New York State Department of Transportation

TPF-5(368) Performance Engineered Concrete Paving Mixtures

Performance Engineered Concrete Pavement Mixture Pilot Project:

Contract # D263826: NY Route 7 Bridge Rehabilitation (deck, bearing, joint) and Pavement Repair (4.2 miles), Green Island, Colonie and Troy

Executive Summary

As part of the Federal Highway Administration's (FHWA) pooled fund study for Performance Engineered Concrete Paving Mixtures: TPF-5(368), the New York State Department of Transportation (NYSDOT) applied for funding for development of a Performance Engineered Concrete Mix (PEM) concrete mix to be used on a rehabilitation project in Albany, New York. A special specification was generated to develop a PEM, which included the use of the Super Air Meter (SAM), Surface Resistivity (SR) and flexural strengths as well as Quality Control and Quality Assurance procedures.

The project was located on NY Route 7 connecting the City of Troy and Latham, NY. 1,331 cubic yards of standard paving concrete was estimated to be placed in various full depth pavement slab repair areas 9 inches. thick, 12 feet wide and ranging in length from 10 feet to 120 feet. Concrete placement on the project began on May 01, 2019 and paving with the PEM was completed on May 31, 2019.

Initial delays in the project letting made it difficult to have the PEM mix design tested and approved in time for the start of the project. The first week of paving was done using NYSDOT Class C concrete since the PEM mix was not approved yet.

SR testing of the trial PEM showed that the initial specified requirements were not going to be met. The SR results did not reach the required 28 day values until 56 days after casting. Compression tests showed that the trial PEM would perform better than the Class C as compared to historical data, so the PEM was approved for use.

As placement progressed, it was found that the PEM mix did place and finish easier than the NYSDOT Class C mix. Both the Department and the Contractor agreed on the beneficial qualities of the plastic PEM concrete. Testing of the plastic concrete included SAM tests which were carried out by Department personnel. SAM testing took longer than expected.

SR values rose slowly and achieved the specified level at about 56 days after casting. Testing continued and the SR values kept rising up to 252 days when the results started to stabilize. SR values also corresponded to Freeze/Thaw values in terms of higher resistivities similarly displayed a higher degree of Freeze/Thaw resistance.

The PEM concrete developed higher compression and flexural strengths as well as better SR values than the standard NYSDOT Class C pavement mix. This project has demonstrated the ability to specify concrete mix designs on specific applications and characteristics, such as strength gain, resistivity and workability. This in turn allows the concrete mixes and pavement designs to be optimized and be more economical in the future.

Some of the challenges encountered on this project included the following:

1) Providing sufficient time for the development of the PEM concrete. Time constraints required the development of the PEM mix to be expedited. With additional time, various mixes could have been evaluated and additional tests could have been performed to collect data on the mix design.
2) Training for Department, Contractor and Testing Agencies. Project personnel were unfamiliar with the concepts behind a PEM mix as well as the use of control charts and the new testing protocols (SAM and SR testing). Consistent training for all parties involved, starting with the reasons for a PEM mix would help familiarize those involved with the goals of the PEM process are and how to achieve them. It is also important that personnel who will perform any testing be trained properly in the use and maintenance of the new apparatus such as the SAM and SR meters. More and more often this includes third party testing agencies working for the Department or the Contractor.

New York State DOT Demonstration Project for
Implementation of Performance Engineered Mixtures (PEM)/AASHTO PP 84

Introduction:

As part of the Federal Highway Administration's (FHWA) pooled fund study for Performance Engineered Concrete Paving Mixtures: TPF-5(368), the New York State Department of Transportation (NYSDOT) applied for the following categories of funding for the project:

Category A: $40,000 for incorporating two or more AASHTO PP 84-17 tests in the mix design/approval process. Shadow testing is acceptable.

Category B: $20,000 for incorporating one or more AASHTO PP 84-17 test in the acceptance process. Shadow testing is acceptable.

Category C: $20,000 for requiring a comprehensive QC Plan from the contractor that will be approved and monitored by the state.

Category D: $20,000 for requiring the use of control charts, as called for in AASHTO PP 84-17.

Originally two projects were submitted for inclusion, one in the Albany, NY area (Region 01) and one in the New York City Area (Region 11). The NYC Project has been delayed indefinitely and therefore was not included in the final project report. The Albany project was started on May 01, 2019 and the majority of paving was completed on May 31, 2019. Due to delays, the first week of paving was placed using NYSDOT Class C concrete, the remainder of the placements used the project developed PEM concrete mix. Some High Early Strength concrete was also placed on some time critical areas of the project.

Project Details:

The project was designated as NYSDOT Contract # D263826: NY Route 7 Bridge Rehabilitation (deck, bearing, joint) and Pavement Repair (4.2 miles), Green Island, Colonie and Troy. (Figure 1 - Project Overview)

Figure 1- Project Overview

The project was located on NY Route 7 connecting the City of Troy and Latham, NY and consisted of 4.2 miles of concrete pavement rehabilitation. 1331 cubic yards of standard paving concrete was estimated to be cast in place, in various full depth pavement slab repair areas, 9 in. thick X 12 ft. wide and repair lengths from 10 ft. to 120 ft. (Figure 2 - Typical Pavement Section). All placements were on the right lane, westbound side of the highway. Smooth epoxy coated dowels (1.25 in. diam X 18 in.) were drilled and anchored into the exposed ends of the existing concrete pavement next to where new concrete was to be placed, and in baskets within larger repairs to act as transverse expansion joints. Longitudinal tie bars (3/4 in. X 28 in.) were drilled and anchored along the right longitudinal joint of the center lane to tie into the new concrete repair areas, and also placed in transverse baskets within larger repairs to act as hinge joints. (Figure 3 – Reinforcement Detail). The project was let and awarded to Harrison and Burrows who subcontracted out the paving work to Rifenburg Construction.

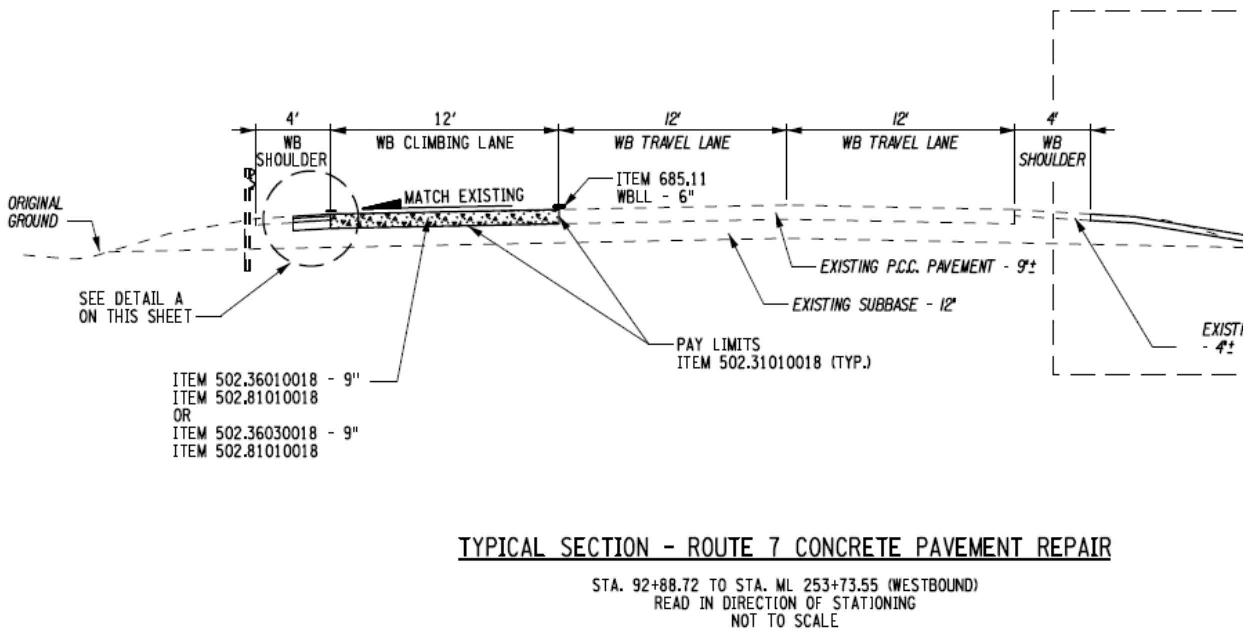


Figure 2- Typical Pavement Section

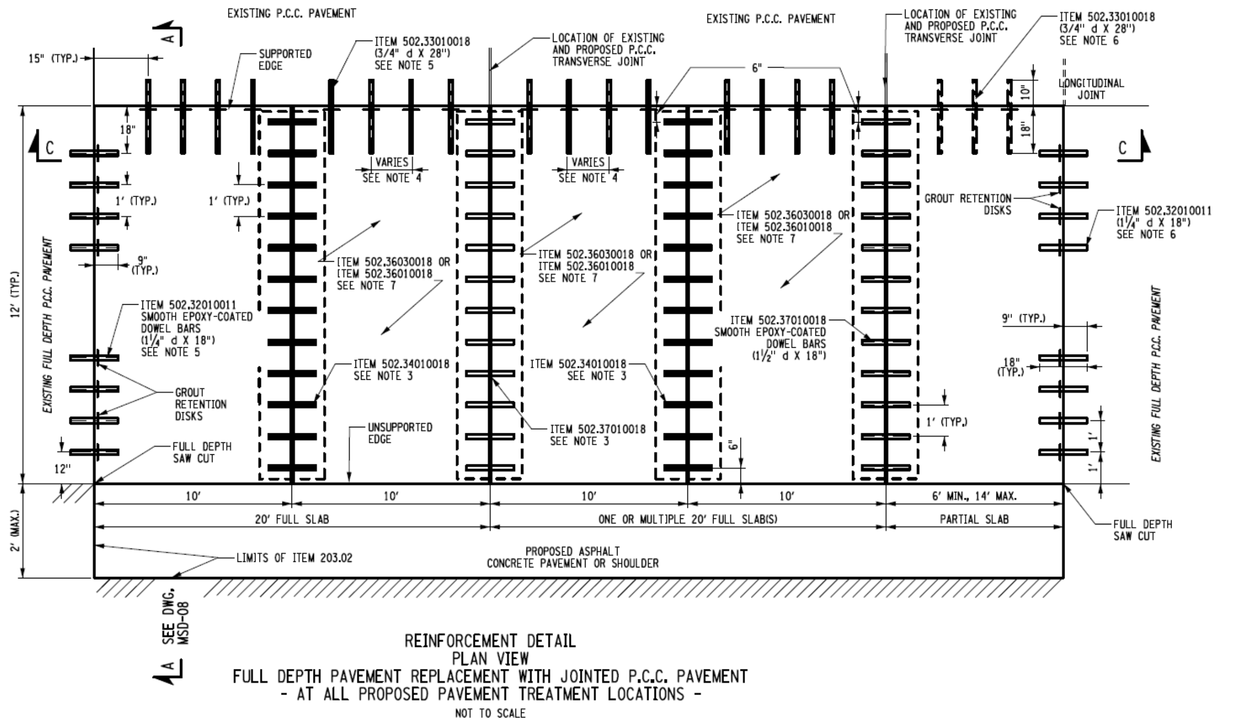


Figure 3- Reinforcement Detail.

Performance Engineered Mix (PEM) Design:

NYSDOT specifications used for the paving operations are attached in Appendix A-1. A new special specification was generated for the development and approval of the Performance Engineered Mix (PEM) and included Super Air Meter (SAM), Surface Resistivity (SR) and Flexural testing as well as Quality Control/Quality Assurance (QCQA) procedures. (See appendix A-2).

The special specification required the concrete mix to be developed using AASHTO PP 84 and meet the following requirements:

Compressive Strength of 4,000 psi minimum. (at 28 days per ASTM C39)
Flexural Strength of 600 psi minimum. (at 28 days as per AASHTO T97)
Slump as desired by contractor for workability (as per ASTM C143)
Entrained Air of 5% to 10%. (per ASTM C231)
Super Air Meter (SAM) number <0.20 (as per AASHTO TP118)
Water/Total Cementitious Material Ratio of 0.40 maximum.
Paste volume maximum 25% (as defined by AASHTO PP84)
Resistivity >16.5 kΩ-cm (as per AASHTO T358)

SAM, SR and flexural testing were not to be used for project acceptance in the field, those procedures were just used for mix design approval and for shadow testing in the field.

Project Delays:

Originally, the project was to be awarded and begin in 2018, but the project was revised and re-let in 2019. At this point there were only a couple of months from the time the project was awarded to the time it was supposed to start. The project was under strict time constraints and paving had to be completed by July 2019.

The Sub-Contractor contracted a local concrete producer who was unwilling to develop and supply the PEM concrete. Clemente Fane Ready Mix Concrete was brought on to the project to develop the PEM mix and supply the concrete. By this time, the project was scheduled to begin in about a month, so the development and approval of the PEM mix had to be expedited. The Department worked closely with the Clemente Concrete to get a mix design developed and approved, then schedule a trial batch. See the producer's proposed mix design below.

Batch Weights and Material Properties

Material	Source of Material	Weight (lbs/cy)	Specific Gravity	Volume (ft^3)
Coarse I	#67	700.00	2.70	4.16
Coarse II	#57	1000.00	2.70	5.94
Coarse III			2.70	0.00
Fine I	Sand	1408.00	2.66	8.48
Fine II			0.00	0.00
Cement	Type I/II	456.00	3.15	2.32
Fly Ash	Fly Ash	114.00	2.30	0.79
Other Cementitious				0.00
Water	City	230.00	1.00	3.69
Air	6.00%	2.00		1.62
Total		3910.0	lbs/cy	27.00
		144.8	lbs/cf	

Paste Properties

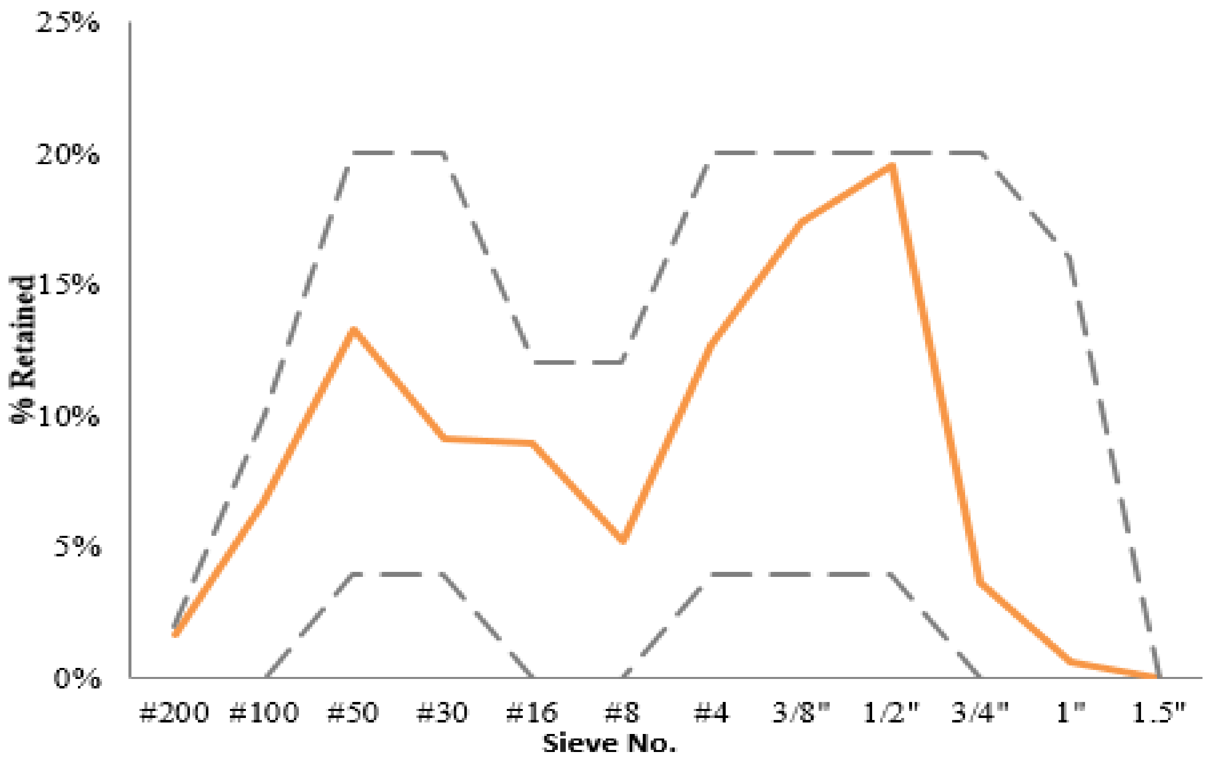
w/cm	0.40	
SCM replacement	20%	
total cementitious	570	lbs
sack content	6.1	sacks
Paste Content w/o air	25.2%	

Aggregate volume percentages

Coarse I	22%
Coarse II	32%
Coarse III	0%
Fine I	46%
Fine II	0%

Admixtures

Admixture Type	Dosage (oz/cwt)
HRWR	6
MR	4
Air entrainer	0.13
accelerator	
set control	



Trial Batching:

The proposed mix was accepted and then batched at the producer's facility, using the same plant, and type of truck to be used on the project. The concrete facility was about 20 minutes from the project site. The proposed PEM mix was batched and dropped into the concrete truck where it was mixed and travel time to the project simulated. First, 4 cubic yards of PEM concrete was batched and checked for air, slump and SAM number. The air content on this first batch was high so a second 5 cubic yard PEM batch was produced which displayed better air content values and was accepted by the Department.

The second batch had a water/cementitious ratio of 0.39. Air content, slump, SAM numbers and unit weights were taken after initial mixing then after 100 additional revolutions of the concrete truck barrel. Air content and SAM number was taken by the Department using the SAM meter and air content was measured by the Producer using a standard air pot. The plastic concrete test results can be seen in Table 1.

Table 1: PEM Trial Batch Plastic Concrete Properties
W/C: 0.39

Air Temp °F	Conc Temp °F	Air Content %		SAM	Slump inches	Unit Weight lbs./cu.yd.
		Department	Producer			
48	70					
After Initial Mixing		10.0	11.0	0.11	4	135
After 100 Additional Revs		7.7	8.7	0.14	3	135

Cylinder and prism samples were cast for lab testing by the producer and the Department (Figure 4 – Trail Batch Samples). A trial slab of 10 feet by 5 feet by 9 inches was cast by the sub-contractor (Figure 5- Trial Panel: Left Section). The mix was found to be workable and acceptable by the sub-contractor for placement. Overall, the batched plastic PEM concrete properties met the requirements of the project specification and was found to have acceptable placement properties.

Figure 4 - Trial Batch Samples

Figure 5 - Trial Panel: Left Section

Trial Batch Lab Testing:

Due to the time restraints of the projects, the Department gave preliminary approval for the use of the PEM before completion of free/thaw and surface resistivity testing.

The samples taken from the accepted trial batch were cured and tested as noted below:

TABLE 2: Compression Tests PEM (PSI) 4 inch X 8 inch cylinders cured in water tank		
7 Day	14 Day	28 Day
3450	3650	4150
3450	3850	4190
3620		4020
3420		
3380		
3440		
Average		
3460	3750	4120

**Breaks are individual cylinders*

TABLE 3: Flexural Strength PEM (PSI) 6 inch X 6 inch X 30 inch prisms cured in fog room	
14 Day	28 Day
555	516
528	600
Average	
542	558

**Breaks are individual prisms*

TABLE 4: Surface Resistivity PEM 4 inch X 8 inch cylinders cured in water tank Average of 2 sets of 3 cylinders		
14 Day	21 Day	28 Day
8.58	8.3	10.1

As seen in Table 4, the SR values did not meet the specified 16.5 kΩ-cm in 28 days. It was decided to accept the mix anyway and proceed with the PEM placement as well as to continue SR testing to determine when the specified value would be reached. The extended SR testing showed the resistivity achieved 16.5 kΩ-cm in about 56 days after casting, and the SR continued to rise till about 200 days after casting.

Several extra 4 inch X 8 inch trial PEM cylinders were available, so the Department performed freeze/thaw testing on these samples, according to NYSDOT TM 502-3 (See attached Appendix A-10). The test consists of 25 freeze and thaw cycles while the sample is fully submerged in a 3% NaCl solution. The results for one sample showed failing values.

The Department allows 3% loss, but after testing was completed, some of the PEM samples experienced an average of 8% loss. Due to the Department's concerns, F/T testing continued on samples of various ages to ensure that the durability grew with time. Later results did show an increase in F/T durability with time (Graph 5: SR and F/T Over Time).

Flexural testing was not a requirement of the typical Class C concrete mix but was a design requirement for the PEM design and approval. Flexural samples were cast in 6 inch X 6 inch X 36 inch steel molds and left for initial set on site for 24 hours. Samples were then brought to the Departments Main Office lab and cured in 100% humidity for 28 days before testing took place. Flexural testing was done throughout the project by the Department for information only.

Concrete Placement:

Concrete paving was scheduled to begin on Monday, May 01, 2019. The lab testing of the PEM trial mix would not be completed by the time paving was scheduled to start so the Department decided to allow the use of the NYSDOT Class C Concrete for the first week of placement. This gave the Department additional time to further evaluate the PEM test data. Plastic concrete testing was carried out on the Class C Concrete including SAM numbers to use as a comparison to the PEM mix (Graph 1). The Class C concrete was placed at night due to work-zone restrictions. There were some delays in concrete delivery, sometimes up to an hour between concrete trucks, because only 2 or 3 drivers were available over night.

Paving was done using fixed forms. The Contractor used a Razorback vibratory power screed. Concrete was vibrated with a backpack vibrator as well before screeding. Surfaces were finished by masons with floats and trowels. A broom finish was established on the surface for temporary friction. Panels were left ¼" thicker than surrounding pavement, to allow for later diamond grinding.

Conventional Class C Mix:

During the night work, it was difficult for the contractor to place due to the truck being outside of the concrete barrier. The first few nights, the producer had some trouble getting the Class C mix dialed in, air percentages and slumps were inconsistent. After a few nights, the Contractor and Producer decided to move to day shifts due to staging adjustments and cost benefits. The Contractor was able to install blocks as ramps to allow the concrete trucks to back-up through the prepared repairs areas and access the next placement location within the staged areas. With the new staging patterns and more trucks becoming available, pavement production was increased, and the producer was able to gain better consistency in the mix from truck to truck.

Figure 6 – Form work for new slabs

Figure 7 – Class C mix being placed

PEM:

On May 13, 2019, paving began with the PEM concrete mix. As part of the PEM special specification, the Contractor was responsible for the Quality Control (QC) of the concrete, which included sampling and testing for properties such as slump, air and compression strengths. The subcontractor, Rifenburg, hired QCQA Inc., as the testing agency to carry out the quality control of the PEM mix in the field (Figure 8 – Third Party QC testing PEM). The producer was required to submit their plant's daily quality control charts to the contractor and the Department (See Appendix A-9 Daily Producer Control Charts). The PEM special specification shows these requirements and can be seen in Appendix A-2.

The Quality Assurance (QA) was carried out by NYSDOT Department personnel. Slump and air content data was collected, and cylinders were cast and tested for compressive strength. The Department also collected Super Air Meter data and concrete prisms for flexural strength testing as well as additional cylinders for surface resistivity testing and freeze/thaw testing. All plastic concrete samples were left on site to cure for 24 – 48 hours as per NYSDOT standards. After curing on site, the Department placed the cylinders in a water bath and flexural beams were stored in a 100% moisture room.

Figure 8 – Third Party QC testing PEM

Paving with the PEM concrete proceeded with minimal disruptions. The contractor was able to place and finish around 100 cubic yards of material on average per day by the end of the project. Overall the PEM went well; the final placement was on May 31,2019. All the new concrete pavement sections were diamond ground a few weeks after placement.

Figure 9 – PEM being placed

Figure 10 – PEM being placed

Sampling and Testing:

All raw data collected can be seen in Appendix A - 3 to 8.

The special specification written for this project (Appendix A-2) increased the number of samples for testing. Surface resistivity, compression, and flexural testing would be completed on the 28-day samples, each day as specified by the Department. Surface resistivity, flexural strength, and SAM testing were carried out as informational purposes only.

During the first week of concrete paving, the Department collected compression and flexural strength samples of the NYSDOT Class C mix, the number of samples taken is noted in Table 5. For the remainder of the project, compression and flexural samples were taken from the PEM, the number of samples is noted in Table 6.

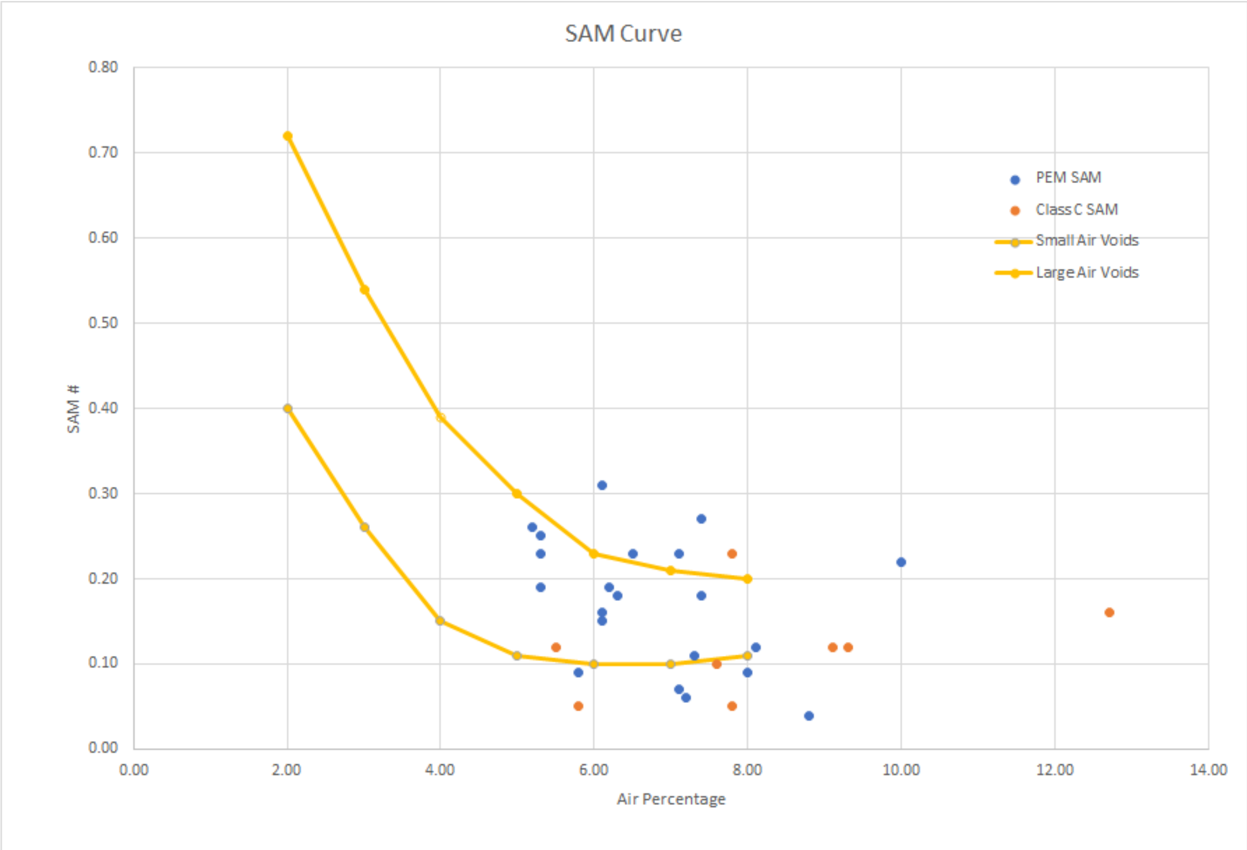
TABLE 5: Class C Samples Per Day		
Date	Compression	Flexural
05/01/19	6	2
05/02/19	4	2
05/06/19	6	2
05/07/19	6	2
05/08/19	6	2
05/09/19	6	2

TABLE 6: PEM Samples Per Day		
Date	Compression	Flexural
05/13/19	14	2
05/15/19	4	2
05/16/19	4	2
05/17/19	2	0
05/21/19	4	2
05/22/19	4	2
05/23/19	4	2
05/24/19	4	2
05/29/19	4	2
05/31/19	4	2

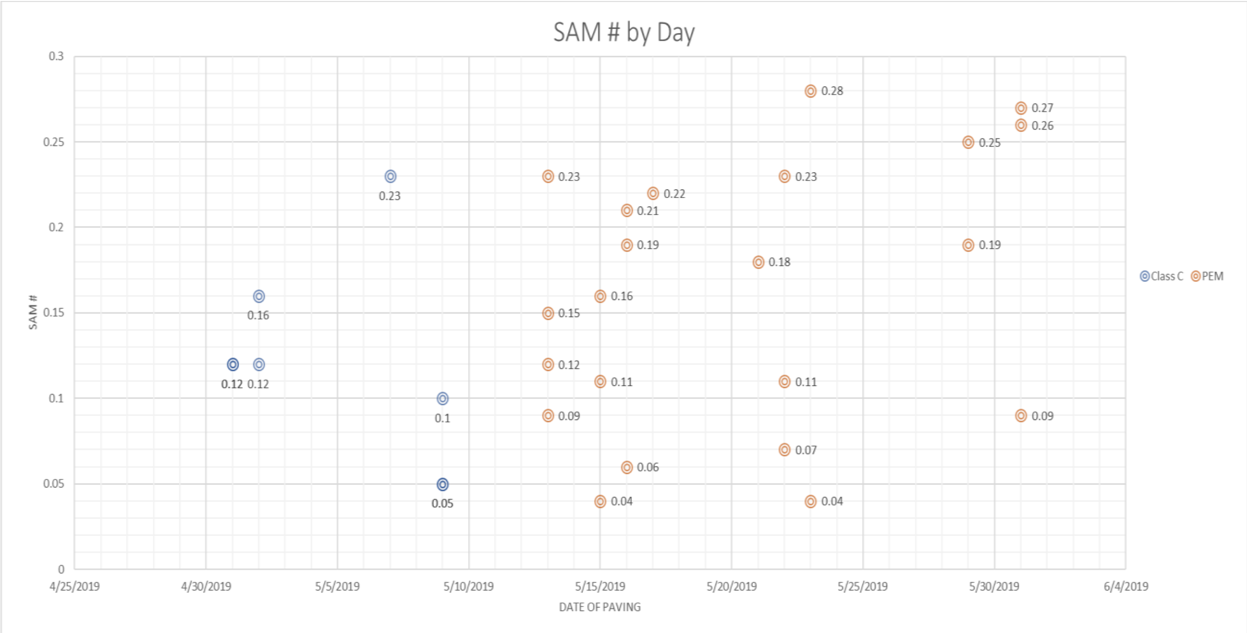
Super Air Meter (SAM):

SAM data was collected by the Department for both the Class C and PEM for informational purposes only. Below is a graph (Graph 1: SAM vs. Air Content) showing the PEM and Class C plot along the SAM curve between large air voids and small air voids versus air content. The raw SAM data can be seen in Appendix A-3. The SAM values for the Class C appear to be a more consistent then the PEM though the majority of PEM results meet the specified values. No direct correlation of the SAM values to other concrete properties has been noted. The spread of SAM values for the PEM on the graph does not seem to show a discernible pattern. Graph 2: SAM number by day, shows the variation of values for each truck sampled during each day of placement. The average SAM number of all SAM data collected is 0.15 with a standard deviation of 0.073.

Graph 1: SAM vs Air Content



Graph 2: SAM # by Date



Compressive Strength:

Compressive strength data from the first day's placement of the NYSDOT Class C and PEM are shown in Table 7. The data shows that there is an increase in the compressive strength of the PEM vs the Class C mix.

TABLE 7: First Day Placement Compression Breaks (psi) 6 inch X 12 inch cylinders			
	Class C	PEM	Percent Increase
7 Day	4254	4758	12%
14 Day	4997	5457	9%
28 Day	5324	6255	17%

**Values are the average of 2-6"x12" cylinders*

More detailed breakdown of the average 28-day compressive strengths can be found in Table 8. Note that there were more samples collected of the PEM than the Class C due to the smaller quantity of class C placed on the project. The Class C concrete was sampled following existing NYSDOT Materials Method 9.2 (Available from the Department). The sampling rate was reduced for the PEM due to the additional quality control (QC) responsibilities put upon the contractor as noted in the special specification. Note 1 on Table 8, the average is taken only from 2 sets of cylinders because quantity placed did not reach the requirement for a third set of samples. Note 2 on Table 8, the samples were taken before inclement weather halted production and no further samples were taken that day. Again, we can see a definite increase in the PEM average compression strengths over the NYSDOT Class C mix.

TABLE 8: 28 Day Compression Avg of 6 inch X 12 inch Cylinder Sets		
• Class C:1 set = 2 – cylinders for every 50 cubic yards of concrete • Class PEM: 1 set = 2 – cylinders for every 100 cubic yards of concrete		
Date	**Class C** (psi)	**PEM (psi)**
5/02/2019	3184 [1]	
5/06/2019	4047	
5/07/2019	4593	
5/08/2019	4542	
5/09/2019	4383	
5/15/2019		5903
5/16/2019		5253
5/17/2019		4679[2]
5/21/2019		5642
5/22/2019		5279
5/23/2019		4784
5/24/2019		5164
5/29/2019		5620
5/31/2019		5660
Average Strength (psi)	4391	5519
Percent Increase	20 %	

Flexural Strength:

Flexural strength samples were collected by the Department from the Class C mix at a rate of once per day, two beams from one concrete truck. The Class C beams were cast by the Department in 6 inch X 6 inch X 30 inch steel molds. PEM flexural samples were cast by the Contractor's quality control representatives at a frequency of two beams per day, taken randomly from two separate concrete trucks. These beams were cast in 6 inch X 6 inch X 21 inch steel molds supplied by the quality control representatives. All beams were tested by the Department and the data was used for informational purposes only. Table 9 shows the average flexural strengths of each pair of beams. The results show an overall increase in flexural strength for the PEM compared to the Class C.

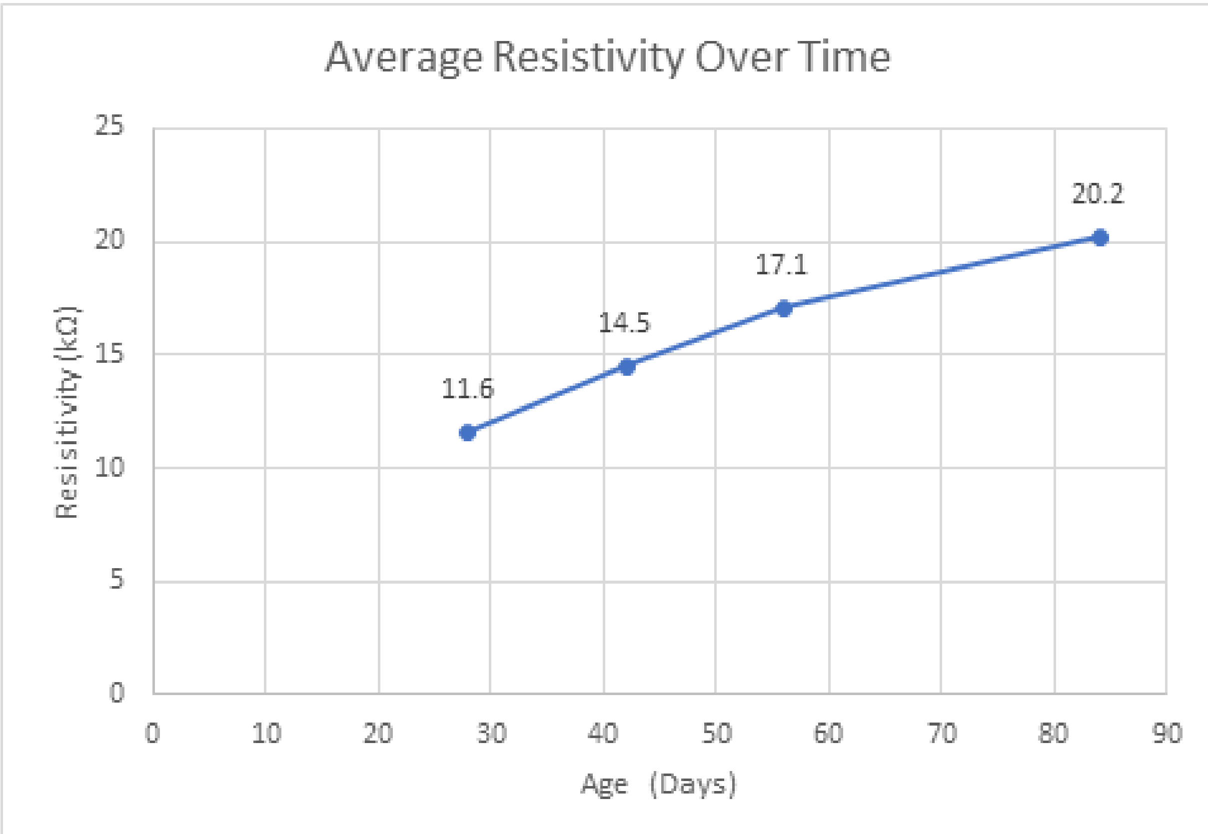
Table 9: 28 Day Average Flexural Strength (psi) Average of each day's pair

Date	Class C (psi) 6 inch X 6 inch X 30 inch	PEM (psi) 6 inch X 6 inch X 21 inch
5/1/2019	578.87	
5/2/2019	482.92	
5/6/2019	594.19	
5/7/2019	611.95	
5/8/2019	656.85	
5/9/2019	687.6	
5/13/2019		692.31
5/15/2019		684.95
5/16/2019		653.52
5/21/2019		666.29
5/22/2019		687.63
5/23/2019		697.1
5/24/2019		657.6
5/29/2019		672.7
5/31/2019		669.05
Average (psi)	602.06	680.3
Percent Increase		12.9%

Surface Resistivity (SR):

SR data was collected for information only from both the Class C and PEM concrete. The Class C samples were cast by Department staff and the PEM samples were cast by the Contractor's testing agency. All SR testing was performed by Department personnel. Initially the 28 day SR target value for the PEM was 16.5 kΩ on a 4"x8" cylinder, but the trial batches showed 28 days was not enough time to achieve this SR target. On average the mix achieved the target value at 56 days. Graph 3 shows the average PEM SR values for all SR samples taken per sample age (28 day, 42 days, 56 day, and 84 day).

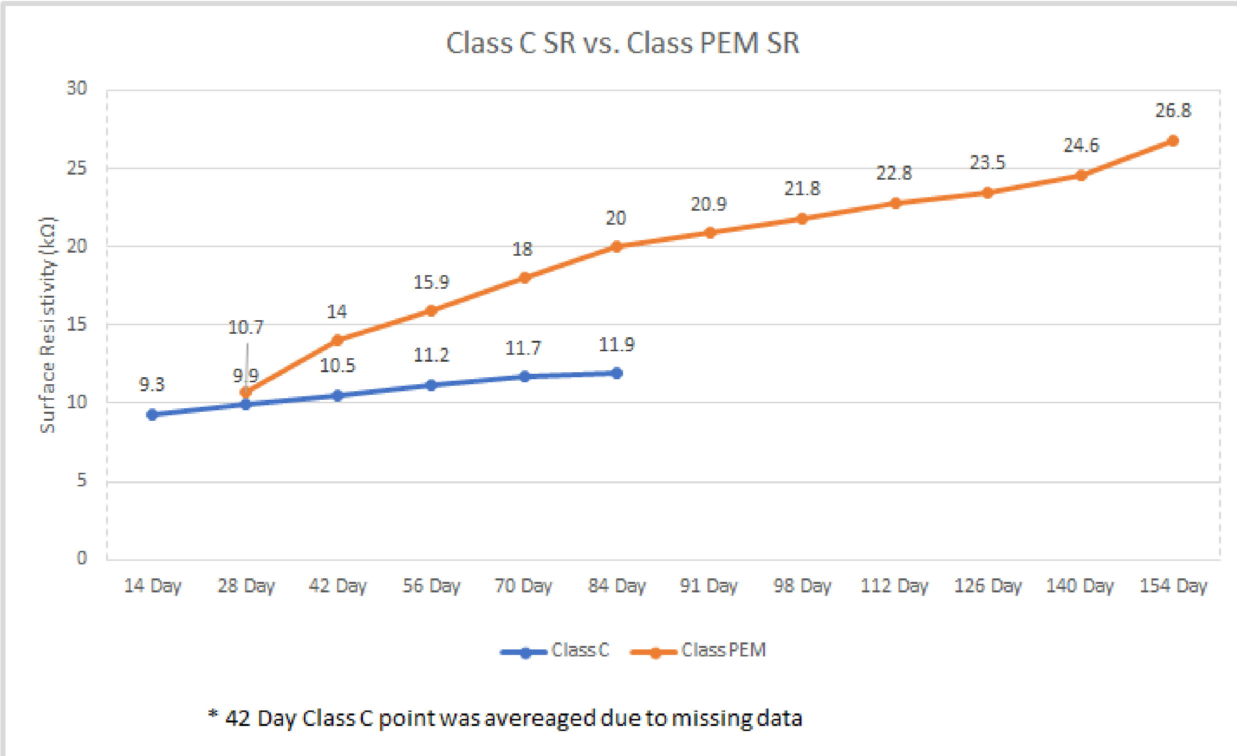
Graph 3: Avg SR vs Time



Average of all SR results for all PEM cylinders.

Graph 4 shows the SR gain of one set of cylinders from the PEM mix and one set of cylinders from the Class C concrete. Testing on the Class C concrete was terminated at 84 days because the values were beginning to plateau at about 11.9 kΩ. The PEM set had a much greater SR growth compared to the Class C mix showing a value of 20 kΩ at 84 days. Due to the continued growth of the PEM SR after 84 days, testing was continued on the PEM concrete for informational purposes.

Graph 4: Class C SR vs PEM SR Over Time

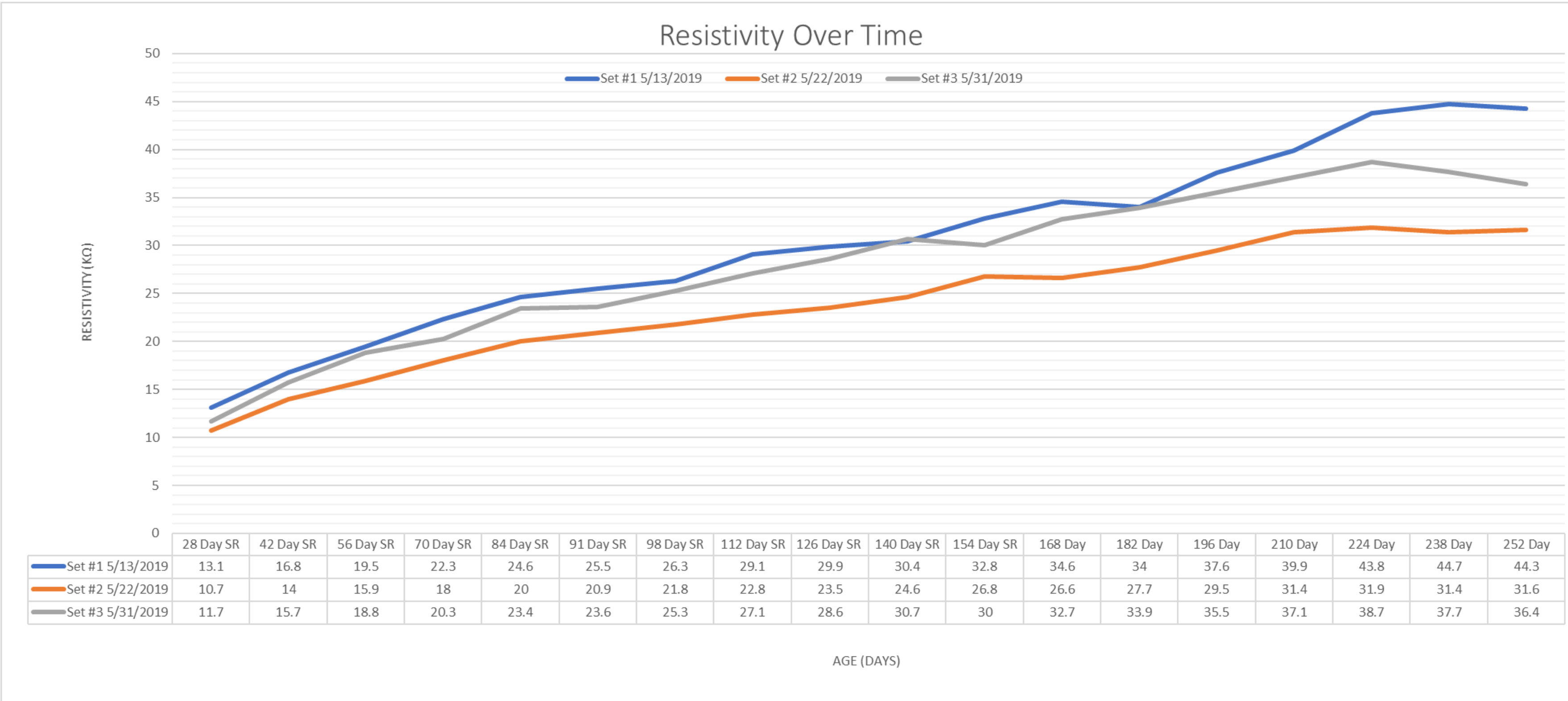


One set of class C cylinders compared to one set of PEM cylinders.

SR testing was continued on a number of PEM samples to determine what the maximum SR value could be and when it would be achieved. Graph 5 shows the average SR gain of 3 sets of PEM concrete cylinders. The SR gain levels out at around 224 days with results averaging about 38.13 kΩ.

Graph 5: PEM SR Curve

Graph 4 represents 3 separate sets of PEM cylinders. Each set of cylinders contained 3 cylinders each, SR values are the average for each set.

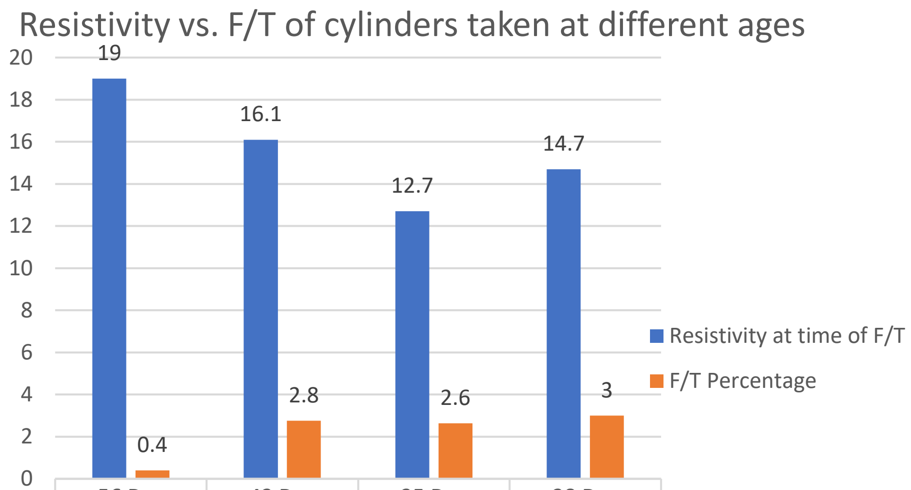


	28 Day SR	42 Day SR	56 Day SR	70 Day SR	84 Day SR	91 Day SR	98 Day SR	112 Day SR	126 Day SR	140 Day SR	154 Day SR	168 Day	182 Day	196 Day	210 Day	224 Day	238 Day	252 Day
Set #1 5/13/2019	13.1	16.8	19.5	22.3	24.6	25.5	26.3	29.1	29.9	30.4	32.8	34.6	34	37.6	39.9	43.8	44.7	44.3
Set #2 5/22/2019	10.7	14	15.9	18	20	20.9	21.8	22.8	23.5	24.6	26.8	26.6	27.7	29.5	31.4	31.9	31.4	31.6
Set #3 5/31/2019	11.7	15.7	18.8	20.3	23.4	23.6	25.3	27.1	28.6	30.7	30	32.7	33.9	35.5	37.1	38.7	37.7	36.4

Freeze Thaw Testing (F/T) NYSDOT TM 502-3:

Freeze thaw testing was performed on PEM cylinders for informational purposes. The goal was to determine any relationship between SAM, SR, and the NYS F/T testing. A correlation between SR results and F/T results is shown in Graph 6. As age increased, surface resistivity increased along with it and the F/T percent loss decreased. No clear correlation with the collected SAM numbers was seen.

Graph 6: SR and F/T Loss Over Time



	56 Day	42 Day	35 Day	28 Day
Resistivity at time of F/T	19	16.1	12.7	14.7
F/T Percentage	0.4	2.8	2.6	3

* F/T samples were taken from four different paving dates. Resistivity data was collected immidiately before F/T testing began at age shown

Conclusions:

Overall the development and use of a PEM concrete mix is beneficial both the Department and to the industry. The PEM mix design was of better quality and better workability than the Department's standard Class C pavement mix. The main problems with the PEM development and implementation deal with the steep learning curve associated with getting all parties involved familiar with the new test procedures. They must also understand their parts in the QCQA process.

Some additional work is needed to address possible aggregate issues. Aggregates required to meet newer PEM gradations may need additional storage and QC on the producer's part and necessitate additional QA on the Department's side. Such requirements may also increase the overall cost of the concrete. The appropriate gradations for specific applications such as slip-forming versus formed-in-place needs to be looked at more closely as well.

Initially there were concerns on the contractor and producer side to the point the initial producer decided to back out of the contract. The contractor was forced to find another producer who was willing to participate in the PEM development. Even after a new producer was in place, they were hesitant to continue after learning they would have to provide a QC report on their concrete process. After some discussion, the producer understood that they would not have to do much more than they already doing for their own plant QC process, and the project proceeded.

An initial observation on the PEM process is that that for a PEM mix to be properly developed, there must be enough lead time before the project begins. Due to the delays on this project, the development and testing of the mix design had to be expedited. A concrete producer needs to have substantial time to develop multiple mixes with the necessary pre-testing to determine the best mix possible for the project. The State Agency needs to have enough time to evaluate and trial batch the proposed mixes after the producer does their preliminary mix development.

The QC/QA requirements introduced new tests and procedures to the project and as such there was confusion on who was responsible for what and when. A quality control plan was required from the Contractor and Producer, which as mentioned before caused some disagreement until the Department explained what was needed and provided a sample plan. The Department also had to very clearly define who was responsible for what aspects of sampling and testing. The Contractor had to hire a third-party testing agency to perform quality control sampling and testing per the specification. Another aspect of the new QCQA process was the review of the daily QC reports which is something different than the normal procedures the Department follows. The reports were not checked regularly. In one instance, this allowed a change in the coarse aggregate ratio of the PEM to occur without any notice until Main Office reviewed the reports after the project ended. Even though the change was minimal and did not affect the PEM, it was a change that would have been noticed with a check of the daily QC reports. Personnel from all sides of a project need to be trained on the presentation, process and review of the QC reports.

On this project, the Department itself sampled and tested for QA purposes and acceptance. Some of the testing such as SAM, SR and flexural were performed by the Department for information only. The producer was held to the values from these tests in the specification for design purposes but not during production for field acceptance.

The introduction of new testing methods required the Department to provide significant training to its personnel and at times needed to have Main Office personnel do some of the sampling and testing to supplement regional personnel. This brings up another aspect of the PEM development, not only does the Department, Contractor and Producer need to be educated in the purpose and process of PEM development and QC / QA, but the third party private agencies representing the Department and Contractors have to be included, since they will be doing much of the work required for QC / QA.

Due to the delays in getting a PEM mix approved, the Contractor was permitted to place the Department's standard Class C mix for the first two weeks of production. This allowed the Department the opportunity to collect data on the Class C mix to do a side by side comparison with the PEM mix. The data collected shows that the PEM performed better than the Class C mix in compression and flexural strengths as well as SR. The Contractor also felt that the PEM mix looked and placed better than the Class C.

The SR gain of the PEM mix was slower than anticipated, originally specified for 28 days, the value was not achieved until about 56 days. The PEM SR values are higher than the Class C Concrete values and the PEM SR values continued to rise beyond the point where the Class C SR values leveled off. Compression and Flexural strengths were on average also higher for the PEM than the Class C. Freeze/Thaw durability was seen to rise with higher SR values.

SAM testing was difficult to carry out in the field and took a much longer time than the standard air content testing. Several errors were encountered with the SAM testing (false readings, failure of the O-ring, operator error). SAM values which were clearly not valid were not collected. At one point a suspect SAM pot had to be replaced with another to ensure accurate readings. The SAM numbers collected do not show a clear relationship with the other data. SAM data varied from batch to batch from the same day's placement and showed little consistency.

Additional PEM Projects:

NYSDOT has proceeded with a second PEM project in Region 11, New York City. Using what was learned from the first project in this report, a new special specification was generated, which more clearly defined QCQA responsibilities and required SAM testing for acceptance. Some of the same issues came up with the second project such as unfamiliarity with PEM and what the purpose of the PEM is. The Concrete producer, at first, did not understand what the PEM was supposed to be and only tried to modify the Department's Class C mix. They were not able to meet the specification requirements using their approach but fortunately, there was enough lead time on this project to work with the producer and develop and test an appropriate PEM. The Producer also had issues finding an aggregate source to meet the tarantula curve requirements. The paving on this project has not fully resumed for the 2020 season. Data on this project will be collected through-out its construction and a third PEM concrete pavement project is already scheduled using the same special specifications as the currently active project.

Appendix

A-1

SECTION 502 - PORTLAND CEMENT CONCRETE PAVEMENT

502-1 DESCRIPTION. Construct a Portland Cement Concrete (PCC) pavement and shoulders, if required, as detailed in the contract documents.

501

Chemically Curing Adhesive for Portland Cement Concrete (PCC) Pavement Applications	701-14
Highway Joint Sealants (ASTM D6690, Type IV)	705-02
Premoulded Resilient Joint Filler	705-07
Preformed Elastic Longitudinal Joint Seal	705-10
Preformed Elastic Transverse Contraction and Expansion Joint Seal	705-12
Lubricant for Preformed Elastic Joint Sealer	705-13
Longitudinal Joint Ties	705-14
Transverse Joint Supports	705-15
Wire Fabric for Concrete Reinforcement	709-02
Epoxy Coated Bar Reinforcement, Grade 60	709-04
Quilted Covers (for curing)	711-02
Plastic Coated Fiber Blankets (for curing)	711-03
Polyethylene Curing Covers (white opaque)	711-04
Membrane Curing Compound	711-05
Form Insulating Materials for Cold Weather Concreting	711-07
Water	712-01

If requested, provide the Engineer with any appropriate manufacturer's details and/or instructions for use of listed materials before use of the product.

In addition to meeting the requirements of §701-14, Chemically Curing Adhesive for Portland Cement Concrete (PCC) Pavement Applications, the material used to anchor longitudinal joint ties, dowels, or other miscellaneous items into hardened concrete must be a pourable, two-component, 100% solid structural epoxy dispensed:

- From side-by-side cartridges by manual or pneumatically powered injection guns.
- Through a static mixing nozzle that homogeneously mixes the material without any hand mixing.

502-2.01 Concrete. Use Class C concrete furnished in accordance with Section 501, Portland Cement Concrete – General, when specified. High-Early-Strength (HES) concrete, meeting the requirements of §502-2.02, may be substituted for closure or short placements, subject to the Engineer's approval.

502-2.02 High-Early-Strength (HES) Concrete. Use HES concrete where required in the contract documents or where the Contractor's request to use HES concrete is approved by the Engineer.

Whether required or requested, design the HES mix to satisfy the opening to traffic time requirements of the project and Table 502-1, High-Early-Strength Concrete Mix Requirements. Submit the HES concrete mix design to the Engineer. Include admixture brands and dosages as well as mixing, transporting, placing, paving, curing, and anticipated strength gain details.

Produce and place a 4.0 yd^3 (minimum) trial batch at an off-contract location selected by the Contractor and agreed upon by the Engineer. Produce the trial batch using the same materials and processes as those to be used to produce concrete for the contract. Provide the Engineer a 7-day minimum advance notification of trial batch production. Produce and place the trial batch in the presence of the Engineer, the Regional Materials Engineer, and Materials Bureau personnel.

Provide an American Concrete Institute (ACI) Certified Concrete Field Testing Technician, Grade I, or higher, to:

- Measure slump, air content, and unit weight of the trial batch.
- Cast cylinders from the trial batch for compressive strength and durability testing.
  Determine the compressive strength of the trial batch concrete at the desired time as discussed in §502-3.16C, Project Strength Determination
  .

The Materials Bureau will render a decision on mix acceptability, curing, and opening to traffic requirements within 45 calendar days of trial batch production. Changes other than minor fluctuations in admixture dosage rates require a new mix design and trial batch. The Engineer will reject the concrete if the specified plastic air content is not achieved. The Engineer may halt paving and order additional trial batches whenever the specified compressive strength requirements are not achieved.

TABLE 502-1 HIGH-EARLY-STRENGTH CONCRETE MIX REQUIREMENTS			
Property	**Minimum**	**Desired**	**Maximum**
28 Day Compressive Strength	4000 psi	-	-
Opening Compressive Strength	2500 psi[1]	-	-
Freeze-Thaw Loss (Test 502-3P, 3% NaCl)	-	0.0 %	3.0 %
Plastic Air Content	5.0 %	6.5 %	8.0 %
Water – Cement Ratio (w/c)	-	-	0.40
Slump[2]	-	-	-

NOTES:

1. See §502-3.16, Opening to Traffic.
2. There are no minimum or maximum requirements for slump, however mix must be fluid enough to finish without segregating.

502-2.03 Performance Engineered Mixes (PEM). If specified, design a concrete mixture proportioned to meet the requirements of the contract documents. Procedures for mix approval and acceptance will also be included in the contract documents.

502-2.04 Load Transfer Dowel Bars. Refer to 705-15 for Dowel bar requirements. If specified, load transfer dowel bars other than epoxy coated steel may be required. The material requirements as well as the approval and acceptance procedures will be included in the contract documents.

502-3 CONSTRUCTION DETAILS. Hold a pre-pave meeting 7 to 14 day before the planned start of paving with the Engineer, any PCC paving and saw cutting subcontractors, and concrete suppliers to coordinate all aspects of paving and inspection, including equipment review, construction methods, and time and personnel requirements.

Construct a smooth, well consolidated, properly finished, textured, and cured pavement to the line and grade depicted in the contract documents, ± 1/4 inch vertically at any location.

502-3.01 Equipment. Provide the Engineer with an equipment list and specifications a minimum of 14 days prior to the planned start of PCC paving. Bring all equipment needed to place, consolidate, finish, texture, cure, saw cut, seal, and test the PCC pavement to the job site a minimum of 1 full work day before its use to allow examination by the Engineer. Repair or replace any equipment found to be defective before or during its use. Discontinue any operation if unsatisfactory results are being obtained. Use of equipment other than described below is subject to the approval of the Director, Materials Bureau.

A. Slipform Paving. Use a self-propelled slipform paver equipped with:

- Rigid side forms that laterally support the concrete and minimize edge slumping.
- A full-width finishing pan.
- Attached internal vibrators capable of consolidating the entire concrete placement.

Slipform paving consists of a single paver, or a placer/spreader followed by a separate paver, capable of placing, spreading, consolidating, screeding, and finishing the concrete such that hand finishing is kept to a minimum. Use equipment guided by a reference system that ensures the pavement is placed to the specified line, grade, and cross section.

B. Fixed Form Paving

1. Forms. Use straight forms without horizontal joints meeting Table 502-2, Form Requirements, and equipped with:

- At least 3 stake pockets spaced 3 feet apart (maximum), each having a positive, nondetachable wedge.
- Positive, interlocking devices capable of holding abutting sections together to form neat, tight joints.

TABLE 502-2 FORM REQUIREMENTS

Characteristic	**Requirement**
Material	Steel, 1/4 inch thick, minimum.
Length	10 feet, minimum.
Depth	Equal to the sum of the edge thicknesses of all pavement layers placed within the form.
Base Width	Equal to the depth, minimum.
Horizontal Top Face	2 inch wide, minimum, and lying in a plane with a maximum variation of 1/8 inch in 10 feet.
Vertical Face	Maximum variation of 1/4 inch in 10 feet and rounded on the upper corner with a 3/4inch radius, maximum.
Flange Bracing	Extends outward on the base 2/3 of the form depth, minimum.

Flexible, curved, or wooden forms may be used in irregular areas or curved sections having horizontal radii of 100 feet or less.

2. Paving Equipment. Use fixed form paving equipment specifically made for placing concrete. The equipment must be capable of placing, spreading, consolidating, screeding, and finishing the concrete to the specified line, grade, and cross section such that hand finishing is kept to a minimum. Use equipment with either attached internal vibrators or in conjunction with hand-held internal vibrators.

C. Vibrators. Use paver-mounted internal vibrators capable of consolidating the entire concrete placement that are:

- Capable of being shut off without shutting off the paver.
- Equipped with frequency controls readily accessible to the paver operator.
- Capable of simultaneously operating at the same frequency as the other paver-mounted vibrators.
- Capable of operating through a frequency range of 6,000 - 10,000 vibrations per minute.

Check vibrator operating frequencies daily when paving begins. Check frequencies under load with the Engineer present. If the paver is not equipped with direct-read frequency gauges for each vibrator, supply the Engineer with a calibrated, hand-held tachometer, including instructions, to monitor vibrator frequencies. The tachometer will remain the Contractor's property after paving is complete.

Use hand-held vibrators capable of operating through a frequency range of 6,000 - 10,000 vibrations per minute in any location that is not consolidated by internal vibrators attached to the paving equipment.

D. Saw Cutting Equipment. Use diamond blade saws capable of making straight cuts to the dimensions depicted in the Standard Sheets that are equipped with cutting guides, blade guards, water cooling systems, dust controls, and cut depth control.

Maintain equipment and supplies to ensure uninterrupted saw cutting. Early entry saws require approval from the Director, Materials Bureau. Submit requests to use early entry saws at least 7 calendar days before paving.

E. Curing Compound Applicators. Use atomizing mechanical sprayers capable of exerting consistent pressure without hand pumping that are equipped with tank agitators to continuously mix the curing compound. Use nozzles with spray shields to prevent drift. Flush nozzles daily before use.

Maintain equipment and supplies, including extra nozzles, to ensure uninterrupted curing compound application. In a multi-lane slip form paving operation, use self-propelled applicators guided by the same reference system as the slip form paver. Otherwise, applicators need not be self-propelled.

F. Drills. Use gang drills with a minimum of 2 independently powered and driven drills. Use tungsten carbide drill bits. Rest and reference the drill rig frame on and to the pavement surface such that the drilled holes are cylindrical, perpendicular to the surface being drilled, and repeatable in terms of position and alignment. Hand-held drills are permitted for drilling holes in longitudinal joints if there is not enough room to use gang drills resting on the pavement surface.

G. Joint Sealing - Highway Joint Sealant. Heat the sealant in a melter constructed either:

- As a double boiler with the space between inner and outer shells filled with oil or other heat-transfer medium.
- With internal tubes or coils carrying the sealant through a heated oil bath and into a heated double-wall hopper.

Do not use direct heating. Use a melter capable of maintaining the sealant's pouring temperature and providing homogeneous sealant equipped with:

- Positive temperature control.
- Continuous full sweep mechanical agitation.
- Separate thermometers indicating the temperatures of the heat transfer medium and the sealant in the hopper. Do not place any sealant if the thermometers are defective or missing.

Provide 2 thermometers having stems 18 inches long and temperature ranges sufficient to meet the requirements of this specification. Use a discharge hose equipped with a controlled heating apparatus or sufficiently insulated to maintain the proper sealant pouring temperature. Use nozzles that apply the joint sealant within the joint confines for the full width and depth of the joint.

H. Air Blasting Equipment. Use equipment with traps or other installed devices that prevent moisture and oil from contaminating the concrete surface. Use a compressor that delivers air at a minimum of 120 cfm and develops a minimum nozzle pressure of 90 psi. Check the compressed air stream purity daily with a clean white cloth.

502-3.02 Weather Limitations

A. Rain. Do not pave in the rain. Supply sufficient quilted covers, plastic coated fiber blankets, or polyethylene curing covers near the paving operation when rain may be expected. Securely cover any concrete exposed to rain that has not reached initial set or will be visibly affected by the rain.

B. Cold Weather. Place concrete when the air temperature is 40°F and rising, or warmer, and when the surface temperature of the area to be paved is 40°F, or warmer. Stop paving when the air temperature falls below 40°F. Measure temperatures in the shade to an accuracy of 1°F. Refer to §502-3.11C, Cold Weather Curing.

502-3.03 Subbase Course. Install a subbase course in accordance with Section 304, Subbase Course, before placing PCC. If the area is available, extend the prepared subbase course at the same line, grade, and cross slope as the area being paved such that it is at least:

- 3 feet beyond the longitudinal edges of a slipform pavement.
- 1 foot beyond the outside longitudinal edges of the fixed forms.

Additional subbase course that is not included in the finished work will be paid for under Section 304 items included in the contract.

502-3.04 Slipform Paving. Establish a reference system to achieve the specified smoothness level. If string lines are used, set them by survey and use dual lines whenever possible.

Maintain uniform concrete quality and head in front of the paver. Coordinate concrete delivery to maintain continuous forward movement of the paver and avoid excessive delivery truck queues. Keep paver tracks clear of concrete and debris before and during paving.

Wet the entire subbase surface without forming puddles or mud immediately before placing concrete.

Consolidate the entire concrete placement using internal vibrators attached to the paver. Combine paver forward speed, vibrator frequency, and vibrator depth to consolidate the concrete without segregation, vibrator trails, or contacting the joint assemblies. Discontinue vibration and tamping if the paver stops.

Determine edge slump by extending a 2 foot (minimum) long straightedge over the longitudinal pavement edges. Immediately correct edge slumps greater than 1/4 inch that are between concrete placements and greater than 3/8 inch at free edges and HMA shoulders.

502-3.05 Fixed Form Paving.

A. Setting Forms. Compact the supporting layer at the form line such that the forms are supported for their full length. Set forms to string lines placed at the pavement elevation, line, and grade and to achieve the specified smoothness. If a form sits above the string line, remove the form and trim the form line to the proper grade. If a form sits below string line, remove the form and fill and compact the low area with granular material at least 6 inches on both sides of the form. Frequently check form grade and alignment while paving. Reset forms as necessary.

Set forms to accommodate a full day's paving before placing concrete. Extend forms beyond construction bulkheads to provide a working platform at the end of a placement. Secure each form with a minimum of 3 pins, each of sufficient length to hold the forms in place without movement during any operation. Lock the forms together such that the form ends are aligned, and the joints are tight and smooth. Run the paving equipment atop the forms before placing any concrete and recheck form alignment. Reset forms as necessary.

Align keyway strips in a smooth, horizontal plane, parallel to the top of the form. Match keyway strips on abutting forms such that a nearly seamless keyway results.

B. Paving. Apply oil to forms before placing concrete. Immediately before placing concrete, wet the entire subbase surface without forming puddles or mud. Uniformly distribute the concrete in front of the paver by maneuvering the delivery truck chute. If concrete is spread by hand, use come-alongs or shovels. Do not use rakes or hand-held vibrators to spread concrete.

Maintain uniform concrete quality and head in front of the paving machine and without running over the screeds. Coordinate concrete delivery to maintain continuous forward movement of the paver and avoid excessive delivery truck queues. Keep form tops clean before and during paving.

Consolidate the entire concrete placement using internal vibrators attached to the paver. Combine paver forward speed, vibrator frequency, and vibrator depth to consolidate the concrete without segregation, vibrator trails, or contacting the joint assemblies. Discontinue vibration and tamping if the paver stops.

Use hand-held vibrators ahead of the paving equipment to consolidate all concrete not consolidated by machine-mounted internal vibrators. Keep hand-held vibrators perpendicular to the pavement surface. Vibrate between 2 and 4 seconds in each location, overlapping adjacent locations. Do not drag vibrators through the concrete. Do not walk through consolidated concrete.

Mark the midpoint (± ½ inch) of each transverse contraction joint such that the saw cut operator can accurately locate the first-stage saw cut locations.

C. Form Removal. Remove forms after the concrete has developed sufficient strength to allow removal without damaging the pavement. Repair pavement damaged during form removal. Remove forms before making second-stage saw cuts.

502-3.06 Joint Construction. The Engineer will inspect the longitudinal joint ties and transverse joint supports for compliance to the relevant Materials Details before any joint hardware placement is allowed. Construct joints in accordance with the Standard Sheets and approved Materials Details. Do not stand on joint hardware.

Base final joint layout on construction staging and the actual location of utilities, drainage structures, intersections, tapers, and other irregular areas. Submit a proposed joint layout to the Engineer at least 10 calendar days prior to PCC paving. Obtain the Engineer's approval of the joint layout before paving.

Inserting dowels and/or longitudinal joint ties into plastic concrete will be considered. Submit a plan to verify dowel and tie locations, depth, and alignment to the Engineer for consideration. Do not insert dowels or ties until the plan is approved by the Engineer.

Make first-stage saw cuts 1/8 inch wide. Make second-stage saw cuts, clean, and seal joints in accordance with §502-3.12, Sealing Joints.

A. Transverse Joints. Transverse joints include contraction, expansion, hinge, and construction joints. Secure joint supports to the subbase as depicted in the Materials Details. Maintain joint supports in their proper position and alignment during paving.

Construct transverse joints perpendicular to both the pavement surface and longitudinal joints in the area being paved. Use a 15 foot maximum transverse joint spacing for pavements having standard slab widths of 12 to 13 feet. For pavements having other slab widths, determine typical maximum and minimum transverse joint spacing in accordance with the following:

$L_{max} = W_{min} \times 1.33$
$L_{min} = W_{max} \div 1.33$

where:

L_{max} = maximum transverse joint spacing (slab length)
L_{min} = minimum transverse joint spacing (slab length)
W_{max} = maximum slab width across the pavement (load carrying slabs only)
$W_{max} \leq 13$ feet
W_{min} = minimum slab width across the pavement (load carrying slabs only)

1. Transverse Contraction Joints. All transverse joints are contraction joints unless otherwise shown in the contract documents. Contraction joints are constructed in a straight line across the full width of the PCC pavement and shoulders. Contraction joints may be angled (rather than straight across a pavement) at tied longitudinal joints between lanes placed separately if the placements do not have the same centerline, e.g., where a ramp centerline diverges from parallel to the pavement centerline. Contraction joints may terminate at, or be misaligned at, untied longitudinal joints as discussed in §502-3.06B3, Untied Longitudinal Joints.

Store transverse contraction joint support assemblies in inverted stacks at the project site. Cover stored epoxy coated steel such that it is protected from direct sunlight. Handle joint supports such that no twisting or bending occurs during storage and positioning. Supports with bent, twisted, or deformed wires will be rejected.

Before placing concrete, position transverse joint supports such that the:

- Entire longitudinal axis of each dowel is located at the mid-depth of the pavement slab or up to 1 inch below the mid-depth of the slab.
- Longitudinal axes of the dowels are aligned parallel with the pavement centerline and pavement surface such that the maximum misalignment of one dowel end relative to the other is ¼ inch.
- Midpoint of the longitudinal axis of each dowel is at the center of the joint (±1 inch).
- Longitudinal axes of the two end dowels are 4 to 8 inches from the longitudinal joints.
- Longitudinal axes of the dowels are spaced 12 inches apart.

Mark the location of each contraction joint on the subbase before placing concrete such that the assembly is properly positioned. Also mark the longitudinal midpoints of the dowels such that the saw cut operator can accurately locate first-stage saw cuts. In a slipform paving operation, mark the joint support midpoint on the subbase immediately adjacent to the pavement. In a fixed form paving operation, mark the joint support midpoint on the form or such that the saw cut operator can easily locate the joint midpoint. Do not cut the shipping wires.

Make first-stage saw cuts as soon as the concrete has hardened sufficiently to permit sawing without causing raveling wider than 1/8 inch. Replace blades if raveling persists. Center first-stage saw cuts within 1 inch of the longitudinal midpoints of the dowels.

Complete first-stage saw cuts before any uncontrolled cracking occurs. Be prepared to make first-stage saw cuts 24 hours a day to prevent uncontrolled cracking. Provide lighting required to make first-stage saw cuts at night at no additional cost to the State.

Sweep or wash first-stage saw cut debris from the pavement before it rains, or before opening the pavement to any traffic, such that debris does not enter the joint.

2. Transverse Expansion Joints. Construct transverse expansion joints as part of the utility and drainage structure isolation systems depicted in the Standard Sheets or where indicated in the contract documents. Handle and position expansion joint supports in accordance with §502-3.06A1, Transverse Contraction Joints.

Construct expansion joints using 1/2 inch thick remolded resilient joint filler placed in 1 piece between longitudinal joints. Tightly place and support abutting sections of joint filler such that no concrete infiltrates the joint. Place expansion caps on the dowels as depicted in the Materials Details. Do not tap or hammer the caps onto the dowels.

No saw cuts are required in expansion joint construction. Remove the finishing cap, if supplied, after the concrete has developed sufficient strength to prevent damage.

3. Transverse Construction Joints. Construct transverse construction joints wherever there is an interruption of more than 30 minutes in concrete paving operations. Construct these joints as wide as the concrete placement, typically 1 or 2 lanes, but not necessarily the full pavement width. Align construction joints with transverse contraction or construction joints in adjacent lanes. Construction joints may be formed by bulk heads, saw cuts, concrete removal, or any combination thereof.

When required, drill and anchor dowels in accordance with §502-3.06D, Drill and Anchor Dowels or Ties, such that they meet the positioning requirements of §502-3.06A1, Transverse Contraction Joints.

a. *Bulkheads.* Ensure the bulkhead can support the weight of the plastic concrete. Bulkheads may be slotted or solid. Place a slotted bulkhead over the dowels of an exposed joint assembly such that half of the dowel lengths are embedded within newly placed concrete. Immediately remove plastic concrete in front of the bulkhead and from the exposed joint support.

The transverse joint assembly may be omitted and a solid bulkhead may be used. In this case, drill and anchor dowels, if required, into the transverse joint face.

b. *Saw Cut*. Saw cut full depth construction joints at locations that satisfy the minimum and maximum slab length requirements of §502-3.06A, Transverse Joints. Saw cut when the concrete has obtained sufficient strength to be saw cut without damage to concrete to remain in place. Do not cut within 12 inches of a longitudinal joint tie. Remove the hardened concrete ahead of the saw cut. Drill and anchor dowels, if required, into the saw cut face such that they meet the positioning requirements. Do not drill into longitudinal joint ties.

In lieu of drilling holes, the contractor may use transverse joint supports fabricated with closed-end, hollow plastic cylinders instead of dowels. Use hollow cylinders with outer diameters equal to the drilled hole diameters described in §502-3.06D, Drill and Anchor Dowels or Ties. Position cylinders as required in §502-3.06A1, Transverse Contraction Joints.

Saw cut the newly placed concrete full depth and full width through the midpoint of the longitudinal axis of each cylinder (± 1 inch). Remove hardened concrete and the joint assembly ahead of the saw cut. Remove the hollow cylinder embedded in the concrete that remains and anchor the dowels in accordance with §502-3.06D, Drill and Anchor Dowels or Ties, to the required alignment in §502-3.06A1, Transverse Contraction Joints.

c. *Removal.* Remove all concrete to the midpoint of the preceding transverse joint without damaging the dowels, dowel coatings, or the pavement to remain in place.

4. ***Transverse Hinge Joints.*** Do not place hinge joints without the Engineer's approval. Construct transverse hinge joints when a slab length exceeds the geometric requirements of §502-3.06, Transverse Joints. (This situation typically occurs near structures that are skewed from perpendicular to the pavement centerline.)

Locate hinge joints such that they are equally spaced between other types of transverse joints. Construct hinge joints in accordance with §502-3.06A1, Transverse Contraction Joints, except the positioning requirements do not apply. Instead, position transverse hinge joint supports such that the:

- Entire longitudinal axis of each deformed bar is located at the mid-depth of the pavement slab or up to 1 inch below the mid-depth of the slab.
- Longitudinal axes of the bars are aligned parallel with the pavement centerline and pavement surface such that the maximum misalignment of one bar end relative to the other is 1 inch.
- Midpoint of the longitudinal axis of each bar is at the center of the joint (±1 inch).
- Longitudinal axes of the two end bars are 4 to 10 inches from the longitudinal joints.
- Longitudinal axes of adjacent bars are spaced 4 to 18 inches apart.

B. ***Longitudinal Joints.*** When a longitudinal joint item is specified, select tie type, size, spacing, and positioning in accordance with the 502 Standard Sheets and contract documents. Provide a minimum clearance of 3 inches between the end ties in a slab and any part of the transverse joint support. Keep ties free of materials that inhibit bonding to concrete or anchoring material. Maintain ties in their proper position during paving.

It is highly desirable to align longitudinal joints with the permanent pavement markings. Tied longitudinal joints located in the wheel paths of the completed pavement will require ties placed 24" on center.

1. ***Longitudinal Joints Between Lanes Paved Simultaneously.*** Use one-piece ties fabricated into assemblies capable of securely holding 2 or more ties. Secure the assemblies to subbase prior to paving in accordance with the Materials Details.

Make first-stage saw cuts parallel to the pavement centerline and perpendicular to the pavement surface before uncontrolled cracking occurs. Use equipment specified in §502-3.01D, Saw Cutting Equipment. Replace saw blades if raveling wider than 1/8 inch occurs. Center first-stage saw cuts within 1 inch of the longitudinal midpoint of the ties.

Sweep or wash first-stage saw cut debris from the pavement before it rains, or before opening the pavement to any traffic, such that debris does not enter the joint.

2. ***Tied Longitudinal Joints Between Lanes Paved Separately.*** In a slip form operation, construct a butt joint and drill and anchor one-piece ties into the hardened concrete in accordance with §502-3.06D, Drill and Anchor Dowels and Ties.

   Use # 6 ties, 22 inches (minimum) long between travel lanes and 18 inches (minimum) long between a travel lane and a PCC shoulder. Anchor ties between travel lanes 10 inches into the previously placed concrete, leaving 12 inches (minimum) projecting from the joint face. Anchor ties between a travel lane and a PCC shoulder 8 inches (minimum) into the previously placed concrete, leaving 10 inches projecting from the joint face.

   Place end ties in a slab 14 to 18 inches from the transverse joint. Typically, space ties between the end ties 36 inches apart, maximum. Pavements having 4 or more tied lanes, or 3 lane pavements 12 inches (or more) thick, may require a decreased spacing in accordance with the contract documents.

   In a fixed form operation, construct either a butt or a keyed joint. Drill and anchor one-piece ties as discussed above, or use multiple-piece ties. Apply a corrosion inhibiting coating to the threads of all multiple-piece tie components before assembly. Bolt the female portion of the tie to the form prior to paving as depicted in the Standard Sheets. Insert and tighten the male ends before paving the adjacent lane. Ensure all threaded connections are tight.

   First-stage saw cuts are not required between lanes paved separately.

3. ***Untied Longitudinal Joints.*** Construct untied longitudinal joints at utilities and/or drainage structures, at intersections, between adjacent lanes having non-parallel center lines (such as ramps), or where indicated in the contract documents. Form as depicted in the Standard Sheets. Transverse joint type, location, and alignment may be changed when a transverse joint intersects an untied longitudinal joint.

   Patch honeycombing along the untied longitudinal joint face to achieve a smooth surface prior to applying the bond breaker and placing the adjacent concrete.

   First-stage saw cuts are not required.

C. Utility and Drainage Structures and Telescoping Manholes. Detail jointing around each utility and drainage structure in the proposed joint layout submitted to the Engineer for approval. Refer to the Standard Sheets for jointing and reinforcement around utilities and drainage structures. When possible, do not isolate, or "box out," utilities and drainage structures from the pavement. Instead, set and center utilities and drainage structures between transverse joints and pave the slab with the structure at the same time as the surrounding pavement. Use a minimum slab length, L_{min}, as defined in §502-3.06A, Transverse Joints. Reinforce the slab that contains the structure. Select reinforcement size and spacing such that:

$$A_s \geq 0.0018(s)(t)$$

where:

A_s = Area of a steel bar (in^2)
s = Spacing of steel bars (in). Minimum 3" clearance between bars.
t = Slab thickness (in)

Use mat reinforcement with steel in both directions. Use top and bottom double mat reinforcement for slabs thicker than 10”. Refer to the Standard Sheet for mat reinforcement placement locations.

When using telescoping manholes, remove temporary support bolts from the telescoping manhole casting as soon as the concrete hardens.

C. Drill and Anchor Dowels or Ties. Do not drill holes until the concrete has developed sufficient strength to withstand drilling without damage. Damage from drilling shall be addressed in accordance with §502-3.14, Damaged or Defective Concrete.

Drill such that the hole diameters are in accordance with the anchoring material manufacturer’s written recommendations. Replace worn bits when necessary to ensure the proper hole diameter is drilled.

Follow the anchoring material manufacturer’s written recommendations for cleaning the holes. As a minimum, clean the drilled holes with compressed air. Insert the nozzle to the back of the hole to force out all dust and debris.

When using new cartridges of anchoring material, ensure the initial material exiting the nozzle appears uniformly mixed. If it is not uniformly mixed, waste the material until uniformly mixed material extrudes.

Place the anchoring material in the back of the hole using a nozzle with sufficient reach. Push the dowel or tie into the hole while twisting such that the air pocket within the hole is heard to burst and the anchoring material is evenly distributed around the bar. Use sufficient amounts of anchoring material such that it slightly extrudes out the hole as the bar is inserted.

502-3.07 Paving Adjacent To Existing Concrete. Wherever paving equipment operates on existing PCC pavement that is to remain, install bolt-on track covers or rubber tired, flangeless wheels. Remove all debris on the existing PCC pavement in the equipment track. Immediately remove any concrete that spills onto the existing concrete.

When paving from (or to) a transverse construction joint or intersecting pavement, use hand-held vibrators to thoroughly consolidate any concrete inaccessible to the paving equipment vibrators. Hand finish these areas with the minimum effort required to produce an acceptable surface. Do not dump the grout box head into the pavement concrete when approaching a construction joint.

502-3.08 Plastic Thickness Determination. Provide the Engineer with a round, rigid, nonaluminum probe, having a 1/8 inch diameter. The Engineer will determine the plastic concrete thickness by inserting the probe and measuring the insertion depth. The Engineer will check thickness at least every 150 feet of paving and at least 2 feet from the placement edge. Keep several probes at the project.

The minimum measured plastic thickness must be equal to (-1/4 inch) or greater than the thickness required in the contract documents. Areas not meeting minimum thickness will be treated in accordance with §502-3.14, Damaged or Defective Concrete. If 2 consecutive measurements do not meet minimum thickness, stop paving and reestablish the paving operation to achieve acceptable thickness.

502-3.09 Finishing. Provide an ACI certified concrete flatwork finisher to supervise finishing. Provide proof of ACI flatwork certification to the Engineer.

Mechanically finish the pavement after consolidation and strike off. Use machine mounted finishers such as full-width finishing pans, transverse oscillating screeds, longitudinal floats, pan floats or separate pieces of equipment such as tube floats. Correct bumps with a 16 foot straight edge or bump cutter specifically made for finishing concrete.

After mechanical finishing, hand finish the pavement to correct and seal minor imperfections. Hand finish with magnesium floats, lutes, and/or trowels. Use work bridges to hand finish concrete inaccessible from the pavement edge. Keep hand finishing to a minimum. Do not use excess mortar or discarded concrete to fill low areas. Do not add water to the concrete surface to close imperfections. Do not trowel bleed water into the surface. Stop paving or reformulate the concrete mix if surface imperfections that require additional water to close routinely occur.

Ensure the saw cut operator can locate joint sealant locations between separate, adjacent placements. This may be accomplished with a small radius (1/4 inch) edger along the edge of the second placement.

502-3.10 Texturing. Immediately after finishing and prior to applying the curing compound, texture the concrete surface using one of the following procedures in accordance with the contract documents. Apply longitudinal tining if no texturing method is designated in the contract documents. Additional requirements, such as Mean Texture Depth measured by a sand patch test or a profiler may be performed to check texturing adequacy. For a closed drainage system, provide an 8 - 12 inch blank in the texture along the pavement edges to enhance drainage to catch basins.

A. Longitudinal Tining. Texture the concrete parallel to the pavement centerline with a set of evenly spaced spring steel tines. Use rectangular tines 1/8 inch wide, 1/32 inch thick, and approximately 5 inches long at a center-to-center spacing of 3/4 inches.

Operate the tine head manually or mechanically. In either case, hold the tines as near an angle of 45° to the concrete surface as possible to minimize mortar dragging. Produce tine texture 1/16 - 1/8 inch deep with minimal dislodging of aggregate. Do not make multiple tine passes in the same area. Keep tines 2 - 4 inches from the placement edges. Keep the tines free of hardened concrete.

B. Artificial Turf Drag. Use a seamless strip of artificial turf drag appearing on the Department's Approved List entitled “Turf Drag” under “Equipment, Concrete Related.” Produce a consistent texture, free of ridges or gouges, parallel to the pavement centerline either by hand or by attaching a weighted strip to the paver, texture/cure machine, or work bridge. Periodically replace or clean the drag to remove hardened concrete paste that compromises texture.

502-3.11 Curing. Apply curing compound no later than 5 minutes after texturing. The Engineer may stop paving if curing lags beyond the time limits noted. Cure Class C concrete placed between June 1 and September 15 for 4 days, minimum. Cure Class C concrete placed between September 16 and May 31 for 6 days, minimum. Cure HES or alternate mixes in accordance with Materials Bureau requirements based on the Contractor-submitted mix design and the trial batch evaluation.

A. White Pigmented Membrane Curing Compound. Cure concrete with white pigmented membrane curing compound. Mix the curing compound before each use and continuously agitate during use. Uniformly coat all exposed surfaces (including slipformed edges and formed edges immediately after form removal) at a minimum rate of 150 sf/gal such that the coated surfaces are completely white. Check the application rate after every paving day, including exposed vertical slab faces in the calculations. Apply the curing compound in 2 direction passes with no longer than 15 minutes between passes.

Immediately reapply curing compound to any damaged coating areas before the curing compound sets. During curing equipment breakdown, cure the pavement in accordance with §502-3.11B, Curing Covers. Do not apply curing compound in the rain. If rain damages the curing compound before it sets, reapply curing compound after the pavement surface dries.

B. Curing Covers. Use of curing covers is subject to the approval of the Engineer. Use quilted covers, plastic coated fiber blankets, or polyethylene curing covers. Do not use covers with tears or holes. Cover all exposed surfaces and extend the covers a minimum of 12 inches beyond the pavement edges or beyond the forms, when used. Overlap successive covers 12 inches, minimum. Secure the covers to keep them in contact with the entire surface and maintain the overlap. Wet the entire surface of quilted covers and maintain them in a wetted condition until pavement is eligible to be opened to construction traffic.

C. Cold Weather Curing. Supply form insulating materials for winter concreting when the air temperature is going to fall below 40°F at any time until pavement is eligible to be opened to construction traffic. Use material capable of maintaining a surface temperature of 55°F and being easily removed and replaced to accommodate first-stage saw cuts. Apply the insulating material to prevent newly placed concrete from being exposed to air temperatures below 35°F for the curing period. Secure the insulation tight to the concrete surface to prevent air intrusion beneath the insulation. Extend the insulation 12 inches beyond the newly placed concrete. Insulate the pavement vertical edge and/or forms as well.

Place recording surface thermometers between the pavement surface and insulating material 12 inches from one of the placement edges wherever insulation is used. Use 4 equally spaced thermometers for each day's paving. Do not subject the concrete to a temperature drop in excess of 50°F during the first 24 hours after removing the insulation.

502-3.12 Sealing Joints. Seal joints in accordance with the Standard Sheets.

First-stage saw cuts may be temporarily left unfilled if a placement is only subjected to occasional construction traffic, such as pickup trucks or cars. In this case, ensure debris does not enter the joints.

Temporarily fill unsealed first-stage cuts with jute or backer rod if a placement is:

- Subjected to consistent construction traffic.
- Used as a haul road for subsequent concrete placements.
- Temporarily opened to general traffic while final sealing has been delayed for convenience, such as to maximize sealing production.

Before cleaning, remove any temporary fillers and repair damaged joints in accordance with §502-3.14, Defective or Damaged Concrete, including chipped joints resulting from debris accumulation in an unfilled or unsealed joint.

A. Highway Joint Sealant. Widen joints to 1/4 - 3/8 inch for a depth of 1 inch to allow full-depth sealing. Immediately wash the widening cut slurry from the pavement such that it does not reenter the joint.

Clean the joints by abrasive blasting before sealing. Keep the nozzle within 2 inches of the joint surfaces. If the project does not allow abrasive blasting, The Engineer may allow pressure washing as an alternate preparation method. When pressure washing, use (1) a 900 psi minimum pressure and (2) a maximum pressure such that no damage occurs to the concrete. Manually dislodge debris remaining in the joint after cleaning, and reclean the joint. Immediately after pressure washing, air blast the joint to remove any debris from the cut and dry the exposed faces. Ensure the joint is completely dry before sealing.

Do not allow any traffic on the pavement between cleaning and sealing. Reclean the joint if it rains between cleaning and sealing or if any traffic is on the placement between cleaning and sealing.

Provide the Engineer a copy of the sealant Manufacturer's written recommendations for heating and application at least 1 work day before sealing. Follow those recommendations. Unless stated otherwise, the recommended pouring temperature is 40°F below the manufacturer's designated safe heating temperature, with an allowable variation of 40°F.

Prior to sealing, discharge sealant from the applicator wand into a vessel and measure the sealant temperature. The temperature must be equal to or above the Manufacturer’s recommended minimum pouring temperature and equal to or below the Manufacturer’s recommended safe heating temperature.

Do not use sealant heated above the safe heating temperature. Sealant may be reheated or heated in excess of 6 hours if allowed by the Manufacturer’s heating and application recommendations. In these cases, recharge the melter with fresh sealant amounting to at least 20% of the sealant volume remaining in the melter.

Seal joints immediately after cleaning. Seal the joint from the bottom of the cut to within 1/2 inch of the pavement surface. Seal when the:

- Air and surface temperatures are 40°F or warmer.
- Air temperature is above the dew point.
- Pavement surface and all joint surfaces are dry.

Open to traffic after the sealant has cured to prevent tracking. Do not blot with fine aggregate.

B. Sealing Joints - Preformed Joint Sealers. Make second-stage saw cuts and/or bevels in accordance with the Standard Sheets and (1) no sooner than 72 hours after concrete placement and (2) after the curing period has ended if curing covers are used. Extend the second-stage saw cut vertically down the free concrete edges. Wash the resulting slurry from the pavement and joint immediately after making second-stage saw cuts and/or bevels.

Second-stage saw cuts may be delayed for convenience, but do not leave second-stage saw cuts unsealed or unfilled while open to any traffic. Temporarily fill second-stage saw cuts with jute or backer rod if (1) they are exposed to any traffic before cleaning and sealing or (2) weather conditions are not favorable for timely (within 2 calendar days) cleaning and sealing, whether or not they are exposed to any traffic.

Clean the joints by pressure washing before sealing. Use (1) a 900 psi minimum pressure and (2) a maximum pressure such that no damage occurs to the concrete. Manually dislodge debris remaining in the joint after cleaning, and reclean the joint. Within 24 hours of pressure washing, air blast the joint to remove any debris from the cut and dry the exposed faces. Reclean the joint if it rains between cleaning and sealing. Do not allow any traffic on the pavement between cleaning and sealing.

Install the sealant in accordance with the Manufacturer’s written instructions. Lubricate the concrete, the sealer, or both before installation such that the lubricant fully covers the sealer/concrete interface, but not the top of the sealer.

Install one piece of transverse joint sealer in a compressed condition across the full pavement width, including concrete shoulders, and down the vertical saw cut at the free edge. Cut the longitudinal sealer where it crosses a transverse joint. Do not splice the longitudinal sealer between transverse joints. Seal the intersection between longitudinal and transverse sealers with lubricant.

Install the sealer such that it is not stretched more than 5%, nor compressed more than 2%, of the minimum theoretical length. Check the installation for stretch and compression by installing sealers in 5 transverse joints and removing the sealer immediately after installation and checking the length. An alternate method for checking stretch and compression, where applicable, may be performed by premarking or precutting the sealer to length prior to installation. If the measurement of any of these 5 sealers exhibits stretching in excess of 5% or compression in excess of 2%, modify the installation method to meet the requirements or discontinue installation.

Once sealing operations begin, remove 1 joint per 100 in the presence of the Engineer to check stretch and compression. If the sealer is found to be stretched in excess of 5% or compressed in excess of 2%, remove the sealer material from successive joints in both directions until sealers are found that meet the stretch and compression requirements. Replace all joints sealers found with excess stretch or compression. Replace joint sealers removed and found to meet the stretch and compression requirements.

502-3.13 Pavement Protection. Protect the pavement and appurtenances from traffic and construction operations. Protect the work and provide for traffic as indicated in the contract documents.

502-3.14 Damaged or Defective Concrete. The Engineer will identify all areas of damaged and defective concrete. Submit a repair plan for the damaged or defective concrete to the Engineer for approval. Repair or replace all damaged or defective concrete in accordance with the approved repair plan. Damage and defects include, but are not limited to, cracking, spalling, poor consolidation, out of specification materials, or imperfections caused by inadequate pavement protection, traffic, and/or construction practices. Slipformed concrete with inadequate plastic thickness as described in §502-3.08, Plastic Thickness Determination, will be rejected in 150 foot segment lengths.

502-3.15 Hardened Surface Tolerance. After the concrete has hardened sufficiently, test each travel lane, including ramps, with straight edges laid both longitudinally and transversely. Do not measure transverse deviations across longitudinal joints. The Engineer will mark longitudinal deviations in the pavement surface exceeding 1/4 inch in 15 feet and transverse deviations exceeding 1/4 inch in 10 feet. Diamond grind these deviations in accordance with §505-3.02, Bump Grinding, such that they do not exceed these parameters when retested.

Shoulders and other areas not routinely exposed to traffic must meet 1/4 inch in 10 feet both longitudinally and transversely.

502-3.16 Opening to Traffic

A. ***Construction Traffic.*** Open Class C concrete pavement to construction traffic and paving equipment at least 7 days after placement. With the Engineer’s approval, the time may be shortened to 3 days if cylinders meet the requirements of Table 502-3 Pavement Opening Requirements. Any pavement damaged from opening to construction traffic in a reduced time frame will be treated in accordance with §502-3.14, Damaged or Defective Concrete.

B. General Traffic. Open Class C concrete pavement to general traffic placed between June 1 and September 15 at least 10 days after placement. Open Class C concrete pavement to general traffic placed outside of the above dates at least 15 days after placement.

With the Engineer's approval, these times may be shortened to 4 days if cylinders meet the requirements of Table 502-3 Pavement Opening Requirements, and the joints are addressed in accordance with §502-3.12, Sealing Joints.

Any pavement damaged from opening to general traffic in a reduced time frame will be treated in accordance with §502-3.14, Damaged or Defective Concrete.

TABLE 502-3 PAVEMENT OPENING REQUIREMENTS		
All the Following Must Apply:	Construction Equipment	General Traffic
Minimum Average compressive strength of all cylinder pairs	2500 psi	3000 psi
Minimum Average compressive strength of each cylinder pair	2000 psi	2500 psi

Note: Automobile only areas may be opened at 1500 psi.

C. Project Strength Determination. Provide an ACI Certified Concrete Field Testing Technician, Grade I, or higher, to cast all cylinders. Unless otherwise noted in the contract documents, use an agency accredited by the AASHTO Accreditation Program (AAP) in the field of construction materials testing of Portland cement concrete to perform compressive strength testing. Cast and test in the presence of the Engineer, or the Engineer's representative. Provide acceptable proof of ACI Certification and AASHTO Accreditation to the Engineer before placing any concrete.

The Engineer, or the Engineer's representative, will complete the Concrete Cylinder Report as cylinders are cast and tested.

Cast a minimum of 3 cylinder pairs (6 total) from each 1000 feet of paving length, or fraction thereof, in accordance with *Materials Method 9.2*, Field Inspection of Portland Cement Concrete. Cast each pair from different delivery trucks. Develop an Engineer-approved marking system that allows a cylinder to be readily associated with the corresponding placement location and placement time. Mark the cylinders and place them adjacent to the pavement under similar curing conditions. Determine the concrete compressive strength at the desired time in accordance with ASTM C39, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. The pavement may be opened to construction (or general) traffic if all the cylinders meet the requirements of Table 502-3 Pavement Opening Requirements.

If these conditions are not met, test 3 additional cylinder pairs at a later time, provided the appropriate numbers of additional cylinders were cast. If the above conditions are not met after additional testing, or, if the required number of additional cylinders were not cast, open the pavement in accordance with the nonreduced time frames of §502-3.16A, Construction Traffic, and §502-3.16B, General Traffic.

D. HES Concrete. Open HES concrete pavements to construction traffic or general traffic based on the requirements of Table 502-3 Pavement Opening Requirements, and if the joints have been addressed in accordance with §502-3.12, Sealing or Filling Joints.

E. Maturity. ASTM C1074, Standard Practice for Estimating Concrete Strength by the Maturity Method, may be used to open the pavement to traffic. Inform the Engineer of the intent to use this method at least 28 days before producing any pavement concrete. Submit a maturity curve development plan to the Engineer that includes an equipment list, the date and time of batching, the testing facility name and address, which must meet §502-3.16C, Project Strength Determination, requirements, and any variations to ASTM C1074. Perform all batching and testing related to developing the maturity curve with the Engineer and Regional Materials Engineer present. Open to traffic at the strengths identified in Table 502-3 Pavement Opening Requirements.

502-4 METHOD OF MEASUREMENT. The Engineer will measure the following quantities for items incorporated into the finished pavement:

502-4.01 PCC Pavement, Unreinforced. The work will be measured for payment as the number of cubic yards of unreinforced PCC pavement placed based on the payment lines shown in the contract documents, to the nearest cubic yard. Deductions will be made for catch basins, manholes, or other similar pavement obstructions requiring either mesh reinforced or heavily reinforced placements.

502-4.02 PCC Pavement, Mesh or Heavily Reinforced. The work will be measured for payment as the number of cubic yards of reinforced concrete placed. No deductions will be made for drainage and utility structures or other similar pavement obstructions within the placement.

502-4.03 Transverse Joints. The work will be measured for payment as the number of feet of transverse joints constructed.

502-4.04 Longitudinal Joints. The work will be measured for payment as the number of feet of longitudinal joints constructed.

502-4.05 Sealing Transverse Joints. The work will be measured for payment as the number of feet of transverse joints sealed, excluding preformed sealers turned down at the pavement edges.

502-4.06 Sealing Longitudinal Joints. The work will be measured for payment as the number of feet of longitudinal joints sealed.

502-5 BASIS OF PAYMENT

502-5.01 This subsection is intentionally blank.

502-5.02 PCC Pavement, Unreinforced. Include the cost of all labor, material, and equipment necessary to perform the work, including first-stage saw cuts, in the unit price bid for PCC Pavement, Unreinforced. No payment will be made for areas that do not meet minimum plastic thickness requirements.

502-5.03 PCC Pavement, Mesh or Heavily Reinforced. Include the cost of all labor, material, and equipment necessary to satisfactorily perform the work, including first-stage saw cuts, in the unit price bid for PCC Pavement, Mesh or Heavily Reinforced. No payment will be made for areas that do not meet minimum plastic thickness requirements.

502-5.04 Transverse Joints. Include the cost of all labor, material, and equipment necessary to perform the work in the unit price bid for Transverse Joints.

502-5.05 Longitudinal Joints. Include the cost of all labor, material, and equipment necessary to perform the work in the unit price bid for Longitudinal Joints. Placing the inside shoulder and inside lane simultaneously, at the Contractor's option, will not generate a Significant Change in the Character of Work. No additional payment will be provided for the additional number of longitudinal joint ties associated with:

- Constructing butt joints between lanes placed separately in a slipform paving operation.
- Constructing longitudinal joints in wheelpaths.

502-5.06 Sealing Transverse Joints. Include the cost of all labor, material, and equipment necessary to perform the work in the unit price bid for Sealing Transverse Joints.

502-5.07 Sealing Longitudinal Joints. Include the cost of all labor, material, and equipment necessary to perform the work in the unit price bid for Sealing Longitudinal Joints. Placing the inside shoulder and inside lane simultaneously, at the Contractor's option, will not generate a Significant Change in the Character of Work.

Payment will be made under:

Item No.	**Item**	**Pay Unit**
502.RCFL	PCC Pavement	Cubic Yard

R – Pavement Reinf.	*C – Concrete Class*	*F – Friction Type*	*L–Load Transfer*
0 – Unreinforced	*1 – Class C*	*1 – Type 1*	*0 – Epoxy coated*
1 – Mesh Reinforced	*2 – Performance*	*2 – Type 2*	
2 – Heavily Reinforced	*3 – HES*	*3 – Type 3*	
		9 – Type 9	

502.91	Transverse Joints	Foot
502.9110	Longitudinal Joints	Foot
502.9201	Sealing Transverse Joints – Preformed Elastic Joint Sealer	Foot
502.9210	Sealing Transverse Joints – Highway Joint Sealant	Foot
502.9301	Sealing Longitudinal Joints – Preformed Elastic Joint Sealer	Foot
502.9310	Sealing Longitudinal Joints – Highway Joint Sealant	Foot

A-2

ITEM 504.02010001 – PERFORMANCE ENGINEERED CONCRETE MIXTURE FOR PAVEMENTS

DESCRIPTION

Develop a Performance Engineered Mixture (PEM) for Portland Cement Concrete (PCC) pavement applications to meet specified performance criteria. The PEM shall be used at locations specified in the contract.

The Contractor shall perform all Quality Control (QC) activities, including providing a QC plan for PCC production, sampling and testing of concrete as required to produce PCC that meets all specification requirements, and provide control charts to track mixture characteristics.

MATERIALS

The provisions of §502-2 shall apply, except as modified herein.

1. Use materials meeting the requirements of 501-2.02
2. Design a concrete mixture proportioned according to AASHTO PP 84, *Developing Performance Engineered Concrete Pavement Mixtures*, for the below specified performance criteria. The mix shall have a well graded aggregate gradation to minimize the paste content while maintaining workability. Aggregate gradation shall meet the requirements of the Tarantula curve (or Shilstone method or 8-18 method) as defined by FHWA at https://www.fhwa.dot.gov/pavement/concrete/pubs/hif15019.pdf

Produce a homogeneous mixture of cement, pozzolan (fly ash or GGBFS), fine aggregate, coarse aggregate, air entraining agent, water-reducing and set-retarding admixture, and water using NYSDOT Approved List materials. Other admixtures may be used as approved by the Director, Materials Bureau.

3. Design a concrete mixture to meet the following requirements:
   - Compressive Strength of 4,000 psi minimum.
   - Flexural Strength of 600 psi minimum.
   - Slump as desired by contractor for workability.
   - Entrained Air of 5% to 10%.
   - Super Air Meter (SAM) number <0.20 using AASHTO TP118
   - Water/Total Cementitious Material Ratio of 0.40 maximum.
   - Paste volume maximum 25% as defined by AASHTO PP84
   - Resistivity >16.5 kΩ-cm using AASHTO T358

4. Perform mix development testing in accordance with ASTM C143, C231, C192, C39, AASHTO T97, T358 and AASHTO TP118 to prove all performance criteria are met.

5. Prior to the start of any concrete placement, submit a copy of the proposed mixture design(s) and trial batch test results to the Regional Materials Engineer, for evaluation. Submit sufficient data to permit an informed evaluation. Include at least the following:

- Concrete mix proportions
- Aggregate composite gradation of mixture.
- Material sources. Include fineness modulus and specific gravity for all aggregates.
- Compressive and Flexural Strength at desired age of opening to traffic, with 28 day results for records when available.
- Target slump for placement
- Target air content of plastic concrete.
- SAM number results of trail mix
- Paste volume calculations for mix
- Resistivity test data

Resubmit any proposed mixture design changes to the Regional Materials Engineer for evaluation. Multiple mixture designs may be used to address performance and placement issues as deemed necessary by the Contractor. Submit each mixture for evaluation, as indicated above, prior to use.

Upon completion of mixture development, trial placement(s) may be progressed at the Contractors discretion. Trial placements may be incorporated into the work as a substitute for the placement of another Class of concrete.

CONSTRUCTION DETAILS

The provisions of §502-3 shall apply, except as modified herein:

Quality Control

Develop and submit for approval a QC Plan (QCP) for batching and delivery of concrete to meet the defined performance criteria above and to maintain quality of the mixture during production. The QCP shall encompass all activities of production and transportation of concrete.

The QCP shall detail the operations at the production facility, describing how such operations are in conformance with the specifications including but not limited to:

- Mixture design(s)
- Plant conditions and operations
- Delivery vehicle conditions
- Material management
    - Cements compliance
    - Aggregate stockpile management, gradation, and friction
    - Admixture condition, use, and compatibility
- Batching operations and QC Transportation operations and QC
- Outlining testing frequencies, testing procedures, and documentation
- Maintaining certifications and documentation

Quality Control (QC) Sampling and Testing

The Contractor shall:

- Perform QC sampling and testing of plastic PCC for all placements. Contractor results will not be used for acceptance.
- Ensure that all tests are in compliance with this specification and targeted values in the approved mixture design.
- Provide an American Concrete Institute (ACI) Certified Concrete Field Testing Technician, Grade 1, or higher to perform the following practices and tests when sampling and testing plastic PCC:
    - Concrete Sampling per ASTM C172
    - Concrete Temperature per ASTM C1064
    - Concrete Slump per ASTM C143
    - Concrete Air Content by Pressure Method per ASTM C231
    - Concrete Cylinder and beam casting per ASTM C31

- Provide acceptable proof of ACI Certification of the Concrete Field Testing Technician before placing any concrete.
- Properly maintain and calibrate all equipment prior to use by the Contractor and provide calibration records for all equipment being used.
- Develop and maintain control charts to be provided to the Department for the following:
    - w/c ratio of each batch
    - paste content of each batch
    - slump for all tests performed
    - air content for all tests performed

Perform all sampling and testing in the presence of the Engineer or designee.

Sampling and testing rate/frequency will be daily on the first load/batch and subsequent loads/batches until consistency of production is proven. QC sampling and testing may then be gradually reduced to frequencies defined per Materials Method (MM) 9.2 *Field Inspection of Portland Cement Concrete (PCC)*. See Table 2 and Table 3 of MM 9.2 for additional Information. QC sampling and testing will be performed before allowing any initial slump adjustment, and again after any retempering as allowed by specification, to prove concrete meets specification requirements prior to the start of discharge.

The Contractor shall cast 6 - 4” x 8” cylinders for each day’s placement with samples taken randomly from 2 different trucks of a placement. Cylinders shall be provided to the Department within 24 hours of casting. Test samples will be cured by the Department for 28 days following the requirements of ASTM C31 (15), *Standard Practice for Making and Curing Concrete Test Specimens in the Field.*

The Contractor shall cast 2 - 6” x 6” beams for each day’s placement with samples taken randomly from 2 different trucks of a placement. Beams shall be provided to the Department within 24 hours of casting. Test samples will be cured by the Department for 28 days following the requirements of ASTM C31 (15), *Standard Practice for Making and Curing Concrete Test Specimens in the Field.*
The Contractor shall develop and maintain control charts to be provided to the Department for the following:

- w/c ratio of each batch
- paste content of each batch
- slump for all tests performed
- air content for all tests performed

Quality Assurance (QA) Acceptance Sampling and Testing
Acceptance sampling and testing will be performed by Department only after the QC testing is complete and the concrete is presented to the Department as being in compliance with contract documents. Acceptance sampling and testing will be performed per Materials Method (MM) 9.2, Field Inspection of Portland Cement Concrete (PCC), at the "Cylinder Series" frequency or as directed by the Engineer-In-Charge.
Acceptance criteria for PEM Concrete shall be:

- Air content 5% to 10%
- Compressive strength >4,000 psi using 6" x 12" cylinders cast by the Department

Informational QA Testing
To evaluate resistivity, the Department will perform Surface Resistivity testing on 4" x 8" cylinders provided by the Contractor, for each day's placement, following AASHTO T-358 *Standard Method of Test for Electrical Resistivity of a Concrete Cylinder Tested in a Uniaxial Resistance Test.* Results will be for informational purposes only.

To evaluate flexural strength, the Department will perform flexural testing on 6" x 6" beams provided by the Contractor, for each days placement, following AASHTO T97 (14) *Flexural Strength of Concrete (using Simple Beams with Third Point Loading)*. Results will be for informational purposes only.

To evaluate freeze/thaw durability of the concrete, the Department will perform air content testing using the Super Air Meter (SAM) per AASHTO TP 118 (17) *Standard Method of Test for Characterization of the Air-Void System of Freshly Mixed Concrete by the Sequential Pressure Method*, on plastic concrete samples during placement. The results of all SAM tests performed for each days placement will be averaged to determine the SAM number for each day, for informational purposes only.

METHOD OF MEASUREMENT
The Quality Control work for the Performance Engineered Concrete will be measured on a Fixed Price Lump Sum basis.

BASIS OF PAYMENT
The fixed amount shown in the proposal shall include the cost of the mixture design, laboratory testing for mixture acceptance, development of a QC Plan, QC sampling and testing throughout production, informational data collection and any incidentals.

Progress payments will be made as follows:

40 percent of the fixed amount will be paid after development of a QC Plan and mix design. 40 percent will be paid after the concrete QC has been completed. The remaining 20 percent will be paid after data and control charts have been provided to the Department.

504.02010001 Performance Engineered Concrete Mixture for Pavements Lump Sum

A-3 Plastic Testing

DATE	CLASS	SLUMP (in)	CON. TEMP	AIR (POT)	AIR (SAM)	SAM#
5/1/2019	C	2.50	64	10.0	9.3	0.12
		3.00	60	5.0	5.5	0.12
		3rd Test	VOID	Not Stable		
5/2/2019	C	4.00	63	12.0	12.7	0.16
		4.00	64	9.0	9.1	0.12
5/6/2019	C	5.00	62	5.8		
		3.00	62	7.3		
		4.50	64	8.5		
5/7/2019	C	3.50	59	7.3		
		4.50	61	7.4		
		3.00	64	7.6		
5/8/2019	C	4.25	60	7.8		
		3.50	62	6.6		
		3.25	65	7.8		
5/9/2019	C	3.50	55		7.6	0.10
		4.00	58	7.8	7.8	0.05
		3.50	64		5.8	0.05
5/13/2019	PEM	3.50	69	8.0	8.1	0.12
	PEM	2.00	70	5.9	5.3	0.23
	PEM	3.50	71	6.0	6.1	0.15
	PEM	4.00	72	8.1	8.0	0.09
5/15/2019	PEM	3.75	69	7.6	7.3	0.11
	PEM	3.75	73	10.0	8.8	0.04
	PEM	3.00	77	6.4	6.1	0.16
5/16/2019	PEM	2.50	71	6.8	7.3	NERR (0.21)
	PEM	3.25	74	6.5	7.2	0.06
	PEM	3.25	74	4.7	5.3	0.19
5/17/2019	REJECTED	Due to TIME and RAIN				
	PEM	4.00	62	8.2	10.0	0.22
5/21/2019	PEM	3.25	68	6.5	6.3	0.18
	PEM	2.5	68	6.4		
5/22/2019	PEM	3.25	66	7.0	6.5	0.23
	PEM	2.50	70	7.0	7.1	0.07
	PEM	3.50	71	6.8	6.3	0.11
5/23/2019	PEM	2.25	70	5.8	6.7	NERR
	RETEST of SAME Material-+/- 15 min Later				6.0	0.28
	PEM	3.00	72	6.2	6.1	0.04
5/24/2019	PEM	2.00	80	6.2		
	PEM	2.25	70	6.4		
5/29/2019	PEM	3.50	68	5.5	5.3	0.25
	PEM	3.50	69	6.6	6.2	0.19
5/31/2019	PEM	4.25	71	7.8	7.4	0.27
	PEM	2.00	75	5.8	5.8	0.09
	PEM	1.75	76	5.0	5.2	0.26

A-4 Compression

REGION	DATE	CLASS	Date Tested	Days to Test	Comp. Strength (psi)		Avg. Comp. Strength (psi)
1	5/1/2019	C	5/8/2019	7 Day	4245	4262	4254
			5/14/2019	14 Day	4988	5005	4997
			5/29/2019	28 Day	5235	5412	5324
1	5/2/2019	C	5/30/2019	28 Day	3184	3360	3272
			5/30/2019	28 Day	2830	3360	3095
1	5/6/2019	C	6/3/2019	28 Day	4156	4192	4174
			6/3/2019	28 Day	4068	4121	4095
			6/3/2019	28 Day	3997	3750	3874
1	5/7/2019	C	6/4/2019	28 Day	4475	4634	4555
			6/4/2019	28 Day	4439	4510	4475
			6/4/2019	28 Day	4775	4722	4749
1	5/8/2019	C	6/5/2019	28 Day	4156	3997	4077
			6/5/2019	28 Day	4770	4970	4870
			6/5/2019	28 Day	4669	4687	4678
1	5/9/2019	C	6/6/2019	28 Day	4068	4280	4174
			6/6/2019	28 Day	3909	4103	4006
			6/6/2019	28 Day	4917	5023	4970
1	5/13/2019	PEM	5/16/2019	3 Day	3007	3007	3007
			5/19/2019	6 Day	4457	4616	4537
			5/20/2019	7 Day	4881	4634	4758
			5/27/2019	14 Day	5536	5377	5457
			6/10/2019	28 Day	6473	6403	6438
		PEM	6/10/2019	28 Day	6544	6686	6615
		PEM	6/10/2019	28 Day	5730	5695	5713
1	5/15/2019	PEM	6/12/2019	28 Day	5730	5447	5589
		PEM	6/12/2019	28 Day	6226	6208	6217
1	5/16/2019	PEM	6/13/2019	28 Day	5005	5235	5120
		PEM	6/13/2019	28 Day	5288	5483	5386
1	5/17/2019	PEM	6/14/2019	28 Day	4705	4652	4679
1	5/21/2019	PEM	6/18/2019	28 Day	4970	5695	5333
		PEM	6/18/2019	28 Day	5943	5960	5952
1	5/22/2019	PEM	6/19/2019	28 Day	5341	5341	5341
		PEM	6/19/2019	28 Day	5094	5341	5218
1	5/23/2019	PEM	6/20/2019	28 Day	4439	4457	4448
		PEM	6/20/2019	28 Day	5164	5076	5120
1	5/24/2019	PEM	6/21/2019	28 Day	4952	4846	4899
		PEM	6/21/2019	28 Day	5465	5394	5430
1	5/29/2019	PEM	6/26/2019	28 Day	5589	5571	5580
		PEM	6/26/2019	28 Day	5677	5642	5660
1	5/31/2019	PEM	6/28/2019	28 Day	5129	5341	5235
		PEM	6/28/2019	28 Day	5907	6261	6084

A-5 Flexural

REGION	DATE	CLASS	Date Tested	Days to Test	Flex. Strength (psi)	Avg. Flex. Strength (psi)
1	4/8/2019	Trial PEM	5/6/2019	28 Day	600.72	558.69
		Trial PEM			516.65	
1	4/12/2019	Trial PEM	4/26/2019	14 Day	555.76	541.89
		Trial PEM			528.02	
1	4/12/2019	Trial PEM	5/10/2019	28 Day	563.48	538.95
		Trial PEM			514.42	
1	5/1/2019	C	5/29/2019	28 Day	624.74	578.87
		C			533	
1	5/2/2019	C	5/30/2019	28 Day	452.36	482.92
		C			513.48	
1	5/6/2019	C	6/3/2019	28 Day	592.65	594.19
		C			598.73	
1	5/7/2019	C	6/4/2019	28 Day	625.35	611.95
		C			598.55	
1	5/8/2019	C	6/5/2019	28 Day	654.14	656.85
		C			659.56	
	5/9/2019	C	6/6/2019	28 Day	694	687.60
1		C			681.20	
1	5/13/2019	PEM	6/10/2013	28 Day	687.62	692.31
		PEM			696.99	
1	5/15/2019	PEM	6/12/2019	28 Day	703.17	684.95
		PEM			666.72	
1	5/16/2019	PEM	6/13/2019	28 Day	657.65	653.52
		PEM			649.39	
1	5/21/2019	PEM	6/18/2019	28 Day	661.23	666.29
		PEM			675.34	
1	5/22/2019	PEM	6/19/2019	28 Day	699.93	687.63
		PEM			675.32	
1	5/23/2019	PEM	6/20/2019	28 Day	708.29	697.10
		PEM			685.85	
1	5/24/2019	PEM	6/21/2019	28 Day	664.97	657.60
		PEM			650.26	
1	5/29/2019	PEM	6/26/2019	28 Day	726.89	672.70
		PEM			618.5	
1	5/31/2019	PEM	6/28/2019	28 Day	650.26	669.05
		PEM	6/28/2019	28 Day	687.83	

A-6 Freeze/Thaw

Date Cast	Age at time of F/T	**F/T % Loss**	Average F/T % loss
5/13/2019	56 Day	**0.6**	0.4
5/13/2019	56 Day	**0.4**	
5/13/2019	56 Day	**0.2**	
5/15/2019	42 Day	**2.7**	2.8
5/15/2019	42 Day	**3.1**	
5/15/2019	42 Day	**2.5**	
5/22/2019	35 Day	**2.9**	2.6
5/22/2019	35 Day	**2.6**	
5/22/2019	35 Day	**2.4**	
5/29/2019	28 Day	**3.7**	3.0
5/29/2019	28 Day	**3.4**	
5/29/2019	28 Day	**1.9**	

A-7 Class C SR

Date Cast	Truck #	Cylinder Size	Class	14 Day SR	14 Day 4x8 Equivalent (1.27 Factor)	21 Day SR	21 Day 4x8 Equivalent (1.27 Factor)	28 Day SR	28 Day 4x8 Equivalent (1.27 Factor)
5/1/2019	2	6x12	C	6.4	8.1		0.0	7.1	9.0
5/1/2019	3	6x12	C	7.3	9.3		0.0	7.8	9.9
5/1/2019		6x12	C		0.0		0.0	7.2	9.1
5/2/2019	NR	6x12	C	5.8	7.4	6.1	7.7	6.4	8.1
5/2/2019	NR	6x12	C		0.0		0.0	6.1	7.7
5/2/2019	NR	6x12	C		0.0		0.0	6.2	7.9
5/6/2019	NR	6x12	C	7	8.9	7.6	9.7	7.8	9.9
5/6/2019	NR	6x12	C		0.0		0.0	6.2	7.9
5/6/2019	NR	6x12	C		0.0		0.0	7.7	9.8
5/6/2019	NR	6x12	C		0.0		0.0	7.1	9.0
5/7/2019	NR	6x12	C		0.0		0.0	7.8	9.9
5/7/2019	NR	6x12	C		0.0		0.0	7.5	9.5
5/7/2019	NR	6x12	C		0.0		0.0	7.6	9.7
5/7/2019	NR	6x12	C	7.1	9.0		0.0	8.1	10.3
5/8/2019	NR	6x12	C		0.0		0.0	7.6	9.7
5/8/2019	NR	6x12	C		0.0		0.0	7.8	9.9
5/8/2019	NR	6x12	C		0.0		0.0	8.3	10.5
5/9/2019	NR	6x12	C		0.0		0.0	7.3	9.3
5/9/2019	NR	6x12	C	6.8	8.6	7	8.9	7.4	9.4
5/9/2019	NR	6x12	C	7	8.9	7.2	9.1	7.7	9.8

A-8 Class PEM SR

Date Cast	Truck #	Cylinder Size	Class	14 Day SR	14 Day 4x8 Equivalent (1.27 Factor)	21 Day SR	21 Day 4x8 Equivalent (1.27 Factor)	28 Day SR	28 Day 4x8 Equivalent (1.27 Factor)
4/8/2019	Trial 1	4x8	PEM	8.5	8.5	9.3	9.3	10.1	10.1
4/12/2019	Trial 2	4x8	PEM	7.2	7.2	8.2	8.2	9.3	9.3
5/13/2019	3	4x8	PEM					13.1	13.1
5/13/2019	6	4x8	PEM					12.7	12.7
5/13/2019	10	4x8	PEM					13.1	13.1
5/13/2019	3	6x12	PEM					9.9	12.6
5/13/2019	6	6x12	PEM					9.9	12.6
5/13/2019	10	6x12	PEM					9.9	12.6
5/15/2019	2	4x8	PEM					12.3	12.3
5/15/2019	10	4x8	PEM					13	13.0
5/15/2019	2	6x12	PEM					10.4	13.2
5/15/2019	10	6x12	PEM					9.8	12.4
5/16/2019	2	4x8	PEM					11.6	11.6
5/16/2019	12	4x8	PEM					10.6	10.6
5/16/2019	2	6x12	PEM					10	12.7
5/16/2019	12	6x12	PEM					9.5	12.1
5/17/2019	2	6x12	PEM					8.5	10.8
5/21/2019	2	4x8	PEM					11.6	11.6
5/21/2019	6	4x8	PEM					13.5	13.5
5/21/2019	2	6x12	PEM					8.9	11.3
5/21/2019	6	6x12	PEM					10.1	12.8
5/22/2019	2	4x8	PEM					10.9	10.9
5/22/2019	7	4x8	PEM					10.7	10.7
5/22/2019	2	6x12	PEM					9.1	11.6
5/22/2019	7	6x12	PEM					8.3	10.5
5/23/2019	2	4x8	PEM					10	10.0
5/23/2019	9	4x8	PEM					10.4	10.4
5/23/2019	2	6x12	PEM					8	10.2
5/23/2019	9	6x12	PEM					8.8	11.2
5/24/2019	2	4x8	PEM					12.5	12.5
5/24/2019	10	4x8	PEM					13.2	13.2
5/24/2019	14	4x8	PEM					12.1	12.1
5/24/2019	2	6x12	PEM					8.6	10.9
5/24/2019	14	6x12	PEM					8.1	10.3
5/29/2019	3	4x8	PEM					10	10.0
5/29/2019	6	4x8	PEM					11.3	11.3
5/29/2019	3	6x12	PEM					7.4	9.4
5/29/2019	6	6x12	PEM					8.3	10.5
5/31/2019	2	4x8	PEM	8.5	8.5			11.8	11.8
5/31/2019	10	4x8	PEM	8.8	8.8			11.6	11.6
5/31/2019	14	4x8	PEM	9.3	9.3			11.7	11.7
5/31/2019	2	6x12	PEM					9.1	11.6
5/31/2019	14	6x12	PEM					9.3	11.8

Class PEM SR Continued

Date Cast	Truck #	Cylinder Size	Class	42 Day SR	56 Day SR	70 Day SR	84 Day SR	91 Day SR	98 Day SR	112 Day SR
4/8/2019	Trial 1	4x8	PEM	12.2	13.8	16.3	16.9			
4/12/2019	Trial 2	4x8	PEM	11.8	14	15.9	15.9		18.8	20.5
5/13/2019	3	4x8	PEM	16.8	19.5	22.3	24.6		26.3	29.1
5/13/2019	6	4x8	PEM	16.1	18.8	21.8				
5/13/2019	10	4x8	PEM	16.1	19					
5/13/2019	3	6x12	PEM							
5/13/2019	6	6x12	PEM							
5/13/2019	10	6x12	PEM							
5/15/2019	2	4x8	PEM	14.7	17.6	19.9	20.9	22.6		
5/15/2019	10	4x8	PEM	16.1						
5/15/2019	2	6x12	PEM							
5/15/2019	10	6x12	PEM							
5/16/2019	2	4x8	PEM	13.7	15.9	18.5	19.5	20		
5/16/2019	12	4x8	PEM	12.5	15	17.3				
5/16/2019	2	6x12	PEM							
5/16/2019	12	6x12	PEM							
5/17/2019	2	6x12	PEM							
5/21/2019	2	4x8	PEM		17.5					
5/21/2019	6	4x8	PEM		19.9	22.6	24.1		27.2	
5/21/2019	2	6x12	PEM							
5/21/2019	6	6x12	PEM							
5/22/2019	2	4x8	PEM							
5/22/2019	7	4x8	PEM	14	15.9	18	20	20.9	21.8	22.8
5/22/2019	2	6x12	PEM							
5/22/2019	7	6x12	PEM							
5/23/2019	2	4x8	PEM	12.4	14.1	16.3	17.2	18.3		
5/23/2019	9	4x8	PEM	14	14.4					
5/23/2019	2	6x12	PEM							
5/23/2019	9	6x12	PEM							
5/24/2019	2	4x8	PEM	16.4	19.3					
5/24/2019	10	4x8	PEM	15.6	18.9					
5/24/2019	14	4x8	PEM	15.3	18.1	21.4	22.7	24.2		
5/24/2019	2	6x12	PEM							
5/24/2019	14	6x12	PEM							
5/29/2019	3	4x8	PEM	13	15.4	17.1	18.8	19.8		
5/29/2019	6	4x8	PEM							
5/29/2019	3	6x12	PEM							
5/29/2019	6	6x12	PEM							
5/31/2019	2	4x8	PEM	15	17.7					
5/31/2019	10	4x8	PEM	15	18.3					
5/31/2019	14	4x8	PEM	15.7	18.8	20.3	23.4	23.6	25.3	27.1
5/31/2019	2	6x12	PEM							
5/31/2019	14	6x12	PEM							

Class PEM SR Continued

Date Cast	Truck #	Cylinder Size	Class	126 Day SR	140 Day SR	154 Day SR	168 Day	182 Day	196 Day	210 Day
4/8/2019	Trial 1	4x8	PEM							
4/12/2019	Trial 2	4x8	PEM	20.7						
5/13/2019	3	4x8	PEM	29.9	30.4	32.8	34.6	34	37.6	39.9
5/13/2019	6	4x8	PEM							
5/13/2019	10	4x8	PEM							
5/13/2019	3	6x12	PEM							
5/13/2019	6	6x12	PEM							
5/13/2019	10	6x12	PEM							
5/15/2019	2	4x8	PEM							
5/15/2019	10	4x8	PEM							
5/15/2019	2	6x12	PEM							
5/15/2019	10	6x12	PEM							
5/16/2019	2	4x8	PEM							
5/16/2019	12	4x8	PEM							
5/16/2019	2	6x12	PEM							
5/16/2019	12	6x12	PEM							
5/17/2019	2	6x12	PEM							
5/21/2019	2	4x8	PEM							
5/21/2019	6	4x8	PEM							
5/21/2019	2	6x12	PEM							
5/21/2019	6	6x12	PEM							
5/22/2019	2	4x8	PEM							
5/22/2019	7	4x8	PEM	23.5	24.6	26.8	26.6	27.7	29.5	31.4
5/22/2019	2	6x12	PEM							
5/22/2019	7	6x12	PEM							
5/23/2019	2	4x8	PEM							
5/23/2019	9	4x8	PEM							
5/23/2019	2	6x12	PEM							
5/23/2019	9	6x12	PEM							
5/24/2019	2	4x8	PEM							
5/24/2019	10	4x8	PEM							
5/24/2019	14	4x8	PEM							
5/24/2019	2	6x12	PEM							
5/24/2019	14	6x12	PEM							
5/29/2019	3	4x8	PEM							
5/29/2019	6	4x8	PEM							
5/29/2019	3	6x12	PEM							
5/29/2019	6	6x12	PEM							
5/31/2019	2	4x8	PEM							
5/31/2019	10	4x8	PEM							
5/31/2019	14	4x8	PEM	28.6	30.7	30	32.7	33.9		37.1
5/31/2019	2	6x12	PEM							
5/31/2019	14	6x12	PEM							

Class PEM SR Continued

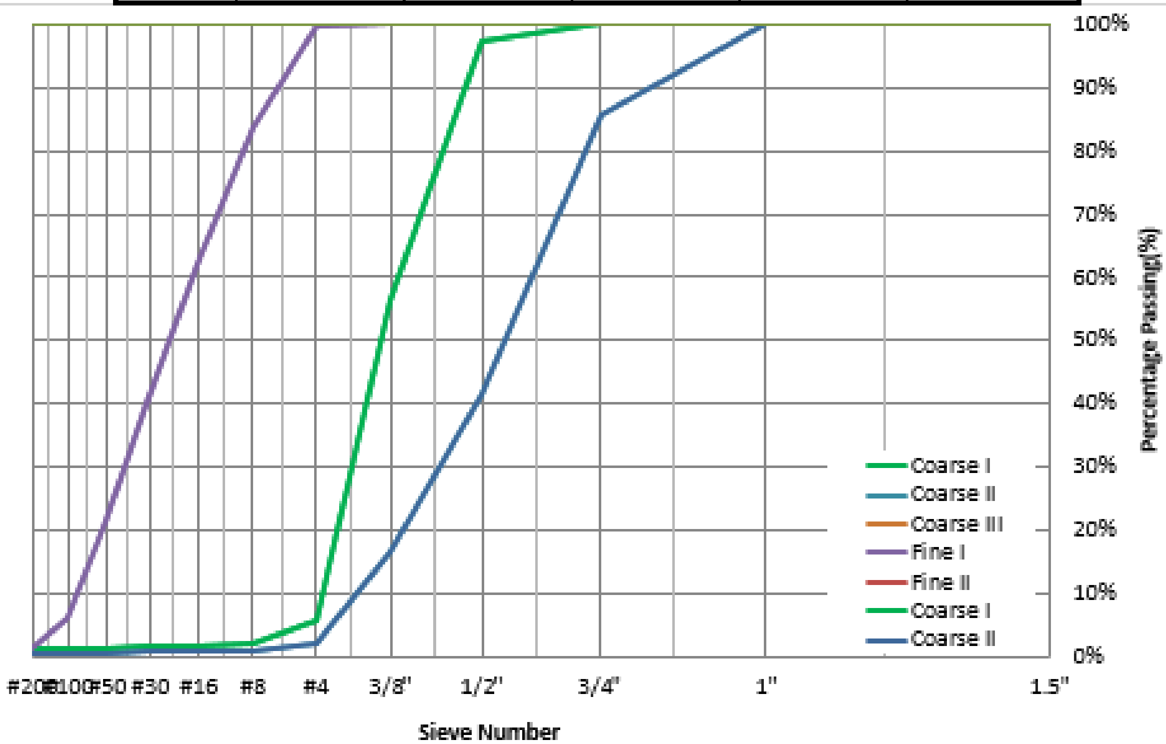
Date Cast	Truck #	Cylinder Size	Class	224 Day	238 Day	252 Day	266 Day	NOTES
4/8/2019	Trial 1	4x8	PEM					Taken 7/1 for 84 Day F/T
4/12/2019	Trial 2	4x8	PEM					
5/13/2019	3	4x8	PEM	43.8	44.7	44.3	42.2	
5/13/2019	6	4x8	PEM					stopped testing after 70 day SR
5/13/2019	10	4x8	PEM					Taken 7/8 for 56 Day F/T
5/13/2019	3	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/13/2019	6	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/13/2019	10	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/15/2019	2	4x8	PEM					Stopped testing after 91 day SR
5/15/2019	10	4x8	PEM					Taken 6/26 for 42 Day F/T
5/15/2019	2	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/15/2019	10	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/16/2019	2	4x8	PEM					
5/16/2019	12	4x8	PEM					stopped testing after 70 day SR
5/16/2019	2	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/16/2019	12	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/17/2019	2	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/21/2019	2	4x8	PEM					stopped testing after 56 day SR
5/21/2019	6	4x8	PEM					
5/21/2019	2	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/21/2019	6	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/22/2019	2	4x8	PEM					Taken 6/26 for 35 Day F/T. 35 Day SR value of 12.7
5/22/2019	7	4x8	PEM	31.9	31.4	31.6	32.7	
5/22/2019	2	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/22/2019	7	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/23/2019	2	4x8	PEM					
5/23/2019	9	4x8	PEM					stopped testing after 56 day SR
5/23/2019	2	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/23/2019	9	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/24/2019	2	4x8	PEM					stopped testing after 56 day SR
5/24/2019	10	4x8	PEM					stopped testing after 56 day SR
5/24/2019	14	4x8	PEM					
5/24/2019	2	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/24/2019	14	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/29/2019	3	4x8	PEM					
5/29/2019	6	4x8	PEM					Taken 6/26 for 28 Day F/T
5/29/2019	3	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/29/2019	6	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/31/2019	2	4x8	PEM					stopped testing after 56 day SR
5/31/2019	10	4x8	PEM					stopped testing after 56 day SR
5/31/2019	14	4x8	PEM	38.7	37.7	36.4		
5/31/2019	2	6x12	PEM					28 day Comp. Strength acceptance cylinders
5/31/2019	14	6x12	PEM					28 day Comp. Strength acceptance cylinders

A-9 Daily Producer Control Charts

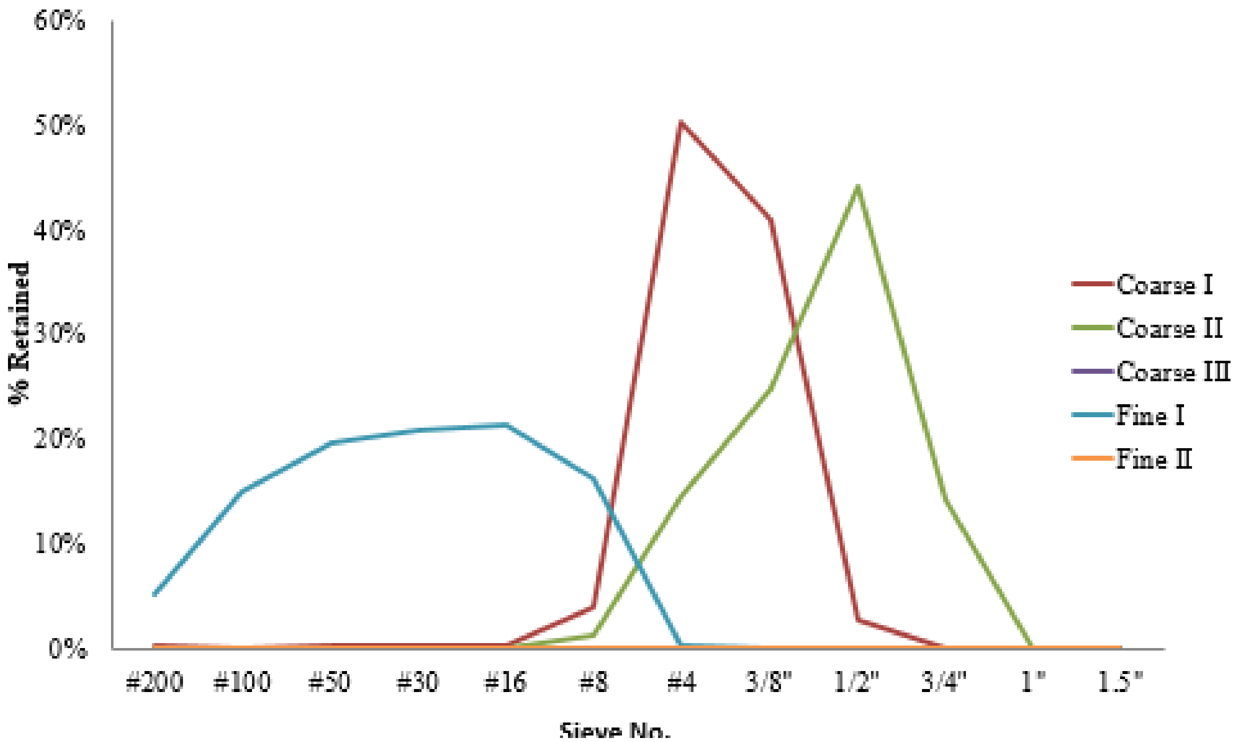
Sieve Analysis for Mixture Design

Percent Passing (input for design)

Sieve Number	1-7R Crop #67	1-7R Crop #57		1-89F Fane Hemstreet	
1.5"	100.0%	100.00%	100.0%	100.0%	100%
1"	100.0%	100.00%	100.0%	100.0%	100%
3/4"	100.0%	85.63%	100.0%	100.0%	100%
1/2"	97.2%	41.45%	100.0%	100.0%	100%
3/8"	56.2%	16.52%	100.0%	100.0%	100%
#4	5.8%	2.10%	100.0%	99.8%	100%
#8	2.0%	0.97%	100.0%	83.5%	100%
#16	1.7%	0.85%	100.0%	62.1%	100%
#30	1.6%	0.78%	100.0%	41.2%	100%
#50	1.4%	0.71%	100.0%	21.4%	100%
#100	1.3%	0.62%	100.0%	6.3%	100%
#200	1.1%	0.52%	100.0%	1.2%	100%



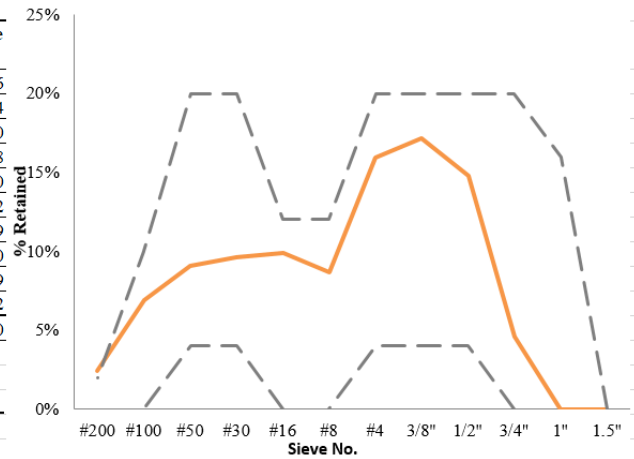
Percent Retained (for information purposes only)					
Sieve Number	1-7R Crop #67	1-7R Crop #57		1-89F Fane Hemstree	
1.5"	0.00%	0.00%	0.00%	0.00%	0.00%
1"	0.00%	0.00%	0.00%	0.00%	0.00%
3/4"	0.00%	14.37%	0.00%	0.00%	0.00%
1/2"	2.82%	44.18%	0.00%	0.00%	0.00%
3/8"	40.98%	24.93%	0.00%	0.00%	0.00%
#4	50.38%	14.42%	0.00%	0.17%	0.00%
#8	3.87%	1.14%	0.00%	16.33%	0.00%
#16	0.23%	0.11%	0.00%	21.45%	0.00%
#30	0.15%	0.07%	0.00%	20.91%	0.00%
#50	0.14%	0.08%	0.00%	19.77%	0.00%
#100	0.12%	0.08%	0.00%	15.05%	0.00%
#200	0.18%	0.10%	0.00%	5.17%	0.00%



Tarantula Mixture Design Procedure
5/23/2019

Batch Weights & Material Properties

Material	Source of Material	Weight (lbs/cy)	Specific Gravity	Volume (ft³)
Coarse I	1-7R Crop #67	700.00	2.70	4.16
Coarse II	1-7R Crop #57	1000.00	2.70	5.94
Coarse III	None		2.70	0.00
Fine I	1-89F Fane Hemstreet	1408.00	2.66	8.48
Fine II	None		0.00	0.00
Cement	08 Lehigh GF Type I/II	456.00	3.15	2.32
Fly Ash	26 Spartan Materials	114.00	2.30	0.79
Other Cementitious				0.00
Water	City	230.00	1.00	3.69
Air	6.00%	2.00		1.62
Total		3910.0	lbs/cy	27.00
		144.8	lbs/cf	



Coarse Sand % (#8-30) = 28.16% **YES**

Should be greater than 20%

Fine Sand % (#30-200) = 28.03%

This allowable range for **slipforming** is between 24-34% **YES**

This allowable range for **pumping** is between 25-

Paste Properties

w/cm	0.40	
SCM replacement	20%	
total cementitious	570	lbs
sack content	6.06383	sacks
Paste Content w/o air	25%	

Aggregate volume percentages

Coarse I	22%
Coarse II	32%
Coarse III	0%
Fine I	46%
Fine II	0%

Admixture Type	Name	Dosage (oz/cwt)
HRWR	4033 Plastol 5000	6
MR	3045 Eucon MR	4
Air entrainer	1039 Air Mix 200	0.13
accelerator		
set control		

Aggregate Gradation

Sieve Number	Combined % Passing	Combined % Retained	Maximum Boundary	Minimum Boundary	
1.5"	100.0%	0.00%	0.00%	0%	**YES**
1"	100.0%	0.00%	16.00%	0%	**YES**
3/4"	95.4%	4.60%	20.00%	0%	**YES**
1/2"	80.6%	14.76%	20.00%	4%	**YES**
3/8"	63.5%	17.14%	20.00%	4%	**YES**
#4	47.5%	15.96%	20.00%	4%	**YES**
#8	38.9%	8.68%	12.00%	0%	**YES**
#16	29.0%	9.88%	12.00%	0%	**YES**
#30	19.4%	9.60%	20.00%	4%	**YES**
#50	10.3%	9.08%	20.00%	4%	**YES**
#100	3.4%	6.92%	10.00%	0%	**YES**
#200	1.0%	2.43%	2.00%	0%	**NO**
	total	99.05%			

Coarse Sand % (#8-30) = 28.16% **YES**

This range amount is a minimum of 15%

Fine Sand % (#30-200) = 28.03%

34% **YES**

This allowable range for **pumping** is between 25-40% **YES**

A-10 NYS Test Method 502-3P (Freeze/Thaw)

SCOPE:

The resistance of Portland cement concrete and grout when exposed to alternate freezing and thawing is determined.

APPARATUS:

1. A freezing-thawing chamber consisting essentially of a refrigeration system, coolant circulation, heating elements, and thermostatic controls, capable of maintaining the temperature of the coolant and test samples at -10 ± 5°F and capable of reaching and maintaining thawing temperatures at 70 ± 5°F.

2. Leak-proof sample receptacles with approximate internal dimension of 6 inch diameter by 9 inch high.

3. Balance, capacity not less than 5000 grams, minimum sensitivity 1.0 grams.

PROCEDURE A: CONCRETE CYLINDERS OR CORES

1. The test specimens are immersed in separate leak-proof receptacles containing a three percent (3%) solution of sodium chloride (NaCl), Specific Gravity approximately 1.020, for a period of 48 hours.

2. After 48 hours, the specimens are removed from the solution and dried to a saturated surface dry (SSD) condition; weigh to the nearest 1.0 gram.

3. Immediately after weighing the specimens are replaced in the original receptacles in the 3% NaCl solution, and placed in the chamber maintained at a temperature of -10 ± 5°F. The receptacles remain in the chamber until the brine solution is completely and solidly frozen and the internal temperature of the specimen reaches -10 ± 5°F.

   Note: To determine the internal temperature, a temperature probe is placed in the center of a dummy specimen.

4. Following the complete freezing, the receptacles are thawed at a temperature of 70 ± 5°F until the brine solution and specimens are completely thawed.
5. Freezing and thawing as described in steps 3 and 4 above will constitute one cycle. One complete cycle shall consist of 23 ± 1 hour with at least half of the cycle being in the frozen state.

6. Between the 12^{th} and 13^{th} cycle, the specimens are reversed top to bottom, and the brine solution is renewed.

7. At the conclusion of 25 cycles, the specimens are removed from the containers, dried to a saturated surface dry (SSD) condition and weighed to the nearest 1.0 gram.

PROCEDURE B: MORTAR AND GROUT CUBES

1. The test specimens are immersed in separate leak-proof receptacles containing a ten percent (10%) solution of sodium chloride (NaCl), Specific Gravity approximately 1.071, for a period of 24 hours.

2. After 24 hours, the specimens are removed from the solution and dried to a saturated surface dry (SSD) condition; weigh to the nearest 1.0 gram.

3. Immediately after weighing the specimens are replaced in the original receptacles in the 10% NaCl solution, and placed in the chamber maintained at a temperature of -10 ± 5°F. The receptacles remain in the chamber until the brine solution is completely and solidly frozen and the internal temperature of the specimen reaches -10 ± 5°F.

   Note: To determine the internal temperature, a temperature probe is placed in the center of a dummy specimen.

4. Following the complete freezing, the receptacles are thawed at a temperature of 70 ± 5°F until the brine solution and specimens are completely thawed.

5. Freezing and thawing as described in steps 3 and 4 above will constitute one cycle. One complete cycle shall consist of 23 ± 1 hour with at least half of the cycle being in the frozen state.

6. Between the 12^{th} and 13^{th} cycle, the specimens are reversed top to bottom, and the brine solution is renewed.

7. At the conclusion of 25 cycles, the specimens are removed from the containers, dried to a saturated surface dry (SSD) condition and weighed to the nearest 1.0 gram.

RESULTS:

1. Report the % loss in weight to the nearest 0.1%.

2. Calculate:

$$\textbf{\% Loss} = \frac{\textbf{Loss in weight after 25 cycles}}{\textbf{Original Weight}} \ \textbf{X 100:}$$

   a) Loss in weight = Original Weight (SSD) – Weight (SSD) after 25 cycles.

3. A description of the condition of the specimen before and after freeze/thaw test may be reported when pertinent.