said with the project and the department as well had very little experience with the use of UHPC for connections. As one of the major aspects as to the connections is the preparation and surface of the precast panels. In order so that water and we don’t get freeze thaw cycles and chlorides into the actual joints themselves, the connection between the actual precast panel had to be very clean. There could not be any dirt. Any surface that you do find that needs to be cleaned okay, during the course of construction, as Scott mentioned and I will mention many times, mockups need to be performed before implementing any type of repairs on permanent material. In order to achieve the surface preparation required, the contractor and precaster decided to use a concrete retardant on the surface. Lesson learned, all the retarders used must be used in the same manner for this duration of the precast production so there is no variation as you will see in the next slide. Or excuse me, in two slides. All surfaces in contact with the UHPC should be uniform. Shear pockets and joints and undersides of the panel over the stringers should all have the same surface texture. There should be no difference between the surface texture that is over the stringers or the actual connections. The surfaces must have an exposed aggregate finish and should not be broken as a result of surface preparation. There was thought while working on the project to possibly sandblast to get a rougher finish. However, you ended up starting to bruise the concrete and the aggregate creating issues.

Next slide, it shows you a typical set up of how a retarder was placed on the actual forms prior to any installation of rebar. In the back corner, on the bottom here, where I'm pointing the arrow is where the form liner sits. It was used to roughen in the surface -- the form liner was used to roughen in the surface. Make sure that you do not get the retarder on the rebar prior to installing and pouring or casting the concrete. The actual retarder will act as a bond breaker from that and you will not have composite action between rebar and concrete. Surface preparation and precast, at the top of the slide here, the typical cross-section that we had for the project. The top is a non-acceptable surface prep. And future slides I will go into more detail. In the middle portion, where the keyway is, the situation where the contractor did not remove all of the retarder. On the bottom, this is what we consider an acceptable surface preparation.

Going into detail about the top of the panel, what we consider to not be a proper surface preparation. You do not have exposed aggregate. It has a smooth texture. If you look, the concrete cream is covering most of the exposed coarse aggregate. This will not provide a bond for the good UH PC to the precast. In the middle, where we had the retarder present, the retarder issue creates not just a smoothness issue but a situation where the retarder again acts as a bond breaker. When you are working with this retarder, it's important that the retarder or that the contractor is aware that the retarder has a life. Meaning, the manufacturers state most of the retarder should be removed within 24 hours of obtaining the precast panel strength. You remove it using a power washer. If not, the retarder does not perform its duty to give you the exposed aggregate situation and you now have again a situation where there is a smooth surface underneath. The final slide for surface preparation, it gives you a exposed aggregate, the aggregate is unbroken. It has a roughened texture. This project, we are lucky where we designed the project using on all the precast panels and some of the exodermic panels, lightweight aggregate which was an expandable shale. It had a high absorption -- it had high absorption content. It made it more difficult to get the proper surface preparation. However, the contractor after learning curve did do a good job of making sure that they obtain a good surface preparation.

So, we get the panels made. We put them on the bridge, we start to form the closure pours. A few lessons learned, forming material must be made of non-absorbent material or plywood coated with non-absorbent material. A good example of this would be a plyform. It's a plywood that has a wax on top of it. Or, we primarily use plyform or a thick plastic. As a lesson learned, plywood wrapped in plastic like a poly sheathing is not a good idea. It tends to sink into the form which creates a full removal and replacement of the joint. All forms should be constructed so they are watertight. The UHPC is a very viscous material. It flows like water. It's not like regular concrete where if you are off by an eighth of an inch or sixteenth of an inch with the formwork, you will get a little bleed out and you are okay. This will continue to ooze out and you will see it in future slides. Top forms are required for all pours. The concrete must be contained. UHPC be contained 365 degrees around. All top forms need to be installed at least an eighth inch for an over pour. We will discuss this later. Chimneys are required to ensure positive head pressure. That will also be discussed later.

Looking at the next slide, you have a picture of a 1/8 inch strip against the precast panel to ensure an over pour. Without an over pour, any entrapped air will cause the depression in the top of the joint. The UHPC, we call it burping or bubbles up. A lot of times air gets trapped at the very top surface of the form. If the form is set flush with the precast, these are going to be depressions. Getting further into it I will discuss grinding and the necessary reasons for the grinding. Flush forming is not acceptable. Also, we have to realize that we are dealing with a substance that is like water. The joints wider than 12 inches, we will usually need whalers to keep them true. The head pressure could cause the forms to bend upward. Not only are we worried about forms bending down but we have to worry about forms bending up. Forms bending up creates a contractor cost for grinding. Once we form everything up, a huge situation that you have, a lot of contractors forget to put this in their bid. The precast panels need to be at SSD condition. Some agencies require wet burlap and soaker hoses to be installed the day prior to pouring. The type of aggregate plays a major role as to how long the panel needs to be

soaked prior to casting. We have both lightweight aggregate which absorbs moisture and very hard and dense trap rock where it takes time to soak. So again, depending on the aggregate in your area, what you are using, this plays a role. Also and you'll see in the next slide, make sure all standing water on the bottom of the forms is removed prior to placing the UHPC.
See here, a typical early morning wet down of panels. Sometimes it could start four hours plus before pouring. You just hose down the panels and shear pockets and joints.

Mixing the UHPC. During the whole time that they are wetting down the panels, beginning at the pouring, the contractor sets up the mixing apparatus. Mixing the UHPC is generally performed on site. Utilizing one cubic meter mixers. There are larger mixers available; however, we did not have good success with larger mixers. All the UHPC comes in premixed super sacks from the manufacturer. The reason why, we like the super sacks is because it makes things easy for the field team. The mixing operation is a precise operation with little room for error. During cold weather, hot water isused, and 90% ice is used during hot weather. Every batch of UHPC should be tested for temperature and flow in order to show consistency with the product. As Scott mentioned, the emphasis was on the manufacturer per us to do all of the on-site testing with my team's oversight. A typical mixing operation consists for our project of three mixers running simultaneously. Three cubic meters at a time. A wheel excavator is loading a super sack of the UHPC into the mixers. Looking at the slide, there are bags and bags of ice stacked next to the mixers keeping the UHPC cold. Fibers are proportioned such that two full bags are required per super sack eliminating any on-site measures. This is key as general labor is not very keen about measuring out exactly 8 pounds, seven pounds, six pounds. It's important that manufacturers know the product – it is important to know that they come up with a good way that we get one super sack with two bags in it. It makes, when you're missing 5000 plus yards, it makes the repetition go easily. Water, ice, and admixtures are concurrently weighed for each batch. Minor adjustments are required to ensure adequate flow without segregation. Up to 90% ice is used during summer months. Mix temperature is key to a successful pour. This plays a role especially for the fact that simple things such as covering the super sacks with black tarps in the summer dramatically increases the heat that you would have to eliminate through ice in working with the material. There is a huge learning curve involved with just the mixing operation. Every batch and cubic meter of UHPC is tested by the manufacturer's team. Mark showed you the test procedures that came out. For our application, static flow of nine inch and dynamic flow of nine inches and a half inches, those were found to be optimum. Mixing time also needed to be monitored as it has an effect on the uniformity of the product. Primarily UHPC is completely driven by temperature. A 70 degree product looks completely different than a 90 degree or 85 degree product. Mixing times is important. The longer it sits in the mixer, the higher the temperature it is when it comes out. As a lesson learned, the super sacks need to stay dry and sealed. A small rip in the bag will allow moisture to seep into the UHPC. It will cause clumps from hydration. Because everything is pre-measured, bags that are full of clumps such as this are discarded. In order for us to not get batches with too little or too much fiber.

Placing the UHPC. Once it's made and ready to go, placing it was a challenging problem on this particular project. Our contractor insisted on using a pump against the manufacturer's recommendations for quite some time which proved to be very challenging for us. Another issue is do not cover the top forms ensuring that the UHPC is flush with the top of the panel before the form is installed. Placing it from low to high, do not try to go high to low. Ensure that the UHPC placement operation will not require driving over freshly placed or uncured material. Again, concrete mixing placement where you put the mixers plays a major role. Have adequate labor on site. The placement operation is a labor-intensive project. A labor-intensive operation. If they try to say we are going to cut a couple of guys here and here, for costs, you have to be mindful of it because it can take away from the overall product. As a general insurance, know that UHPC is segregated and goes into the project. Again, I will reiterate. Do not pump UHPC. The pump operation has too much heat due to the friction of the pump itself and discharge line. Pumping reduces the flow of the UHPC. Making the UHPC have a more sticky texture. If you see in this slide, due to pumping UHPC lost its flow characteristics. That's a picture of the stringer and haunch were we made the contractor remove the haunch angle because we suspected by just a gentle tap, we had hollow spots. Upon removing it we found that there actually were voids in the haunches. Again, all due to pumping the material, it got hot and sticky with the flow. The contractor has since stopped pumping the UHPC.

What does it take to place UHPC? It is placed with a buggy. The placement team consists of seven carpenters, four laborers placing the UHPC into panels. Four buggy operators, six laborers at the mixing plant, two operators, one on the generator and mixers and one loading the wheel excavator. Two Teamsters delivering the material to the project or super sacks.

I mentioned chimneys before. UHPC requires constant head pressure. Without it, you will end up with a little bit leaking out and you have a little bit reserve. The fact of the chimney that I talked about in the slides, all it is. So the chimneys keep head pressure on the UHPC during cure time. Depending on the ambient temperature, the UHPC can remain plastic for more than 20 hours. We were finding typically during summertime, four hours or so is actually when it starts to set. Not the 11,000 psi. It's just when it starts to set up. You'll see a typical photo immediately after pouring. All the chimneys are secured and filled with UHPC. We spoke about air at the top. The UHPC will continue to burp as long as it remains plastic. We use the word burp but all it is doing is pushing out the in trapped air. There is no entrained air in the UHPC. With tight formwork, UHPC find its way out. Inspection holes are drilled into the formwork to ensure that once the forms are covered up, we have adequate UHPC underneath the plyform.

Forms being installed without haunches being completely filled with UHPC, that is not a good idea. What you can do is that, it's better to put the UHPC through the top of the panel and then, put the top form on. If you see in this picture, there are carpenters walking on top of the formwork. Bending it down. Again, creating a situation where you can have bond break on the UHPC, on the plyform panel. You will get minor leakages. Ensure that the UHPC is placed in a way that it is close to the form. Looking on your left you will see that this is previously placed. Looking on the right here, this is newly placed UHPC. The UHPC in this situation did not meet up correctly with the previously placed UHPC. Even though they did not mesh together you have to watch to make sure that the flow is seen between each batch. The UHPC on the right, it flowed. Leaking forms are the primary cause of low spots. UHPC we have learned through lots of experiments is not repairable. Full depth removal and replacement is required. UHPC does not stick to new UHPC. If you see, there is actually, this is a brand-new bar exposed with the low shear pockets. You could see the studs starting to protrude up.

Placing the UHPC, I had discussed that it does not fix it self. At the top of the photo, you see it was a patch that the contractor attempted to install. Even though it's the same type of material, the patch material is completely different than the first material creating a cold joint. The contractor was told to remove all of the areas for the full depth. A huge lesson learned is that UHPC is unforgiving. Since it flows like water, any debris in the formwork will accumulate at the low end of the joint at the bottom of the form. If you see the littlest bit of sawdust, it will accumulate at the bottom and create this issue.

Air bubbles, I mentioned the air bubbles. This is actually only trapped air. No entrained air. The air bubbles create a surface that is not homogeneous. If you do not grind the surface of the UHPC, it does not give bond to a potential overlay which we are using a PPC overlay. It doesn't give adequate strength to bond. So all UHPC needs to be over poured and ground. More importantly, sometimes air bubbles are not visible. You actually, you have the UHPC crust over. You get a minuscule amount. Less than a 16th of an inch. At the very top, even if you walk on it, you could actually crush it down a little bit and get these air bubbles. Grinding over the over pour will remove that. A typical grinding operation for the Skyway, after the concrete has obtained 11,000 psi. Usually we have about 15,000 psi. Contractor comes in, using a walk behind grinder and a skid steer mounted grinder. This is a core from a plug that we pulled off of the UHPC. There are air bubbles in here which dramatically reduces the strength of the top surface.

Curing the UHPC, it is high in pozzolanic material which means it acts as a retarder. Again sometimes the UHPC can take some time to set up or as much as 20 hours during spring and fall months. Cold-weather plan is required when temperatures are less than 50 degrees. And I'm a big proponent of using a maturity method to monitor the temperature with them -- within the curing for the UHPC. Adding additional fiber so that if we had the vibration were where placing this, we don't want the fiber to possibly have issues.

The curing of the UHPC is key to making sure that we have a good product. Ensuring the contractor has adequate blankets on site during winter months. Hydronic heating systems weres used to keep UHPC above 60 degrees until full compressive strength was reached. Lessons learned, do not stop curing panels during winter months to complete pouring operations. We can see that the contractor has removed the tarps or the protective and heating coils in order to place the next pour. We are in process right now with the contractor figuring out how to remediate this.

As far as UHPC and cold-weather, a huge issue we had, there were areas where the UHPC did not maintain 60 degrees, then the fibers were segregated on the bottom. We forced the contractor to remove that material so if you see, there is a cluster of fiber between the rebar. That's not a typical UHPC situation. Curing the UHPC - field cylinders are made. Once set, we usually take multiple sets of cylinders. This is a typical situation. Not typical, but this is not what you want to see. The top two inches of that UHPC, it has had no fibers in it. All the cylinders are stored on top of the forms. Subject to the same conditions with which we have proven they actually depict the cast material.

Three by six cylinders are molded on site. Again, placed directly on top of formwork. Stripping cylinders are collected and tested prior to removing the formwork. Once stripping strength is achieved the rest of the cylinders are brought to the curing room. Due to the high compressive strength, the tops of the cylinders are ground flush to ensure uniform loading. Cylinders are unique because we can experience 20,000 psi or so at 28 days. It's key that the actual cylinders are ground perfectly smooth. If there is any type of imperfection in them, you can get results that do not depict what's on the actual project.

As Scott mentioned testing the UHPC in the field should be the responsibility of the material supplier, with the owner’s oversight from our experience. NJDOT conducts QA on all pours and utilizes the materials lab to verify results from the independent lab.

A typical cylinder end grinding machine, it's not something you see too often. There are only specific labs that are set up to work with the UHPC. These grinders are, they are very expensive. If you are working on one small project, it does not pay for the state to invest in to having a grinder of this size. Something else that we do on a random basis. We check the UHPC cylinders to ensure good fiber distribution. The picture on the left is of uniform fibers and then you see segregation on the top surface for the other one.

I think that's about it. I will turn it back to Michael. So we could get started with the Q&A.

Thank you David. Thank you Scott again. Before we launch into the Q&A, we will add a quick poll. This helps us understand further guidance that you find helpful to you for a UHPC implementation. This is a fill-in the blank question about activities you might like to see federal highways undertake to assist you with UHPC implementation. [Silence] [Event participants are being polled.]

I'm going to give it about a be 10 more seconds for people to input ideas that they think federal highways could do to help them in the future. Valuable feedback for federal highways. I see answers coming in. I will give it 10 more seconds. All right let's move into the Q&A session.

The questions for today session will be answered by our presenters. Which again include Mark Leonard, Scott Thorn, and David Hawes. And I may try to answer a few since I was a designer on the Skyway. You will be joined by an additional panelist which is Dr. Ben Graybeal. He is a team leader for the office of infrastructure research. He is a leader in UHPC since they began researching the topic in 2001. He has a wealth of experience with UHPC. Making a quick observation, it doesn't look like we have too many questions. Feel free to add questions as we launch this Q&A. We will try to get to as many as we can.

First question we have from Glenn Steffen, what is the thickness of the precast deck panels and PPC overlay? I can answer that easily. The deck panels, full depth precast panels are eight inches thick. The exodermic panels have a structural depth of eight inches. Four inches of that is concrete. There is a one inch thick PPC overlay everywhere.

Why was stainless steel rebar used in standard panels and galvanized rebar used on the exodermic panels? It seems the thinner slabs would benefit more from stainless steel bars. I will let Scott answer that one.

The stainless steel bars, we use those on the eight inch thick panels. We would like to use them across the entire structure. The reason why used the galvanized bars on the exodermic panels, is because the grid deck panel itself is galvanized. We did not want to have a galvanic corrosion possibility between the panel itself, grid deck panel and the other bars. Yes because the rebar index actually sits on top of the one galvanized. Yes we wanted to make sure the different types of metals were not touching. To also add, it did not seem like it was justified the cost of the stainless bar, we had other structural columns that were galvanized any way.

Next question from Glenn Steffen again, slide 32. Are the top edges chamfered? I will let David answer this one.
>> All the top edges are chamfered by about three quarters of an inch. It makes it easy to remove the panels from the forms when being cast with the precast and it prevents spalling, when the forms are removed at the precaster. It was decided on right at the beginning of the project all the edges will have a three-quarter inch chamfer on the 45 degrees. I would add from a design standpoint, that was not something we called for but it was a construction decision.

The next question comes from Dorrie Mellon, she asks what the cure time was to reach 11 KSI. Usually we get 11,000 psi if we are maintaining say 60 degree ambient temperatures within three days. During winter months, during heating or hot summer, we achieve well above 11,000 within thirty hours. I know New Jersey has done research on and we are finding out that you can put accelerator in the UHPC. You could get much shorter set times. 6-8 hours to achieve the 11,000 KSI. I would also add or note, our project used 11,000 KSI as when you can pull the forms. The federal highway guidance that came out after the design was completed calls for a minimum of 12 KSI. That would be the preferred limited use for any new project.

Another question from Glenn Steffen referring to slide 36. The mockup, was it a pay item or incidental? That was a pay item. That was a simple answer. [laughter]
I have to add to that. It was a very worthwhile pay item. For all parties. Absolutely.

Alright another question from unidentified guest. Were the joints tested for leaks?
I can assume we're talking about leakage during the placement. Some states, some agencies require sometimes a filled joint with water before you pour, we did not require that. If you're doing a box beam, it's probably easy to do that. You're not pouring that much material. When you're pouring 5000+ yards, there is no way you'd be able to maintain any type of schedule. And fill it with water. Plus water on the project is an issue. We are 80 feet in the air. No set water line up there. You need a lot of water to be able to test that every pour. I suspect the question they might be asking about joint after the cure, it's something NY State has done, they would flood the finished deck and check for leaks. I will have to say though that, unfortunately, we have done a lot of full depth repairs. The material does not come off of the roughened surface. The roughened surface is the key to maintaining that deck seal there. The roughened texture is key. I cannot remember one repair that we did where we were actually able to save the roughened service. We actually had to chop back and prep it again. So.

Okay thank you David. What is the performance of the bond between the UHPC and the PPC overlay?
I'll grab that one. So the PPC overlay we required I believe, 275 psi of tensile force as the bond strength between the PPC and UHPC and bridge deck. With a good proper surface prep, we have not had any issues obtaining that strength. As part of this we require the contractor to pour and do a pouring test.

Skipping ahead because we have a related question Dave, what's the need for surface preparation of the UHPC in order to receive the PPC overlay?
And a few of the slides I showed, you must grind the U HPC. No question, it has to be ground. In addition to the grinding, we have abrasively blast it, or Roto blast it, the top surface of not only the UHPC, the whole entire bridge deck before placing the primer down for the PPC overlay.

I think will give you work out here David. A question from Minnesota DOT. How is the set retarder applied? To the precast panels?
It was applied using a brush or a roller. I believe we used a 3/8 inch nap roller most of the time. Again, it had to be applied evenly all of the time. One of those learning curves. What you get it right, you sustain the effort and complete the course. Again it was usually rolled on. The corners who had a little brush on. Primarily rolled on.

Thank you. A question from Dimitrios Givas, what is the unit costs of the UHPC?
I believe, the unit bid prices is $4000. $4600 per cubic yard. Yes. All-inclusive grind it, everything, correct? Yes.

We have a related question from Ohio DOT, how did they vary from state to state? I suggest a variation has more to do with project size and less to do with geography. I've seen unit prices ranging from the low of $4600 which is an enormous job to as high as $15,000 per cubic yard for very small jobs and the reason behind that is that you have a lot of mobilization cost associated with the mixers. Supplier technicians. If you are placing the heavier weight, the overhead costs have on unit costs. Ben I will ask you, if you care to elaborate on that, are you aware of any state to state variation.

You said it well Michael. I think it's more driven by the fixed coss. And the size of the project.

Okay thank you Ben. A question from Sheila, will the FHWA funded bridge deck overlay project include non-UHPC joints, and how would it bond to itself? Will the entire surface have to be diamond ground to ensure no weakened surface bubbles? The overlay is AID funded.

The last comment there, there is a project that meets the description of this questioner ongoing in Delaware right now. So, yes, there are some projects using UHPC overlays. Sometimes those projects might also use prefabricated components and UHPC connections. They would not necessarily, they could use it as a rehabilitation scheme or traditional reinforced bridge deck. So, you do need to prepare any UHPC connection for any overlay that should be over it. You don't want to have those bubbles in there. So you do need to overfill and grind the surface. So that you have a good and high quality UHPC ready to accept the overlay material whatever it is. A question in there about the UHPC bonding to itself. I think David had made a comment during his presentation about UHPC not bonding to itself. It will bond to itself but the bond strength will not be as high as the inherent tensile strength of the UHPC without a cold joint. In this case, there would be some good bond there between connection and overlay. Similar to the bond that you have between the overlay and conventional concrete. The bond would not be as high as tensile strength of the UHPC and a sort of unit of material.

Did you answer the part about the entire overlay surface having to be diamond grinded.
The surface of the deck needs to be prepared for the overlay. Whether it's an existing concrete deck or whatever type it is, you need a roughened surface and it needs to be clean. That's true for any sort of overlay on a bridge deck.

There's also the issue that after you place the ultra-high performance concrete you need to diamond grind the ultra-high performance concrete overlay. On the one application, in Iowa, they did diamond grind the ultra-high performance concrete. They were doing this as far as concerns about air bubbles. Of course, with an overlay the thickness of the ultra-high performance concrete, it's quite a bit shallower than when you're filling the connection. Consequently the amount of air that would rise to the top would be significantly less. However in any case, you probably do want to diamond grind the ultra-high performance concrete overlay.

Right, because the overlay are of a different consistency, you don't end up with the entrapped air floating up to the surface. There also not top formed. They are laid out on the surface. With the thixotropic mix so it does not flow. It flows when vibrated. There are some intricacies to it. It's a little different. You don't top form and don't have surface bubbles. Right, I think any grounding that you would do would be to achieve the texture that you want for the skid resistance. Not because of the air bubbles typically.

All right, getting back to the Pulaski Skyway we have a question from Eric Carlton. Was the UHPC manufacturer prequalified to the bid? How many were available, at the time of bid and now?

As far as prequalification, at the time of the bid, as stated in the presentation, we basically tailored the specification to the sole source supplier. We tailored it because they had the experience. We knew through the work they did previously, as far as prequalification, no they were not prequalified for the project. They are a prequalified supplier of material. How many are there today? Then, Michael? I look to you for that one.

I'll take a stab at it. I want to say in 2013, I think Lafarge may have been the only viable option as far as an existing supplier. Nowadays, they're still the main one. I'm aware of two other suppliers. They are both kind of trying to figure out their supply chain and support network. They do not yet appear to be ready to play so to speak. There getting closer every day. Ben do you want to add into that?

I add it's not just about proprietary mixes. There is non-proprietary versions, in various states. Concrete suppliers are developing their own version of UHPC. We begin to see those used on projects around the country. So, there is the proprietary sort of turnkey kind of solution. You might hire a company. There is another solution that could fit into this class of material as well.

Thank you Ben. Question from it looks like Wisconsin DOT. How did you replace the full deck UHPC joint? David?

I could take a stab at that one Mike. Unfortunately, the only replacement of the UHPC joint is a full removal. 20 pound, chipping guns, and very delicate diamond wheels and saws to cut the precast panel. The only way it could be done. I believe you're saying is what you would do is cut the precast panel just outside of the UHPC? Correct. Then we would demo there to the bottom. And basically do the same thing on the bottom. Put a three quarter inch saw cut at the bottom of the panel. And then, chop out the UHPC in the middle. It's a very daunting task. When you're talking 20,000+ psi concrete to be removed. And you do not want to damage the existing rebar or go into the panel anymore. The only thing I will add, they have said you don't want to go to the panel very far. It's a very difficult operation. When the contractor did remove the full depth joints, many times the eight inch closure pour ended up being 16-18-24 inches. Before they successfully chipped it out. They kept cracking the panel. If you could avoid this, absolutely.

Next question is from Kyle, what kind of fiber did you use and how did you specify the acceptable amount of fibers to be added? Poundage should not be acceptable since results vary with different brands of fiber. I will take a first stab there and say that since the Pulaski Skyway, we used a proprietary product. The UHPC supplier is one that chooses a fiber and then delivers a fiber with the cementitious materials as a single package. I don't know if you want to add anything to that Ben. It's one of the constituent materials. Yes, fibers could vary. In this case, just like the supplier supplying the premixed cement and silica fume, there fully in control of what they're doing. In this case the mix that was ordered was a mix that had 2% by volume fibers. As Scott or Dave was saying, that meant two bags of fiber would be added for everyone cubic meter super sack of cement. It was predefined, pre-measured by the UHPC supplier.

The next question from a guest, what is the location of the joint and girder spacing in the transverse direction? I'm trying to understand the question here.
The girders were space roughly, are roughly 9 and 11 feet - it varies in range typically. The panel joints, the panel joints were located, transverse to the bridge centerline. Panels were approximately eight feet wide. Eight feet along the bridge length. Roughly every eight feet. A panel joint. I hope that answers the question.

How about longitudinal joints? What did you have there? Do you have a joint above every girder or for the panels, continuous out to out for the girders?
>> That's a good clarification Mark. Within one contract. Contract three did the northbound half of the bridge. Contract four did the southbound half. Within one of the contracts there, generally there were no longitudinal joints with a few minor exceptions. The length of the panel which was already in the transverse, it went the full width of the roadway. 25 feet. Roadway plus safety walk. Once the contractor pour was complete, they were beginning some of the

work, the two halves we stitched together, we are using a closure pour for the typical condition. That will join the contract three panels with the contract four panels on the southbound side.

We have one last question. Why was the overlay needed?
It was a decision to maximize durability. Correct. It was to provide a good riding surface to maximize the durability of the panels, the stainless steel to make it last 75 years. The last thing we want to do is go out there to divert traffic off the Skyway anytime in the near future or anytime in the next 75 years. In order to implement a full replacement again. We want this to last.

Thank you. If you are attending some of the other webinars. One of the previous ones, in New York they do not do overlays. I would say overlays are not required when using the UHPC. The owner took a belt and suspenders approach to sort of maximum possible durability. I'm going to wrap up the Q&A. A few final things to point out to you. Federal highways has a number of resources at your disposal. There is a UHPC state-of-the-art report. This is downloadable in the bottom box on your screen. These are files you can download. We also have, a website for the UHPC - federal highway research and technology page. Use the link to get it or type UHPC into your favorite web browser or search engine.

As a reminder we will leave the room open for a few minutes. Once we sign off to allow people who want a certificate they could type in their name and email address. We have one final poll that we would like feedback on. I will bring that up right now. If you would take a moment to let us know whether we met your expectations during today's webinar or not. [Event participants are being polled.] It looks like we had a lot of positive feedback. And happy to see that. We are going to conclude the webinar here. Before you go I will leave you with contact information. Here's the webinar series completed. We mentioned where you could review past webinars. That any future contact, regarding UHPC. Your main points of contact will be Mark Leonard and Ben Graybeal who have been part of the session today. That concludes today's webinar. Thank you for your attendance. If you did not need a PDH certificate you may disconnect now. If you do need a certificate, I'm going to bring that up right now. The registration part, I would ask that you enter your name and email address here. We will leave is open for 5-10 minutes. Make sure you provide your name and not just email address. Speaking specifically to the e-construct. We have emails with no names to go with it. All right so, if you don't need this or entered in your information you may disconnect now. Like I said, the pod will remain open and we are going to sign off for the webinar at this time. Thank you everyone. Have a nice day.

[Event Concluded]