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DEPARTMENT OF TRANSPORTATION

Overlay Field Application Program Pennsylvania US-119

FINAL REPORT - PA-2011-008-85977-DWR

November 2010

National Concrete Pavement Technology Center

Uniting agencies, industry, and researchers to advance concrete pavement technology

U.S. Department of Transportation
Federal Highway Administration

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

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The objective is to evaluate the performance of bonded and unbonded concrete overlays and determine the efficiency of the rehabilitation techniques for future implementation.

16. Abstract

The Concrete Overlay Field Application Program is administered by FHWA and the National Concrete Pavement Technology Center (CP Tech Center). The overall objective of this program is to increase the awareness and knowledge of concrete overlay applications among state departments of transportation (DOT), contractors, and engineering consultants. Expert teams have been assembled from across the U.S. to assist DOTs and strengthen their confidence in concrete overlay solutions.

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Overlay Field Application Program
Pennsylvania US-119
Final Report
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U.S. Department of Transportation
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PennDOT

National Concrete Pavement Technology Center

Tech Center

Background

The Concrete Overlay Field Application Program is administered by FHWA and the National Concrete Pavement Technology Center (CP Tech Center). The overall objective of this program is to increase the awareness and knowledge of concrete overlay applications among state departments of transportation (DOT), contractors, and engineering consultants. Expert teams have been assembled from across the U.S. to assist DOTs and strengthen their confidence in concrete overlay solutions.

The Pennsylvania DOT (PennDOT) elected to participate in the FHWA/CP Tech Center Program. The following items summarize the overlay implementation process:

- February 2009 – conducted an overlay workshop and visited potential overlay projects
- March 2009 – initial site visit report and overlay recommendations report prepared and distributed
- Second quarter 2009 – continued review and recommendations on plans and specifications
- June 2009 – a representative of the Overlay Implementation Team attended the pre-bid meeting to provide clarification of potential issues
- June 26, 2010 – on-site documentation of the overlay construction process and material testing
- June 30, 2010 – a Concrete Overlay Open House was hosted by PennDOT
- August 2010 – a four-page tech brief describing the US-119 concrete overlay and open house was prepared and distributed

Site Visit

A site visit was conducted on February 25, 2009 to evaluate five potential concrete overlay projects. A team of four experts met with representatives from PennDOT, Pennsylvania Turnpike Commission, Federal Highway Administration and the Pennsylvania Chapter of the American Concrete Pavement Association (ACPA). A primary objective of the site visit was to identify which roadways are viable candidates for a future concrete overlay.

All of the projects reviewed were deemed to be candidates for the implementation of a concrete overlay. The expert team suggested the 2.2-mile long Penn State section of US-119 (Figure 1) be the focus of PennDOT's initial concrete overlay implementation efforts. This was in concurrence with the informational sheets provided by PennDOT which identified the Penn State section as PennDOT's number one priority.

Figure 1 – US-119 Concrete Overlay Approximate Project Limits

Subsequent to the Overlay Implementation team's recommendation, the US-119 project was designed and let to contract by PennDOT; the successful contractor was Golden Triangle Construction Company.

Existing Conditions

The roadway was originally constructed in 1947 and 1955 as a two-lane facility and was later widened and overlaid with asphalt to create the existing five-lane roadway. The 2007 ADT for this pavement was 12,500 vpd including 12% trucks. Cores taken on the project indicated an average asphalt depth of 13.8 in, 18 ft right and left of the roadway centerline. The southern end of the project (about 1,100 centerline-feet) consisted of 6 inches or less of asphalt over jointed plain concrete pavement. The next 500 centerline-feet of pavement appeared to be a transition to full-depth asphalt pavement, with up to 14 ½ inches of asphalt overlaying the concrete pavement. The remainder of the job to the north featured an average of about 14 ½ inches of asphalt over approximately 12 inches of crushed stone base. As expected for roadways of this age, periodic maintenance had been performed on this pavement over the years, and modest levels of rutting and fatigue cracking were observed throughout the project, as indicated in figures 2 and 3.

Figure 2 - Typical Pre-overlay Pavement Condition

Figure 3 - Fatigue Cracking with Moderate Rutting

Overlay Recommendations

The overlay implementation team recommended a six-inch bonded concrete overlay on the 5-lane roadway (two lanes in each directions, plus a center lane for two-way lefts or left turns with islands) based on the expected life of the project and the existing composite and full-depth asphalt sections provided by the in-situ pavement (Figure 4, composite section not shown). PennDOT determined all overlay thicknesses using the *AASHTO 93 Guide for Design of Pavement Structures*. Specific design issues regarding the project can be found in the *Overlay Field Application Program Implementation Site Visit Report on Pennsylvania SR-119, SR-1032 and Mon-Fayette (43)* report, February 25, 2009.

Final construction plans included the following concrete overlay typical sections:

- From the north project limit south approximately 2 miles - 6" bonded concrete overlay placed on the composite and asphalt pavement (11" to 14 ½" existing thickness) after 4" nominal milling depth of the existing asphalt
- From the south project limit north approximately 1,100' – 6" unbonded concrete overlay placed on a new asphalt separation layer after milling the full thickness of existing asphalt

The construction sequence and maintenance of traffic should be a primary consideration during the design phase. The type of overlay design (bonded or unbonded) can also have an impact on how the project is constructed. Finite element analysis performed by Dr. Mark Snyder showed that the opening strength for a 6" bonded concrete overlay over the thick asphalt and base layers could be reduced to 2,000 psi (as compared to 3,000 psi for a 6" unbonded concrete overlay) to hold concrete fatigue stresses approximately constant. Earlier opening can ease maintenance of traffic issues.

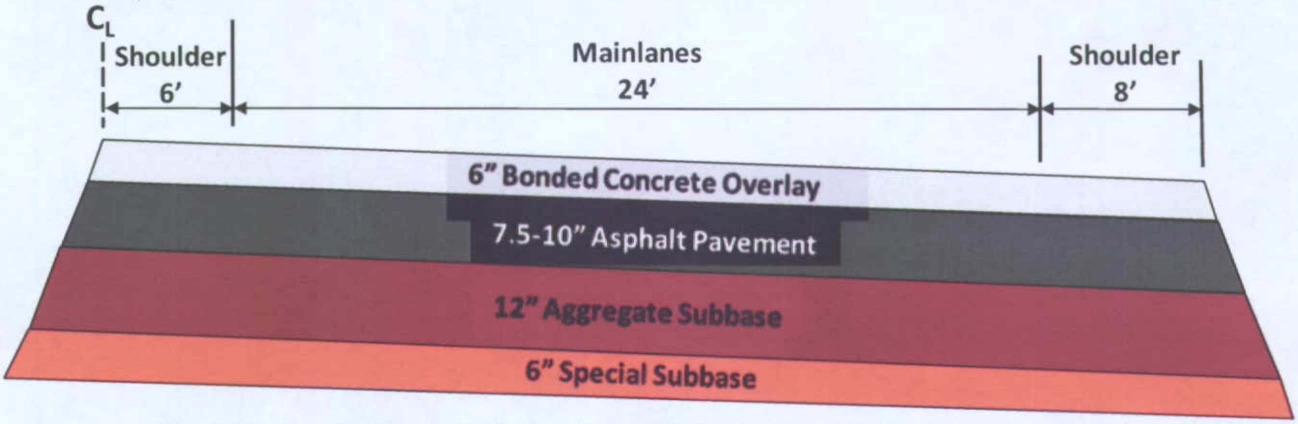

Figure 4 – Bonded Concrete Overlay Typical ½ Section (composite section not shown)

PA Concrete Overlay Open House

The Pennsylvania Concrete Overlay Open House was held on June 30, 2010 for the 5-lane, 2.2-mile U.S. Route 119 project. One hundred and seven participants attended the one-day Open House to learn about the five-lane concrete overlay project located between Uniontown and Connellsville near the Eberly Penn State University campus north to the intersection with Pechin Road. The attendees included representatives from PennDOT central office, 9 of 11 PennDOT engineering district's, FHWA, the Pennsylvania Turnpike Commission, two Pennsylvania universities, the City of Pittsburgh, the Port Authority of Allegheny County, engineering consultants and contractors, and agencies from neighboring states. The event was staged at the Eberly Penn State University Campus in Uniontown, who provided the facility to PennDOT at no cost. The Open House morning agenda featured presentations from the CP Tech Center, FHWA, ACPA Pennsylvania Chapter, PennDOT and the project contractor on concrete overlay design technology and project-specific information (Figure 5). Following a short box lunch, provided by the Pennsylvania Chapter, two buses transported all participants safely to the project site (Figure 6). The participants were able to see the milled areas, completed overlay areas, project concrete batch plant and an older section of ultra-thin bonded concrete overlay on U.S. Route 40 which was placed five years earlier. The buses returned to the University on schedule and brief closing remarks were made.

Figure 5 – Particpants at the Morning Session of the Open House

Figure 6 – Open House Participants on the Project

Overlay Construction

Prior to concrete paving operations, the existing pavement surface was milled and cleaned (Figure 7). A central mix batch plant (Figure 8) and a combination of Agitor and transit mix trucks were utilized by the contractor for concrete production and transport.

Figure 7 – Close-up of the milled surface between the raised median and previously placed concrete overlay

Figure 8 – Central mix batch plant

Paving operations were observed by CP Tech Center representatives on June 26, 2010. No quality issues were observed by the CP Tech Center representatives. Figures 9 through 12 illustrate the paving operations and portions of the completed concrete overlay as documented on June 26, 2010.

Figure 9 – US-119 partially completed overlay construction looking north near Eighty Acres Road

Figure 10 – Slipform paving the south bound turn lane near the Flea Market entrance

Figure 11 – View of concrete overlay placement behind the paver

Figure 12 – Close-up of sawed contraction joint showing controlled cracking

Lessons Learned

A primary objective of the Overlay Implementation Program is to equip state highway agencies with the tools and confidence to consider concrete overlays as part of their normal practice for pavement rehabilitation projects. With this in mind, we offer the following comments that pertain to consideration of future concrete overlay projects undertaken by PennDOT.

- Consideration of geotextile fabric for use as a separation layer for unbonded overlays
  - PennDOT followed the overlay implementation team's recommendation to utilize an asphalt separation layer for the short section of unbonded overlay. Since early 2009 when this recommendation was made, the use of a geotextile fabric as a separation layer has become more widespread. PennDOT should consider its use on future unbonded overlays; geotextiles offer constructability, cost and scheduling advantages over asphalt separation layers. The contractor estimated that the use of geotextile on the 1,100' unbonded overlay section would have saved approximately $25,000.
- Construction surveying
  - Construction staking practices vary widely across the U.S.; some states perform all survey duties while others require the contractor to perform surveying. In general, concrete overlays do not require any more or any less construction staking than asphalt overlays when equivalent smoothness requirements are applied to both types of overlay. One exception to this generalization is when the concrete overlay is designed to match existing features (e.g. gutter, inlets, etc.). This can require additional surveying and profile milling to match existing features, construct the designed cross-slope, and maintain minimum thickness and achieving specified smoothness criteria. Often these objectives require compromises in the field. It is a learning process between the DOT and contractors. When these conditions occur, it is advisable to include the appropriate survey bid item so that all parties are clear on the scope of construction staking.
- Transitions from existing pavement to overlay sections
  - The length of transitions was recommended as per the "*Guide to Concrete Overlays*". The next revision of the "Guide" will note that transition lengths can be reduced for design speeds less than 70 mph.
- Existing shoulders were not milled on this project which did create some surface drainage issues while maintaining traffic as well as constructability issues. Future overlay projects should allow for weep holes in the shoulders to prevent ponding of water in the traffic lanes.

- The use of early-entry saws appeared to be successful regarding the prevention of random cracking. Saw timing is especially critical for thinner concrete pavements which have a higher surface area to volume ratio.
- While PennDOT opted for sealed joints on this project, this is not typically recommended for slab dimensions equal to or less than 6'; unless there is poor drainage and/or heavy truck traffic. This recommendation may change in the future as evidence from Michigan and Minnesota showing that bonded concrete overlays with sealed joints are outperforming those with unsealed joints is fully analyzed.
- In general, urban concrete overlays (such as was constructed on U.S.119) require a well-conceived construction sequence and maintenance of traffic plan. Many agencies have adopted the use of lane rental and/or "A+B" incentive/disincentive provisions to encourage accelerated construction of concrete overlays.
- PennDOT should consider including a special provision requiring the use of automatic vibrator monitors on future projects.
- Accelerated concrete mixtures
    - In many cases, high early strength mixtures that included high dosages of accelerating admixtures have had poor performance histories. Maintenance of traffic plans should be carefully developed to allow for the placement of normal mixtures whenever possible. When accelerated mixtures are necessary to maintain reasonable roadway closure times the mixtures should be designed to meet the accelerated opening with increased cement content. If this is not possible, the use of non-chloride accelerating admixtures should be considered.
- Curing of thinner concrete overlay sections.
    - Proper curing of thinner sections is critical. Application of the curing compound should occur before any surface evaporation occurs and should also provide full coverage of the concrete overlay pavement (rates vary depending on specified curing material). Multiple coats of cure can be applied in stages in areas of steep profile grade and/or superelevated cross-slopes that can cause saws to slide on the heavily cured pavement surface.
- Tie-bars
    - PennDOT followed the overlay implementation team's recommendations regarding the use of tie bars. During the open house, the contractor explained that the tie-bars were presenting some constructability and maintenance of traffic issues because the width of milling had to be wider than the width of overlay placement to allow placement of the tie bars due to the 4.5" milling depth and the 6" concrete overlay depth. This complicated the maintenance of traffic throughout the project. The team's recommendation was conservative, as the bonded overlay is restrained by the bond to a milled surface and the median curb and the outside shoulders. In hindsight, tie bars were not necessary on this project because of the restraint provided by the bond. Thus, tie-bars were not an absolute requirement and, considering the constructability issues, could be eliminated or reduced if similar conditions are found on future projects.
- Matching existing features
    - Matching existing features such as median curb, shoulders and drives was complicated by requiring cross-slope correction and strict adherence to the cross-slope depicted on the typical section. Regardless of pavement type, adherence to a constant cross-slope is nearly impossible when constraints are placed on one or both sides of the pavement. Two options exist when designing concrete overlays. First, when existing features are left in place, a minimum and variable cross-slope should be allowed (e.g. cross-slope = variable [1% minimum]). Second is the removal of existing features that constrain the elevation at pavement edges; although this method allows full adjustment of the cross-

slope, construction costs can be significantly higher when there are multiple storm sewer inlets and driveways to remove and replace.
    - Cost comparisons should continue to be made during the design stage to determine whether it is cost-effective to preserve existing gutter, curbs, inlets, etc.
    - When existing gutters are matched, matching the joints when possible is the preferred option over installation of an expansion/isolation joint. Expansion/Isolation joints are prone to higher maintenance costs.
    - Inlet design and construction for concrete overlay projects should be considered early in the design stage. Construction staging, equipment and maintenance of traffic may impact the inlet design.
- Pre-overlay preparation
    - Ideally, placement of the concrete overlay should follow the milling operations by only a few days. This is often affected by the maintenance of traffic plans. The need to coordinate the concrete overlay design with a sound maintenance of traffic plan is important.

Materials Testing Results

The CP Tech Center's mobile concrete laboratory was on-site during concrete overlay paving operations. Material testing was performed on both the standard and accelerated concrete mixtures placed on June 26, 2010. Conflicts between the mobile lab's schedule and the concrete paving schedule prevented testing beyond the day's placement on June 26, 2010. Subsequent testing on sample older than 3 days was performed on cylinders at the CP Tech Center's main laboratory at Iowa State University.

Summary of Concrete Tests:

Due to limited paving during the mobile lab's site visit, one sample of the AA handwork mixture and one sample of the accelerated slipform mixture was obtained. The materials test results serve as documentation of the project and to assist with the CP Tech Center's concrete overlay implementation efforts in other states. Test results are shown on pages 7 through 15 and are provided for information only.

Mix Proportions AA Handwork Mixture:

General Information

Project:	Pennsylvania Overlay Implementation
Contractor:	Golden Triangle
Mix Description:	AA - Handwork
Mix ID:	10-204
Date(s) of Placement:	26JUN2010

Cementitious Materials	Source	Type	Spec. Gravity	lb/yd³	% Replacement by Mass
Portland Cement:	Cemex Louisville	I - LA	3.150	519	
GGBFS:					
Fly Ash:	Separation Technologies	F	2.300	92	15.06%
Silica Fume:					
Other Pozzolan:					
				611	**lb/yd³**
				6.5	**sacks/yd³**

Aggregate Information	Source	Type	Spec. Gravity SSD	Absorption (%)	% Passing #4
Coarse Aggregate:	Hanson, BMC, Springfield Pike	dolomitic limestone	2.670	0.55%	3.0%
Intermediate Aggregate #1:					
Intermediate Aggregate #2:					
Fine Aggregate #1:	Hanson, PMA Ohio River	natural	2.580	1.28%	96.0%

Coarse Aggregate %:	58.70%
Intermediate Aggregate #1%:	
Intermediate Aggregate #2%:	
Fine Aggregate #1 %:	41.30%

Mix Proportion Calculations

Water/Cementitious Materials Ratio:	0.421
Air Content:	6.00%

	Volume (ft³)	Batch Weights SSD (lb/yd³)	Spec. Gravity	Absolute Volume (%)
Portland Cement:	2.640	519	3.150	9.779%
GGBFS:				
Fly Ash:	0.641	92	2.300	2.374%
Silica Fume:				
Other Pozzolan:				
Coarse Aggregate:	10.554	1,758	2.670	39.090%
Intermediate Aggregate #1:				
Intermediate Aggregate #2:				
Fine Aggregate #1:	7.426	1,195	2.580	27.503%
Water:	4.119	257	1.000	15.254%
Air:	1.620			6.000%
	27.000	**3,822**		**100.000%**
	Unit Weight (lb/ft³)	**141.6**	**Paste**	**33.408%**
			Mortar	**60.983%**

Admixture Information	Source/Description	oz/yd³	oz/cwt
Air Entraining Admix.:	Euclid - euco aea 92	3.54	0.58
Admix. #1:	Euclid - plastol 341	48.88	8.00
Admix. #2:			
Admix. #3:			

Table 1 – Batch Proportions for the AA Handwork Mixture

Mix Proportions AA Accelerated Slipform Mixture:

General Information

Project:	Pennsylvania Overlay Implementation
Contractor:	Golden Triangle
Mix Description:	Accelerated
Mix ID:	10-603
Date(s) of Placement:	26JUN2010

Cementitious Materials	Source	Type	Spec. Gravity	lb/yd³	% Replacement by Mass
Portland Cement:	Cemex Louisville	I - LA	3.150	677	
GGBFS:					
Fly Ash:	Separation Technologies	F	2.300	75	9.97%
Silica Fume:					
Other Pozzolan:					
				752	**lb/yd³**
				8.0	**sacks/yd³**

Aggregate Information	Source	Type	Spec. Gravity SSD	Absorption (%)	% Passing #4
Coarse Aggregate:	Hanson, BMC, Springfield Pike	dolomitic limestone	2.670	0.55%	3.0%
Intermediate Aggregate #1:					
Intermediate Aggregate #2:					
Fine Aggregate #1:	Hanson, PMA Ohio River	natural	2.580	1.28%	96.0%

Coarse Aggregate %:	64.45%
Intermediate Aggregate #1%:	
Intermediate Aggregate #2%:	
Fine Aggregate #1 %:	35.55%

Mix Proportion Calculations

Water/Cementitious Materials Ratio:	0.360
Air Content:	6.00%

	Volume (ft³)	Batch Weights SSD (lb/yd³)	Spec. Gravity	Absolute Volume (%)
Portland Cement:	3.444	677	3.150	12.756%
GGBFS:				
Fly Ash:	0.523	75	2.300	1.935%
Silica Fume:				
Other Pozzolan:				
Coarse Aggregate:	11.002	1,833	2.670	40.747%
Intermediate Aggregate #1:				
Intermediate Aggregate #2:				
Fine Aggregate #1:	6.068	977	2.580	22.476%
Water:	4.343	271	1.000	16.085%
Air:	1.620			6.000%
	27.000	**3,833**		**100.000%**
	Unit Weight (lb/ft³)	**142.0**	**Paste**	**36.777%**
			Mortar	**59.576%**

Admixture Information	Source/Description	oz/yd³	oz/cwt
Air Entraining Admix.:	Euclid - euco aea 92	8.95	1.19
Admix. #1:	Euclid - plastol 341	45.12	6.00
Admix. #2:	Euclid - accelguard 80	188.00	25.00
Admix. #3:			

Table 2 – Batch Proportions for the Accelerated Slipform Mixture

Combined Gradation:

Combined gradation test results (Figures 13 through 15) show the mixtures to be slightly gap-graded, as shown by the percent retained graph and the 0.45 power chart. The mixes did not appear to be harsh or overly difficult to finish in the field though.

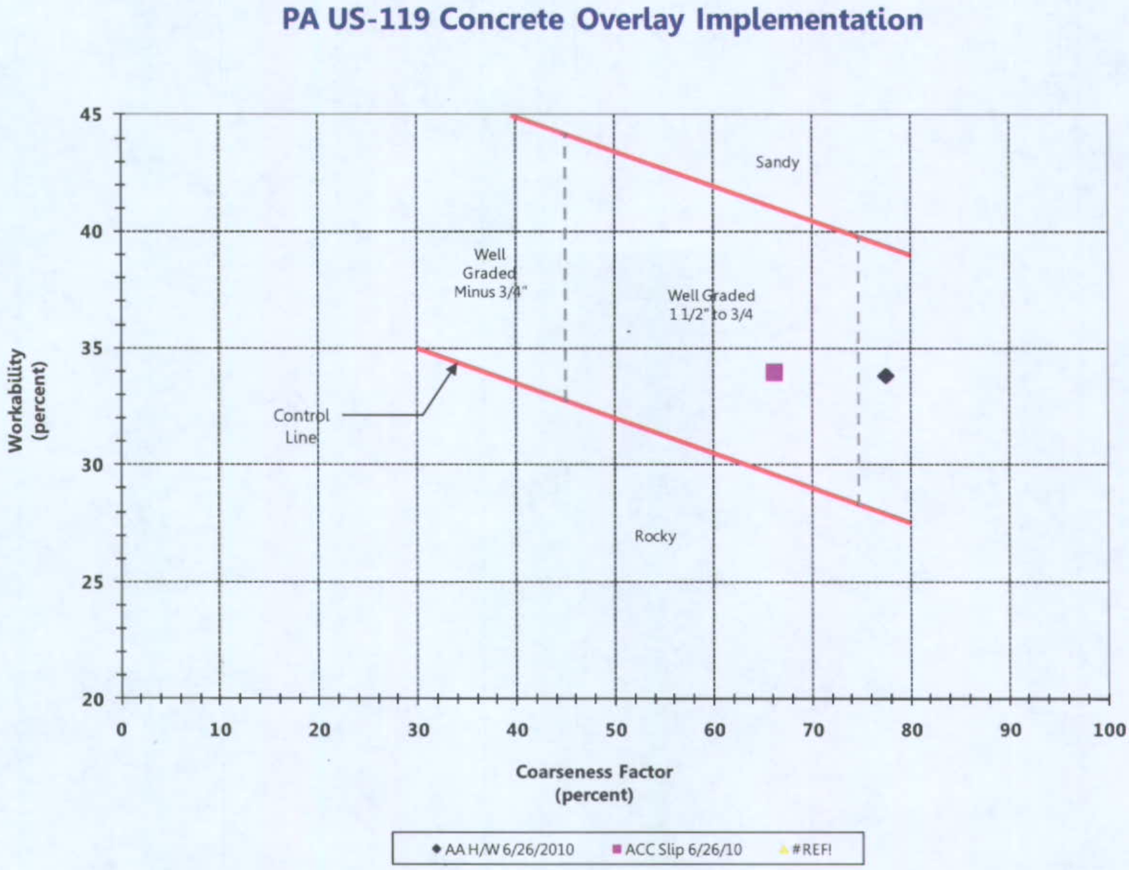

Figure 13 – Coarseness and Workability Chart

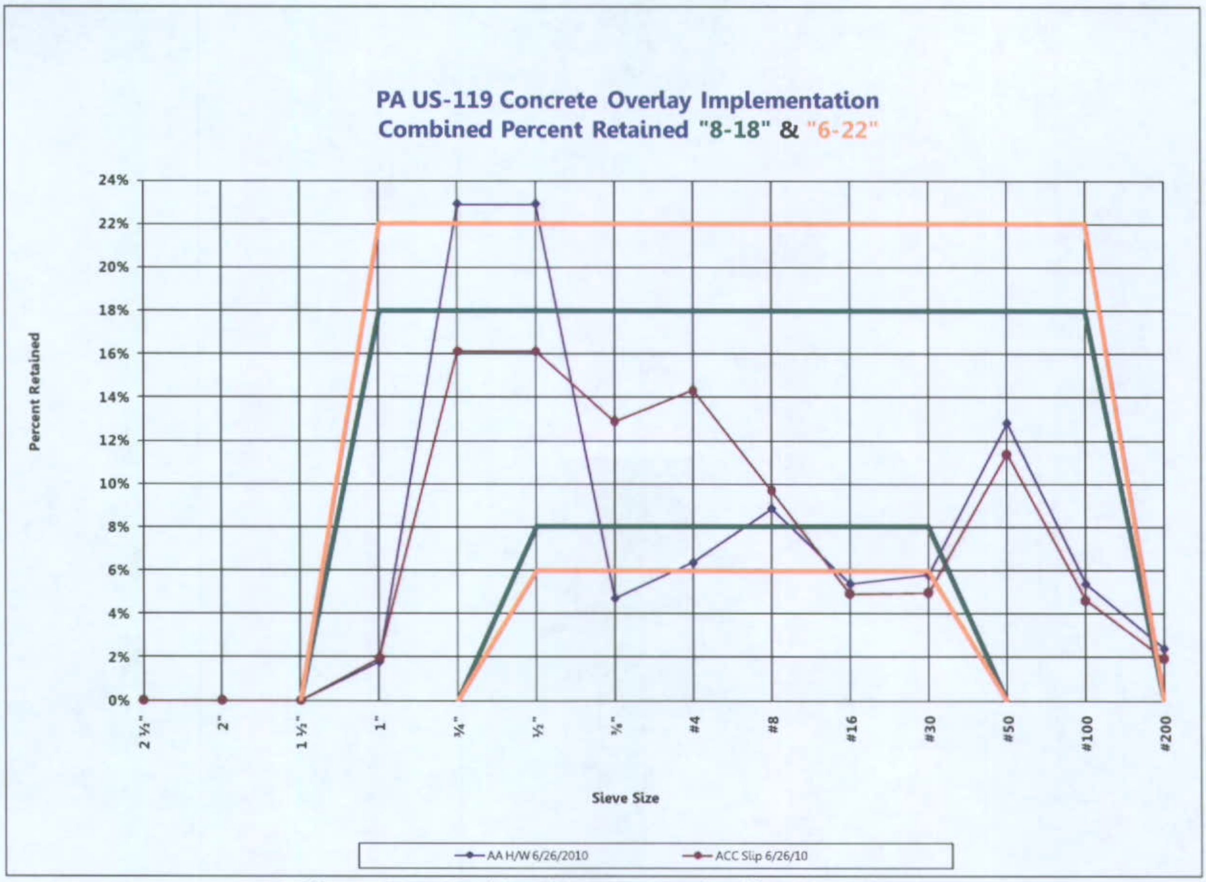

Figure 14 – Combined Percent Retained by Sieve Size

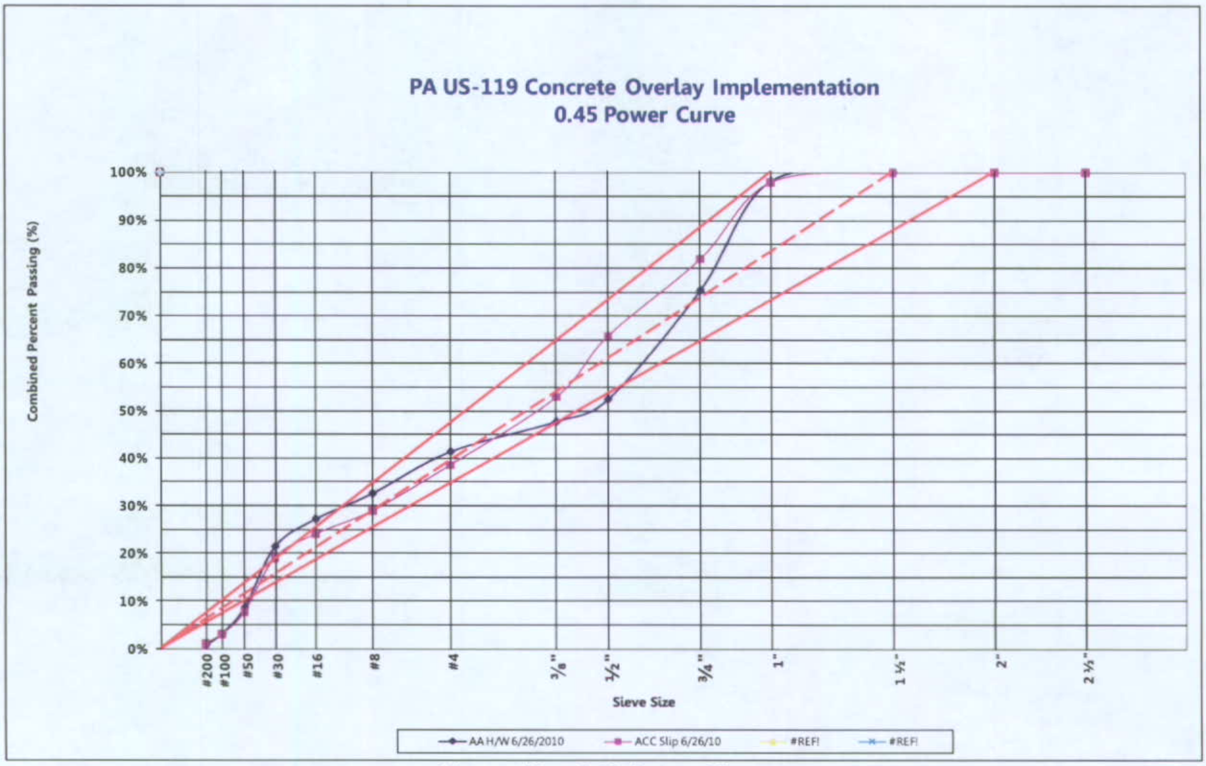

Figure 15 – 0.45 Power Chart

Fresh Concrete Testing:

A summary of test results for fresh concrete properties is shown for each sample (Table 3).

	AA Handwork Mixture	Accelerated Slipform Mixture
Sample Location	NB Turn Lane at Eighty Acres Sign	SB Turn Lane at Flea Market Entrance
Time of Sample	11:40 AM	1:40 PM
Wind Speed (mph)	0	0
Relative Humidity (%)	48	46
Ambient Temperature (°F)	81	85
Asphalt Base Temperature (°F)	112	115
Concrete Temperature (°F)	87.3	93.3
Slump (in)	3	2
Air Content (%)	6.5	6.0
Unit Weight (lb/ft^3)	143.24	143.84
Microwave W/CM (%)	0.442	0.382

Table 3 – Summary of Fresh Concrete Test Results

The test results of fresh concrete properties were acceptable. However, one item of note is the concrete temperature. In the opinion of the CP Tech Center team, continued placement with mixture temperatures above 90 °F may lead to early stiffening issues. With elevated mixture temperatures, early stiffening is an indication of an imbalance between aluminates and sulfates in the cementitious materials. This is noted as a cautionary comment for consideration on future projects, as no such condition was observed on June 26th.

Time of Set:

A setting time test was performed on the AA Handwork mixture, the results are shown in Figure 16.

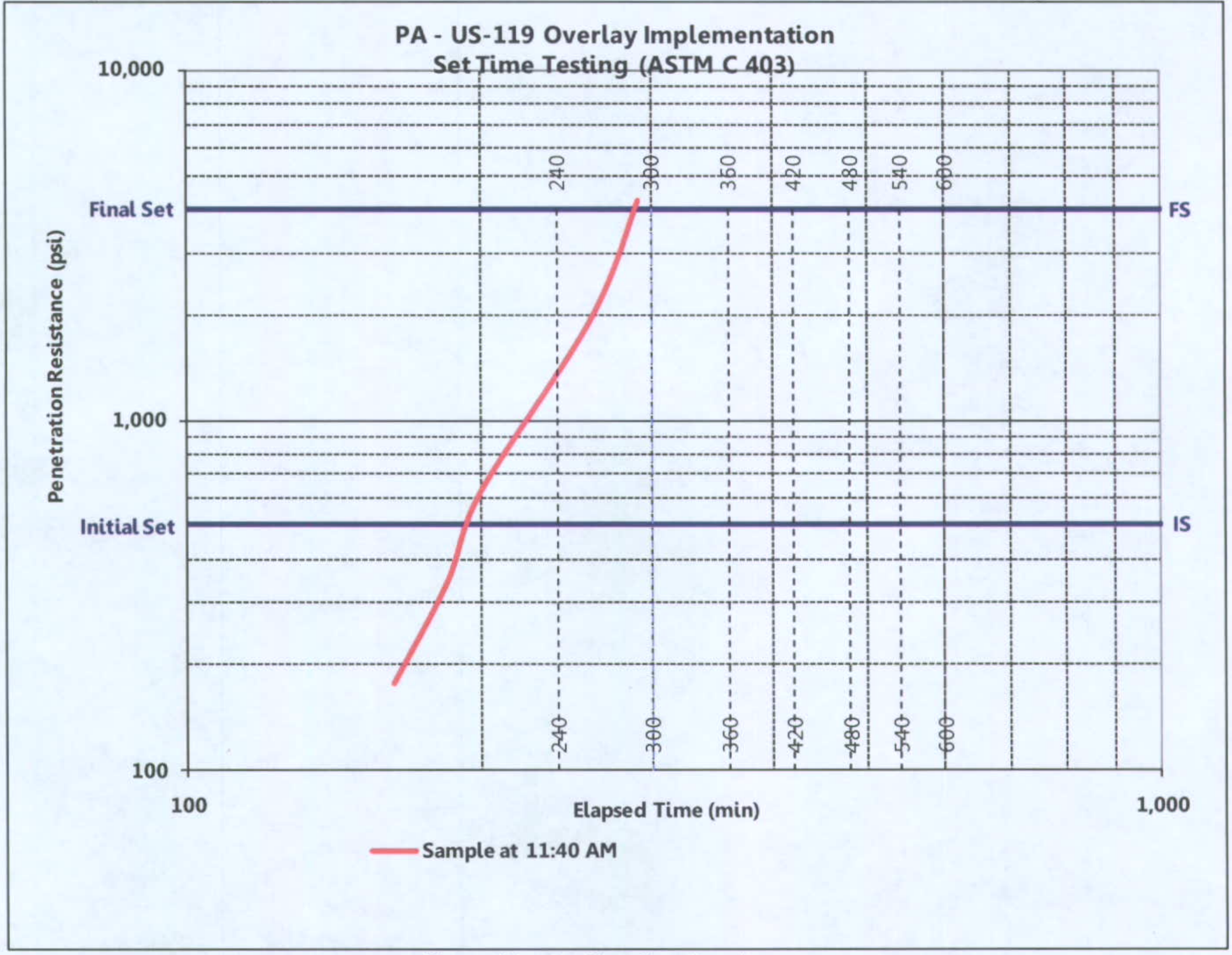

Figure 16 – Set Time Test Results

The results show final set for this mixture occurred within 5 hours of mixing. While there is no standard acceptance criterion for set time, typical final set time for paving mixtures is approximately 7 hours. Set time is sensitive to the fineness of cementitious materials, initial concrete temperature and admixtures. It is likely that all three of these factors contributed to the faster-than-normal set time for this mixture.

Calorimetry:

Heat signature testing was performed on both mixtures using the AdiaCal device (Figure 17). Initial and final set times are estimated using the fractions method.

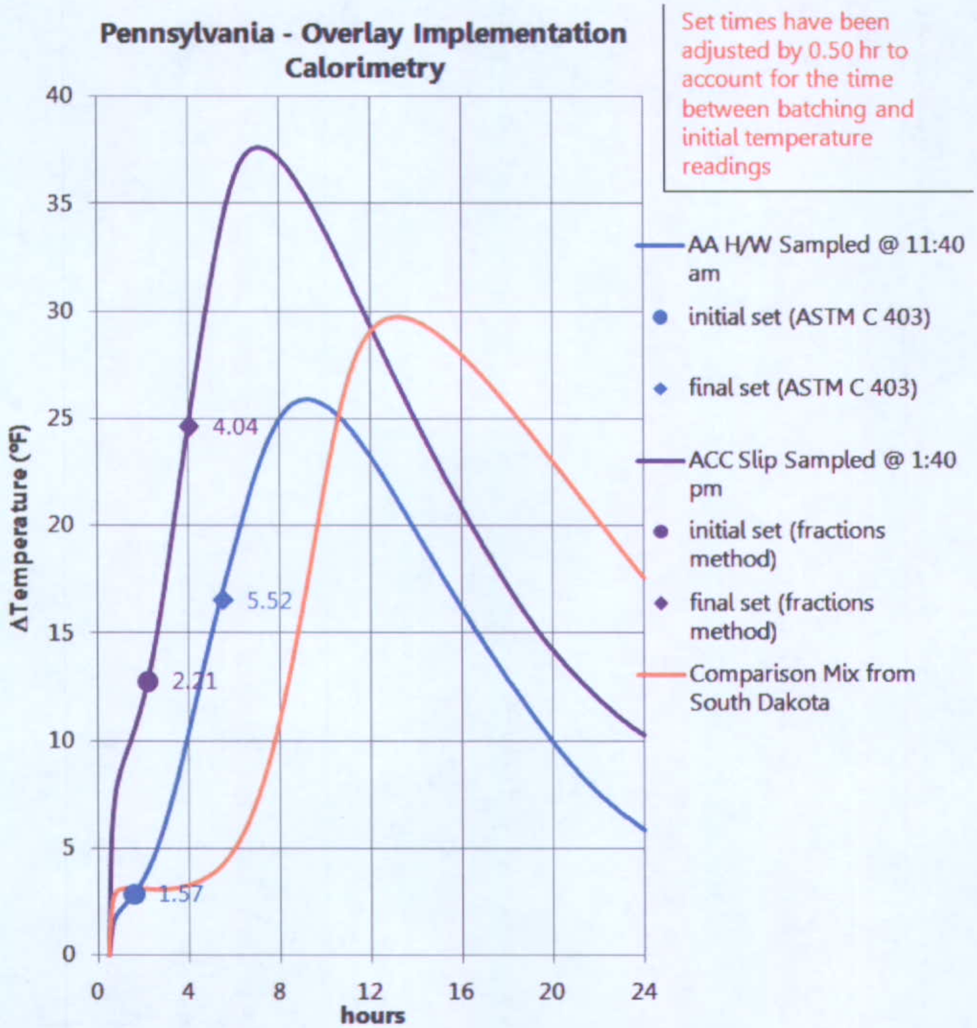

Figure 17 – Heat Signature (calorimetry) Test Results

Heat signature is a way of characterizing a concrete mixture. For comparison purposes, consider these two mixtures from PA US-119 and a paving mixture used in South Dakota:

- The Accelerated Slipform mixture from PA US-119 has a maximum ΔT of 38 °F at 7.2 hours after batching
- The AA Handwork mixture from PA US-119 has a maximum ΔT of 26 °F at 9.2 hours after batching
- A mixture used for an unbonded concrete overlay in South Dakota had a maximum ΔT of 30 °F at 13.4 hours after batching

Over time, a history of heat signatures can be developed along with a characterization of the workability properties at different placement temperatures, and then as an indicator of potential issues that may arise in the field or as confirmation that the mix will allow for easy placement under the expected field conditions.

Hardened Concrete Properties:

A summary of test results for hardened concrete properties is shown for each sample (Table 4).

	AA Handwork Mixture	Accelerated Slipform Mixture
Sample Location	NB Turn Lane at Eighty Acres Sign	SB Turn Lane at Flea Market Entrance
Time of Sample	11:40 AM	1:40 PM
Compressive Strength (28 day)(psi)	4,140	5,110
Modulus of Elasticity (28 day)(psi)	4,150,000	4,350,000
Shrinkage (28 day)(ΔL %)	-0.031	-0.041
Coefficient of Thermal Expansion (microstrain/°C)	8.064	8.805
Rapid Chloride Permeability (56 day)(coloumbs/permeability class)	1,796/low	2,103/moderate
Permeable Voids (56 day)(%)	8.9	8.5
Entrained Air Content (%)	6.0	4.6
Spacing Factor (in)	0.004	0.007
Specific Surface (in^{-1})	1213	893

Table 4 – Hardened Concrete Properties

Items to note regarding hardened concrete test results:

- **Test results are based on one sampling location and are not indicative of the project as a whole**
- The shrinkage of the Accelerated Slipform mixture is 30% greater than the AA Handwork mixture; this is likely due to the increased paste volume (752 lb/yd^3 of cementitious material vs. 611 lb/yd^3 cementitious material)
- Both mixtures are adequate with respect to permeability properties
- Air void properties for both mixtures are acceptable

On-Site Weather Data:

Weather data was recorded over the duration that the CP Tech Center mobile laboratory was on-site (Figures 18 and 19); there was no precipitation over the duration of the weather data collection.

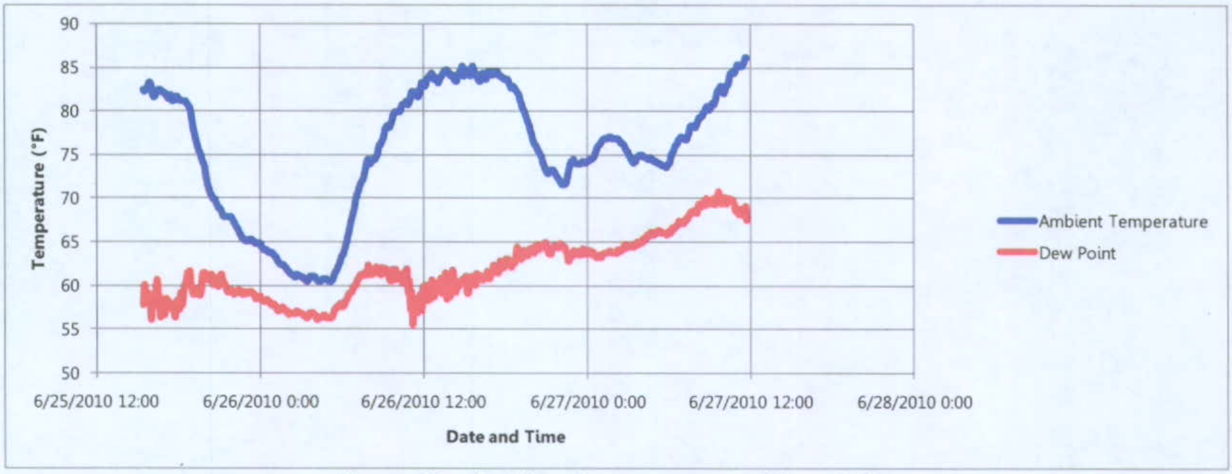

Figure 18 – Ambient Temperature and Dew Point

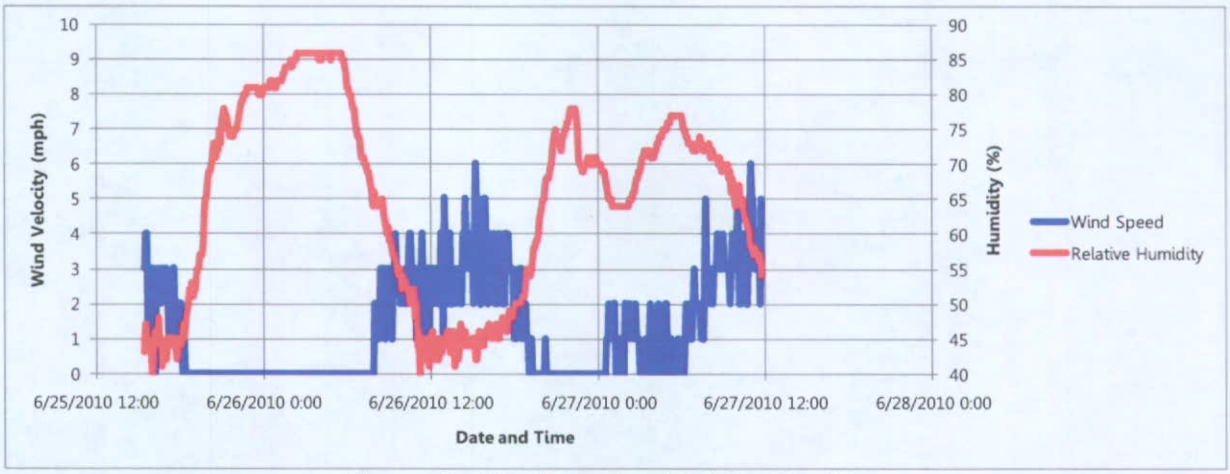

Figure 19 – Wind Speed and Relative Humidity

Temperature and evaporation conditions were conducive to placement and curing of a concrete overlay on June 26th, 2010.