United States
Department of Transportation

SUMMARY REPORT

Concrete Overlay on I-35

Forest Lake, MN

July, 2018

FHWA MCT Project # MN1803

Federal Highway Administration
Office of Preconstruction,
Construction, and Pavements
1200 New Jersey Avenue, SE
Washington, DC 20590

BUCKLE UP AMERICA

MCT Field Report – Minnesota Visit

Summary of the Visit

The Federal Highway Administration (FHWA) Mobile Concrete Trailer (MCT) visited the concrete overlay project over I-35 in Forest Lake, MN from July 16 through 26 at the request of Maria Masten with the Minnesota Department of Transportation. The objective of the MCT visit was to demonstrate innovative technologies currently in the implementation phase; this is in conjunction with the work being done on this project using FHWA Performance Engineered Mixtures Implementation Incentive funding. This report summarizes the test results, observations, and other activities conducted during this visit. Numerical values of the test results are presented in the Appendix.

Testing and Observations

The Box Test indicated the mixture was workable but some edge slump was observed. The pavement edge was straight and stood without slumping. The surface did require some effort to finish. The mixture had an excellent combined gradation, as per the Tarantula Curve, as well as a very low paste content, well below the PEM recommendations.

The air void system, as tested in the plastic concrete, was very good, with almost all test results falling in the desirable range. The unit weight was very consistent and near the middle of the desired range. The unit weight and total air content tracked well. The calorimetry data indicated very consistent concrete for the second and third days but the fourth day test data was somewhat shifted compared to the other two days data.

Minnesota does not base acceptance on concrete strengths. The 56-day strengths were well above what most states use in design, indicating strength was satisfactory. The permeability test results (Surface Resistivity) fell in the low category at 56-days, which is very good. But, the first two samples indicated significantly lower (better) permeability than the last three. All were good but the difference was intriguing.

Maturity was used to measure opening strength. It was reached in two and a half days but with the high air content of the samples, likely the pavement reached opening strength in less time than that. The MIT SCAN found dowels to be in the proper location and alignment. The MIT T2 measured pavement thickness and found all tests to exceed the required thickness.

The MCT Open House was conducted in coordination with the PEM presentation and the event was very well attended. The Concrete Pavement Association of Minnesota and the National Concrete Pavement Technology Center assisted with this event.

Positive Observations

- Consistency in Materials
    - Air Content / Unit Weight
    - Cementitious Contents / Sources
    - AVA / SAM Numbers
    - Compressive Strengths
- Low cement content
- Low paste content (excellent)

- Optimized aggregate gradation
- Excellent air characteristics
- Use of the microwave water content test
- Knowledgeable agency staff
- Committed contractor staff

Recommendations

- Consider adopting the use of Surface Resistivity
- Consider adopting the use of Super Air Meter
- Consider adopting the use of MIT Scan T2 for pavement thickness

For questions pertaining to the report, please contact either Mike Praul (Michael.Praul@dot.gov), FHWA Senior Concrete Engineer or Jagan Gudimettla (Jagan.m.gudimettla.ctr@dot.gov), consultant, MCT Project Engineer. Details on the MCT program and the technologies listed in the report can be found on the MCT website at https://www.fhwa.dot.gov/pavement/concrete/trailer/.

Background of the Project

Six miles of I-35 from just south of the I-35 split to a half mile north of Hwy 8 at the Chisago/Washington county line will be resurfaced. Road resurfacing helps to preserve and extend the use of the pavement. The work will also include replacing three bridges.

Project Details

- Resurface (concrete overlay) I-35 from Hwy 97 to Hwy 8
- Paving subcontractor: Shafer Contracting Co. Inc
- Pavement Design Thickness: 8"

Project Specifications

- Air content range: 7±1.5%
- Maximum w/cm: 0.40
- Optimized gradation check (four times a day)

Concrete Plant

- Duel Drum Rex-Con plant
- 12 Yard Capacity
- 90-105 second mixing time

Aggregates and Stockpile Management

- Aggregate stock piles well managed
- Class 5 aggregate as a separation layer to build stockpiles
- Good job of mixing delivered aggregates

Concrete Plant

MCT at the Concrete Plant

Coarse (#67)

Intermediate (#4)

Fine (Sand)

Aggregate Stockpiles

Mixture Designs

- Cement (70%)
- Fly Ash (30%)
- Total Cementitious Content: 560 lbs

Material	Source	Weight (lbs)
Cement (I/II/)	St. Genevieve	390
Fly Ash (Class C)	Portage	170
CA1, # 67	Pit # 13004	1008
Cas, #4	Pit # 13004	805
FA, Sand	Pit # 13004	1345
Water		196
Admix #1	GRT Polychem SA	.5-3
Admix # 2	GRT Polychem 400 NC	0-8
Design W/Cm Ratio		0.37
Target Air Content, %		7.0%

Paste Calculations

VOLUME OF PASTE CALCULATION

MN1803

Absolute volume for 1 cubic yard

	Batch Weights wt.cu/yd	Specific Gravity	Absolute Volume cu,yd	Percent of Total Volume
Cement	390	3.15	1.984	7.35
Fly Ash	170	2.72	1.002	3.71
Sand	1345	2.64	8.165	30.24
#4	805	2.72	4.743	17.57
#67	1008	2.66	6.073	22.49
Water	196	1.00	3.141	11.63
w/c ratio				
% Air	7	0.00	1.890	7.00
Total volume of known ingredients			27.0	100.00

PERCENT PASTE

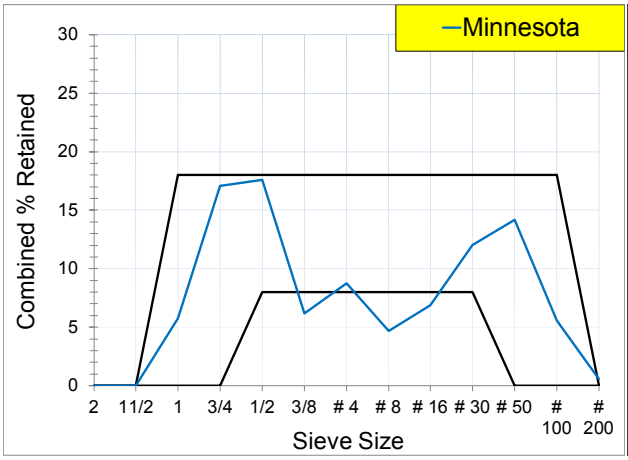
1 cu.yd.

% Paste = 22.7

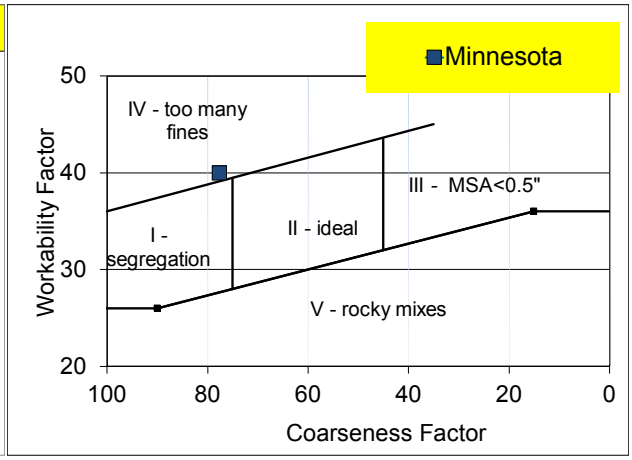
% Paste should be less than 25% for lowering the crack tendency of concrete (PEM requirement)

Mixture Design Gradations

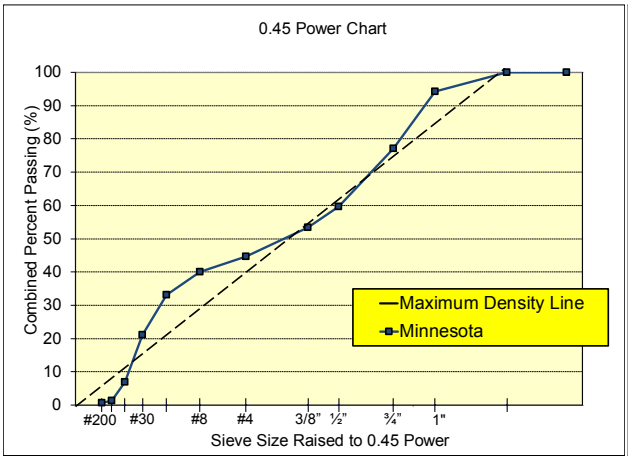
- Combined gradation did not meet the 8-18 and Shilstone gradation criteria
- Combined gradation met the Tarantula Curve gradation criteria



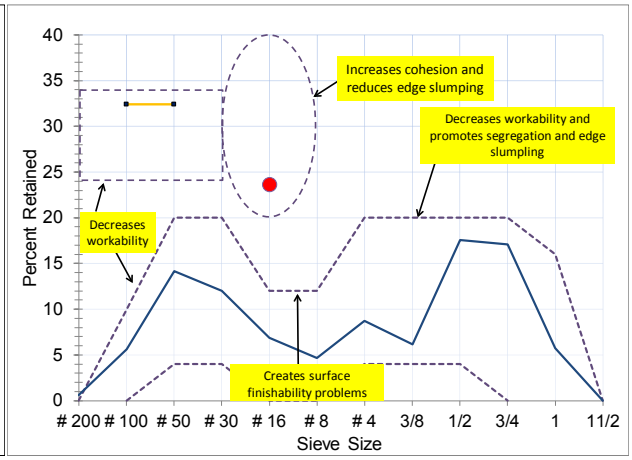
Coarseness Factor Chart



Percent of Aggregate Retained



FHWA 0.45 Power Chart



Tarantula Curve

Paving Operations

- Stringline paving
- Shoulder construction
- No dowels (shoulder)
- Astro turf drag
- Daytime paving
- Dump truck used to transport concrete
- Mixture produced to pave the mainline and shoulders is the same






Sampling and Testing Locations

QC/QA on the grade

MCT Sampling at the plant

MCT Fresh Concrete Test Matrix

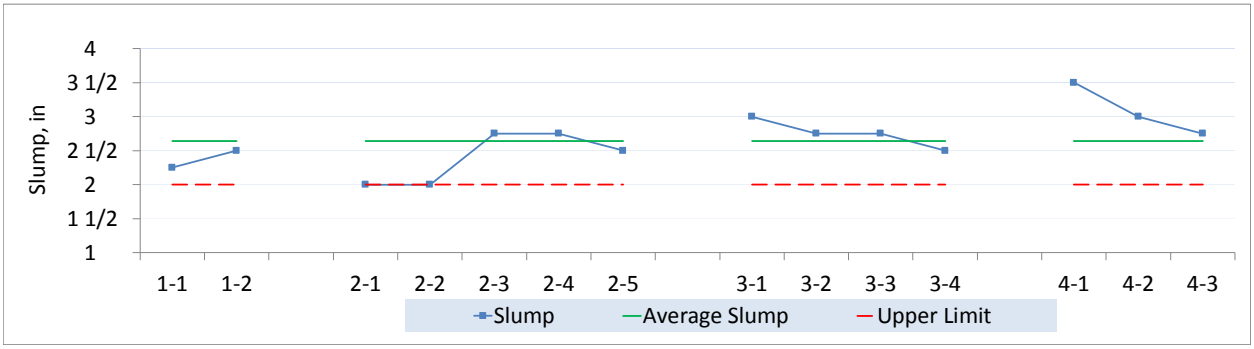
Section	Date	Sample ID
Shoulder	7/16/18	1-1, 1-2
Shoulder	7/18/18	2-1, 2-2 2-3, 2-4, 2-5
Shoulder	7/19/18	3-1, 3-2, 3-3, 3-4
Shoulder	7/23/18	4-1, 4-2, 4-3, 4-4(F), 4-5(F)

Note F denotes field samples

TEST RESULTS

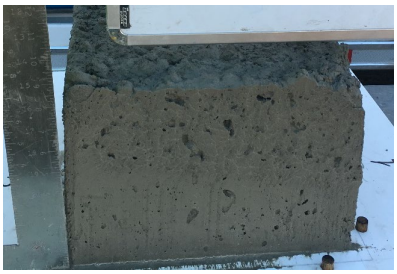
Slump

- Fourteen slump tests were performed at the plant
- Average slump: 2.6”, Standard deviation: 0.4"

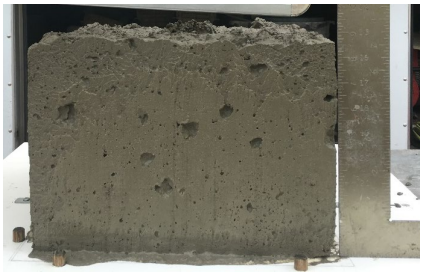


Box Test

- ❑ Three box tests were performed
- ❑ Edge slump noticed in one sample (2-3)
- ❑ Did not notice any consolidation issues



Sample 2-3



Sample 3-3

Sample 4-3

Edge and Finish

- ❑ Finish was identical to the Box Test. Pavement edge was smooth and stood without any slumping
- ❑ There seemed to be a few bug holes that are benign

Edge

Surface Finish

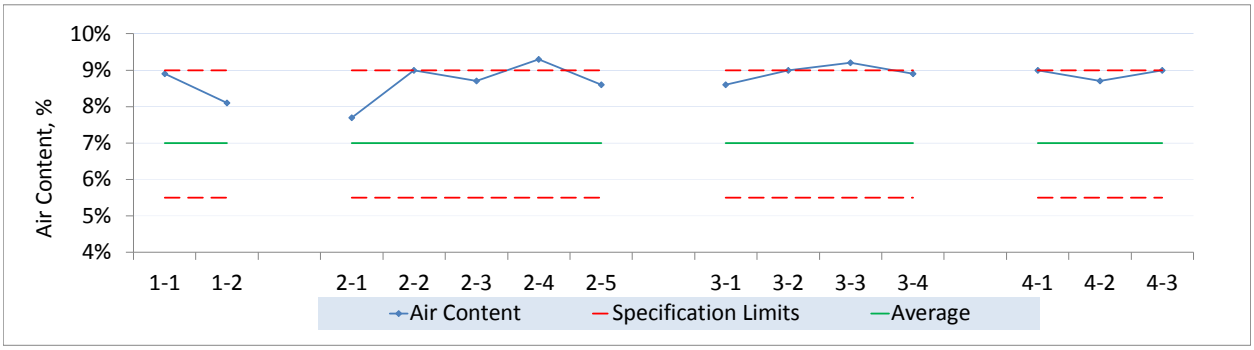
Bug holes

Air Content and Air Void System

- Total Air is different than Air Void System

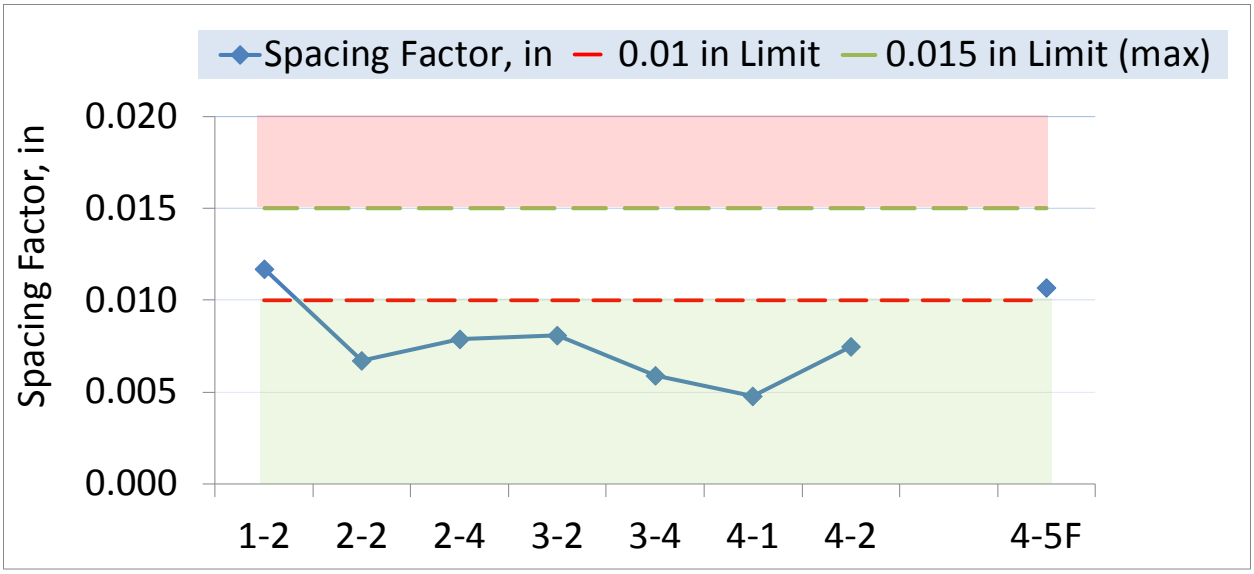
Total Air Content

- Fourteen air tests performed at the plant
- Total air content was very consistent
- Average air content: 8.8%, Standard Deviation: 0.4%



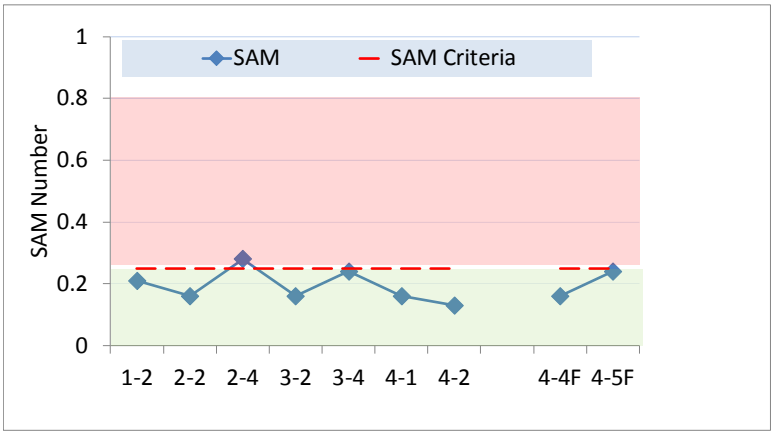
Air Void System Measured by the Air Void Analyzer (AVA)

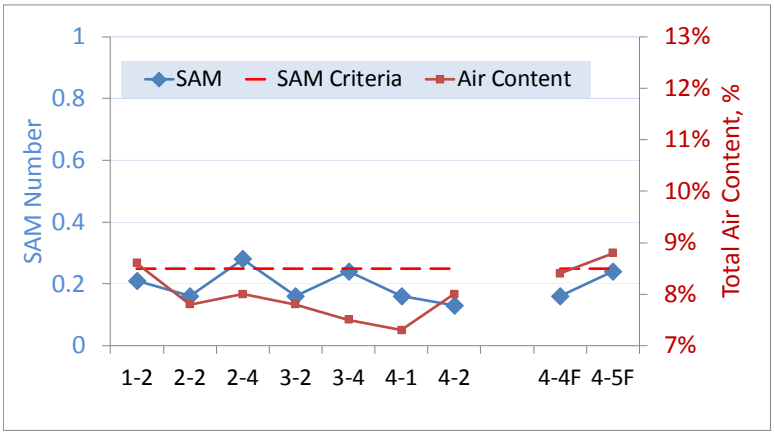
- Eight AVA tests performed (seven at the plant and one in the field before the paver)
- Six of the eight measurements had excellent air void characteristics
- Two of the eight samples had good air void characteristics
- Overall, similar to the air content, the spacing factor was very consistent with a standard deviation of 0.002 in

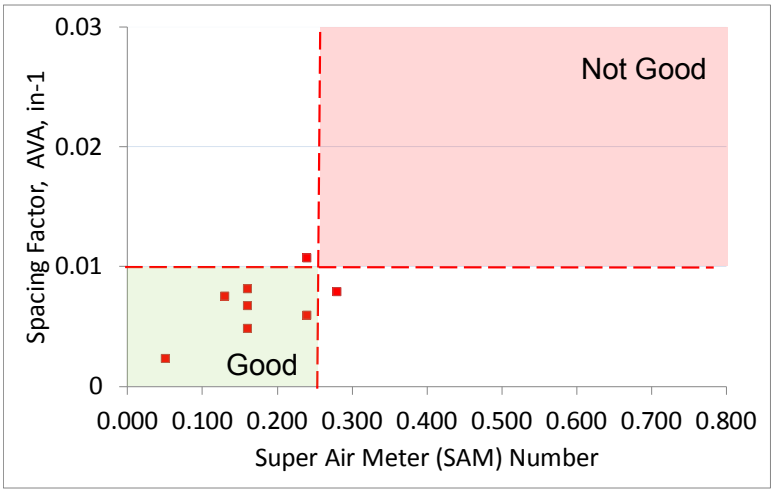


Air Void System Measured by the Super Air Meter (SAM)

- Nine SAM tests performed (seven at the plant and two in the field before the paver)
- Like the AVA, the SAM data was also excellent. All but one test were less than 0.25
- The consistency of the SAM data was very good with a standard deviation of 0.05
- For six of the nine SAM tests, SAM number tracked the total air content (from SAM)
- Very good correlation between the SAM and AVA data

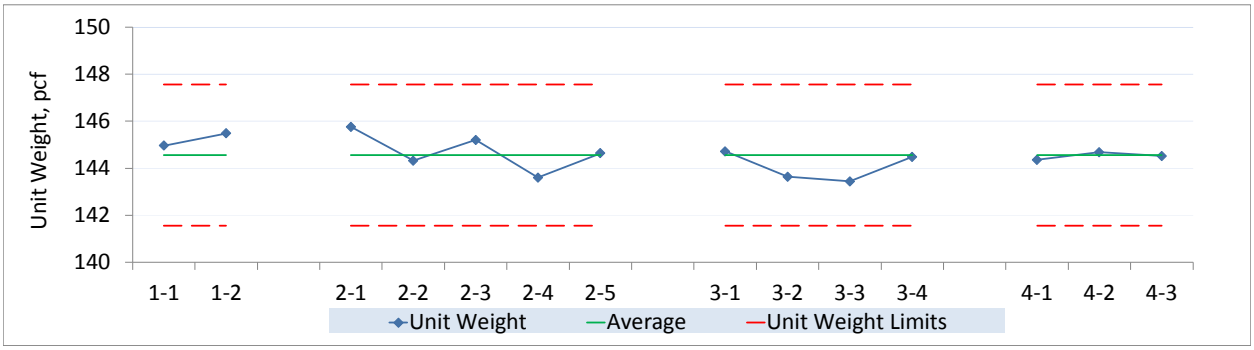






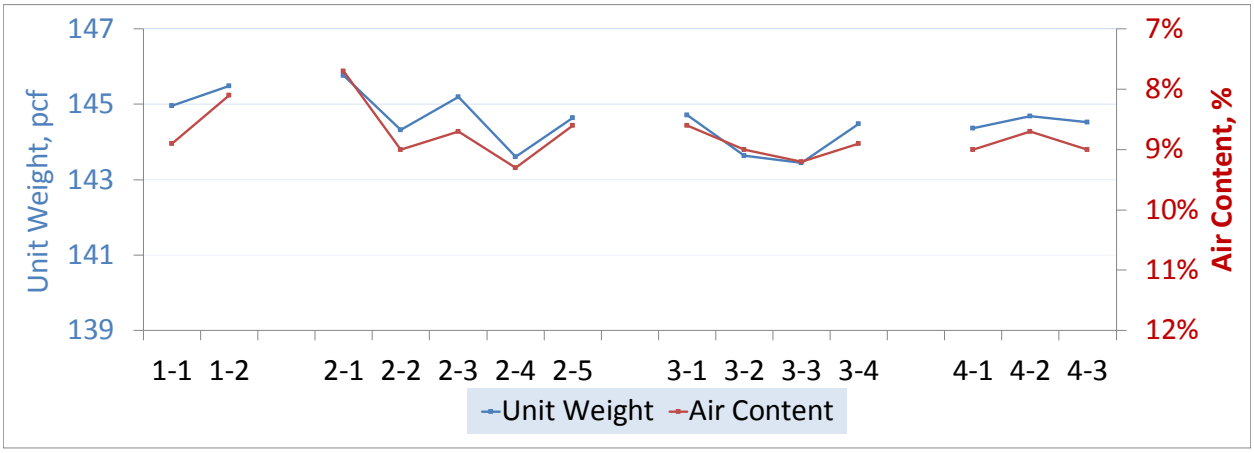
Unit Weight

- Simple test to check uniformity: weight and volumetric proportions
- The fourteen unit weight tests that were performed indicate concrete production that is very consistent
- Average unit weight: 145.0 pcf, Standard Deviation: 0.7 pcf (excellent)



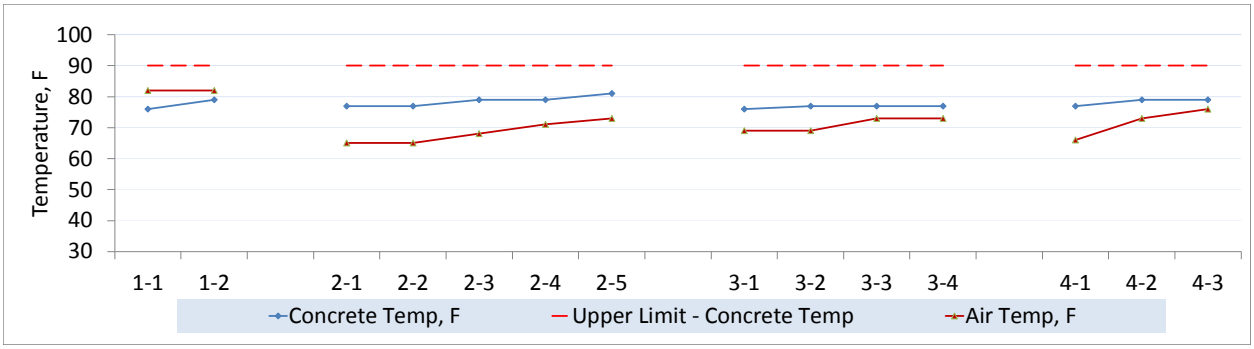
Unit Weight and Air Content / Slump

- Normally unit weight and air content will run parallel
  - Unit weight changes if air content changes
  - Unit weight changes if water (slump) changes
- When they diverge it indicates change in materials or proportions
- Unit weight and air content tracked for all samples



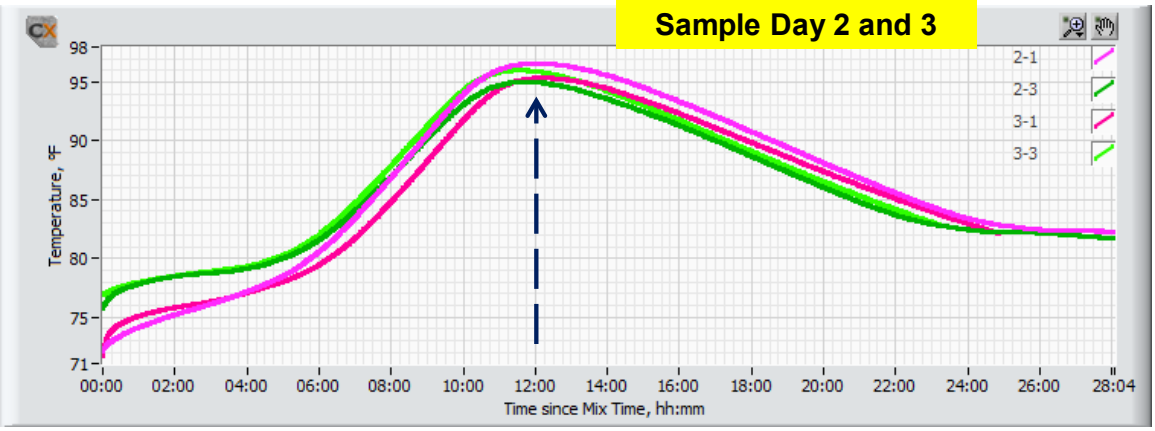
Concrete Temperature

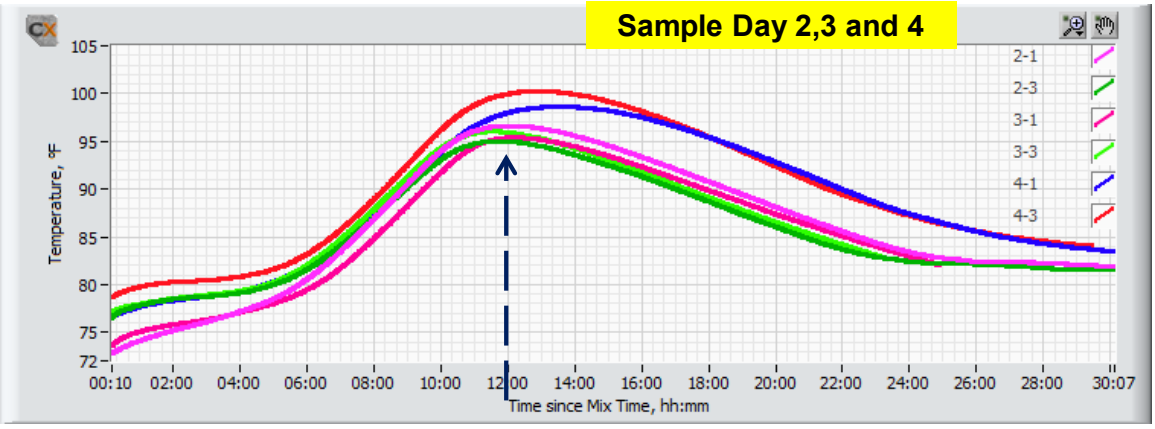
- Concrete temperature affects hydration rate which can impact workability and compatibility



Heat Signature / Semi-Adiabatic Calorimetry

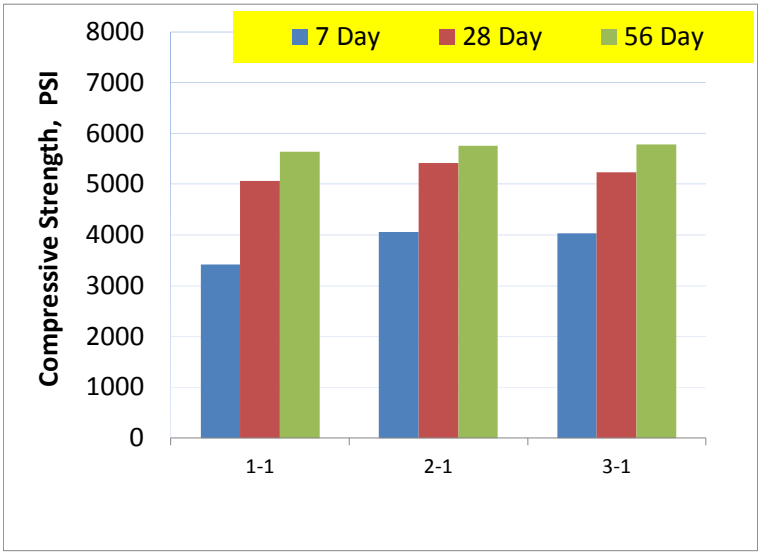
- Identifies changes in cementitious hydration due to cement, SCMs and admixtures
- Heat signature curves for the sample day 2 and 3 were consistent
- Sample day 4 showed slightly higher heat of hydration. This increase could be attributed to the higher initial temperature of the samples from day 4
- Overall, samples from all three days indicate consistent heat signature curves, indicating consistent cementitious contents and sources





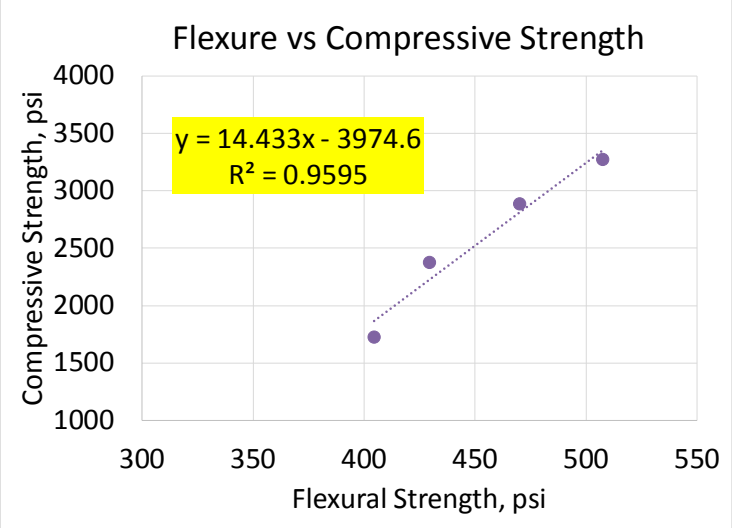
Concrete Strength

- All samples were over 5000 psi at 28 days
- Similar to other properties, the compressive strength data was also very consistent
- Specimens for strength cylinders were cast at the plant (higher air content than field)



Relationship between Flexural and Split Tensile / Compressive Strengths

- Tests performed at 1, 2, 3, and 5 days of age



Modulus of Elasticity (MOE) and Poisson's Ratio

- AASHTO Pavement ME Input
- Typical MOE (E) range: 4-6,000,000 psi
- Typical Poisson's Ratio (μ) value used in Pavement-ME: 0.20

	28 Day	
	Modulus of Elasticity, E	Poisson's Ratio, μ
Run 1	4,667,806	0.21
Run 2	4,615,596	0.21
AVG	4,641,701	0.21

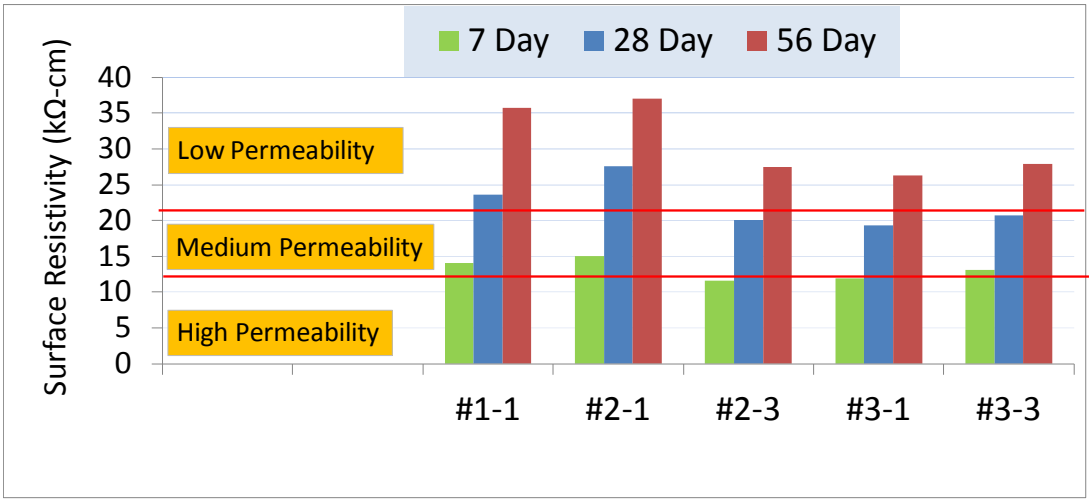
Coefficient of Thermal Expansion (CTE)

- AASHTO Pavement ME Input
- Heavily influenced by the coarse aggregate in the mixture
- Typical CTE value used in Pavement-ME: 5.5 microstrain/^{0}F

Sample ID	Age, Days	CTE, Microstrain/^{0}F
2-2	70	4.9
3-1	69	5.0

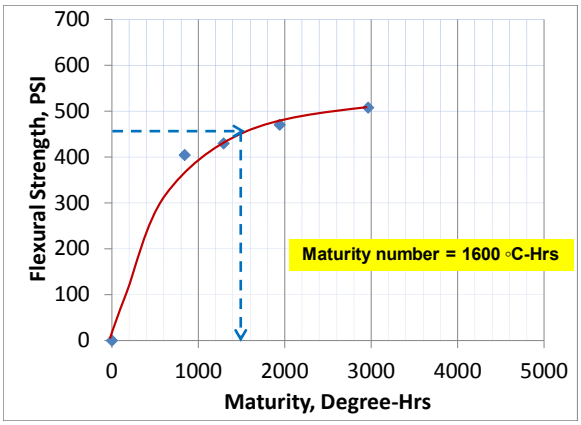
Surface Resistivity

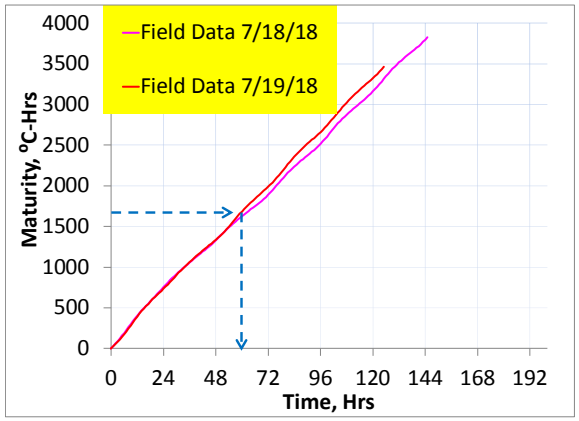
- Easy and quick test compared to the traditional Rapid Chloride Test
- Relates to the permeability of the concrete, which in turn influence durability
- At 56 days, all the specimens were in the low permeability category



Maturity

- Technique used to determine in-place pavement strength of concrete
- Two-step process
  - Build a Maturity Curve in the laboratory or in the field (uses temperature and time factors)
  - Measure maturity in the field to determine in-place strength using the maturity curve



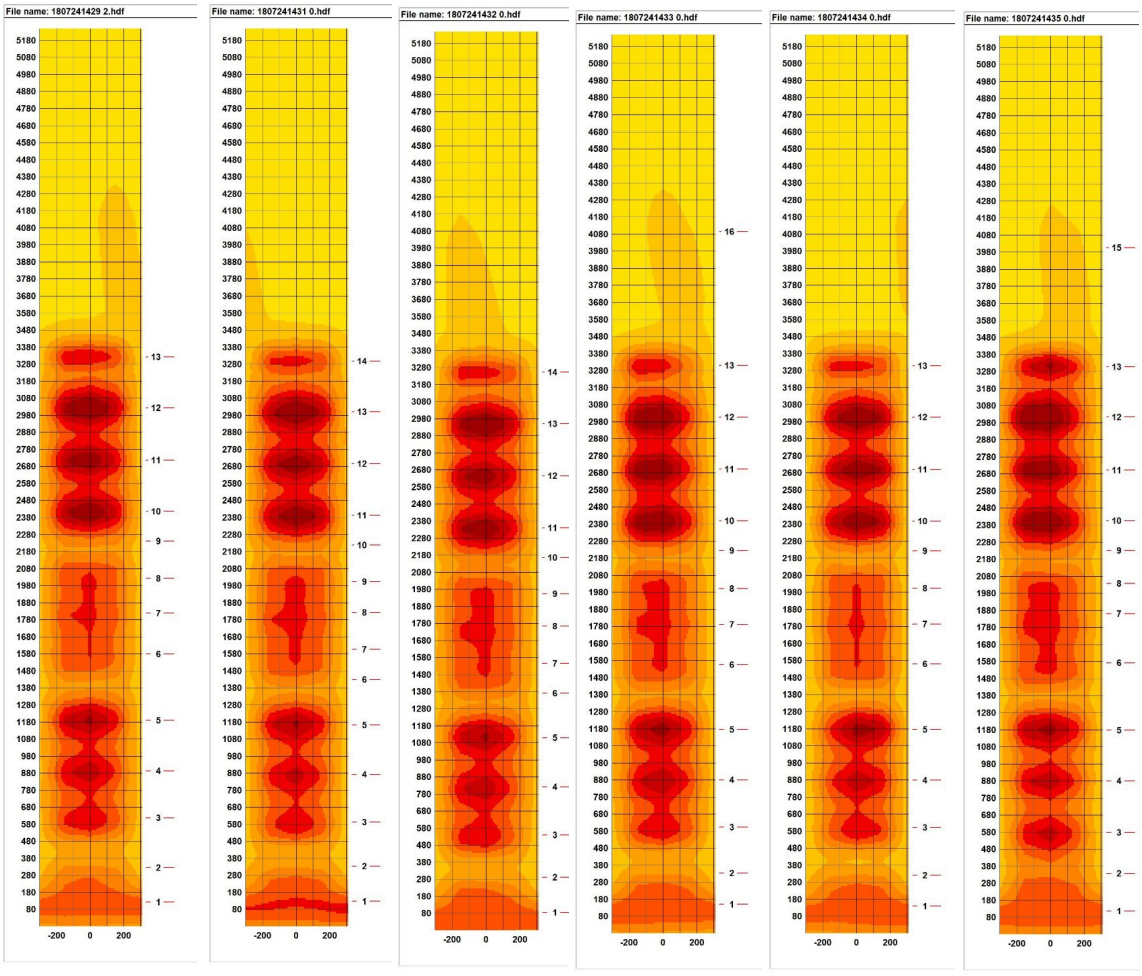


- Opening strength for construction traffic at this project is 460 psi flexural
- The above curve (on the left) was built on specimens cast from concrete produced on 7/16/18. For the flexural strength of 460 psi, the maturity number for the mixture was 1600˚C-Hrs
- In the field (curve on the right), opening strength is reached in 2 and half days

Dowel Bar Alignment

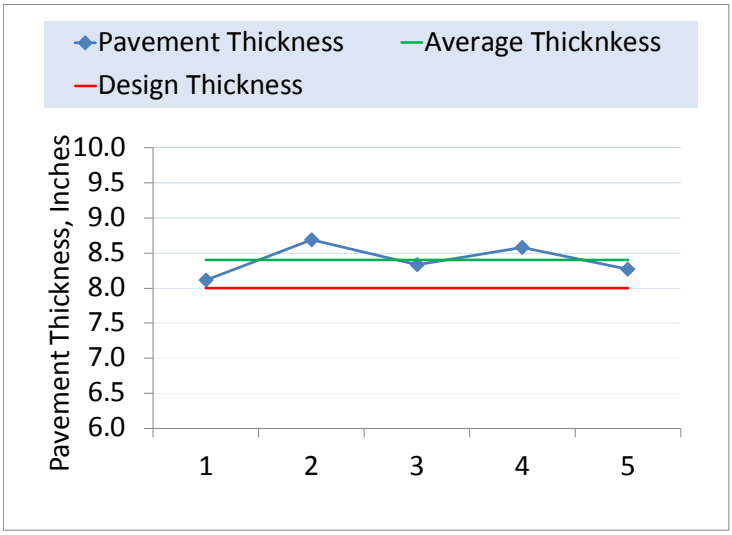
- Magnetic Tomography used to determine dowel alignment at 15 consecutive joints
- Nondestructive approach
- As expected, there were no dowels in the shoulder section
- Dowel bars were placed using baskets (in the wheel path) and shipping wires were not cut (reason for distorted images). Additional scans included in the appendix

Dowel Bar Scans



Pavement Thickness (MIT Scan T2)

- Used Pulse Induction Technology to determine pavement thickness
- Faster, real time, and nondestructive
- Average thickness measured 8.4 inches with a standard deviation of 0.2 inches (design thickness 8.0 inches)



Observations

- Contractor was prepared and proactive with covering the new pavement with plastic due to the likelihood of rain

Other MCT Activities

- Kick-Off Meeting and PEM / MCT Open House
- Close-Out Meeting at Minnesota DOT (Minnesota DOT, FHWA Division Office, Minnesota Concrete Paving Association and Contractor)
- Additional data collection for Dr. Jason Weiss's Resistivity Study (not included in this report)
- Data collection for Performance Related Specifications validation for Turner Fairbank Highway Research Center
- Training on the new Phoenix water cement ratio device

Open House Presentations

Attendees during the Open House

Training on the Phoenix

Open House

Acknowledgments

- Maria Masten (Minnesota DOT)
- Robert Golish (Minnesota DOT)
- Kevin Kliethermes (FHWA Division Office)
- Matt Zeller (Concrete Pavement Association of Minnesota)
- Greg Pelkey (Shafer Contracting)
- Troy Vrieze(Shafer Contracting)
- Gordon Smith (CP Tech Center)
- Jarod Gross (Snyder & Associates)
- Rabi Pariyar (Snyder & Associates)

Appendix

Fresh Concrete Properties

Sample ID	Date	Time, Local	Slump "	Conc Temp, F	Air Temp, F	UW,PCF	Air Content
1-1	7/16	12:05 p.m.	2.25	76	82.0	145.0	8.9%
1-2	7/16	1:50 p.m.	2.50	79	82.0	145.5	8.1%
2-1	7/18	8:05 a.m.	2.00	77	65.0	145.8	7.7%
2-2	7/18	12:14 p.m.	2.00	77	65.0	144.3	9.0%
2-3	7/18	9:38 a.m.	2.75	79	68.0	145.2	8.7%
2-4	7/18	10:15 a.m.	2.75	79	71.0	143.6	9.3%
2-5	7/18	10:50 a.m.	2.50	81	73.0	144.6	8.6%
3-1	7/19	8:18 a.m.	3.00	76	69.0	144.7	8.6%
3-2	7/19	10:36 a.m.	2.75	77	69.0	143.6	9.0%
3-3	7/19	11:42 a.m.	2.75	77	73.0	143.4	9.2%
3-4	7/19	12:13 p.m.	2.50	77	73.0	144.5	8.9%
4-1	7/23	8:47 a.m.	3.50	77	66.0	144.4	9.0%
4-2	7/23	10:23 a.m.	3.00	79	73.0	144.7	8.7%
4-3	7/23	11:04 a.m.	2.75	79	76.0	144.5	9.0%

Combined Aggregate Gradation

Sieve Size, in	Sand	#67 (34")	#4 (1-1/2")	Combined % Passing
2"	100	100	100	**100**
1.5"	100	100	100	**100**
1"	100	100	77	**94**
3/4"	100	95	15	**77**
1/2"	100	51	1	**60**
3/8"	100	32	0.7	**53**
No. 4	100	5	0.3	**45**
No.8	93	0	0	**40**
No.16	77	0	0	**33**
No.30	49	0	0	**21**
No.50	16	0	0	**7**
No.100	3	0	0	**1**
No.200	1	0.5	0.5	**1**
Blend %'s	**43%**	**32%**	**25%**	

Air Void System Characterization

	AVA				SAM		
Sample ID	Spacing Factor, in	Max Rec	Specific Surface, 1/in	Min Rec	SAM Number	Max Rec*	SAM Air
1-2	0.0117	**0.0100**	498	**600.00**	0.21	**0.25**	8.6%
2-2	0.0067	**0.0100**	750	**600.00**	0.16	**0.25**	7.8%
2-4	0.0079	**0.0100**	678	**600.00**	0.28	**0.25**	8.0%
3-2	0.0081	**0.0100**	602	**600.00**	0.16	**0.25**	7.8%
3-4	0.0059	**0.0100**	827	**600.00**	0.24	**0.25**	7.5%
4-1	0.0048	**0.0100**	919	**600.00**	0.16	**0.25**	7.3%
4-2	0.0075	**0.0100**	691	**600.00**	0.13	**0.25**	8.0%
4-4F		**0.0100**		**600.00**	0.16	**0.25**	8.4%
4-5F	0.0107	**0.0100**	549	**600.00**	0.24	**0.25**	8.8%

*Maximum Recommended Number

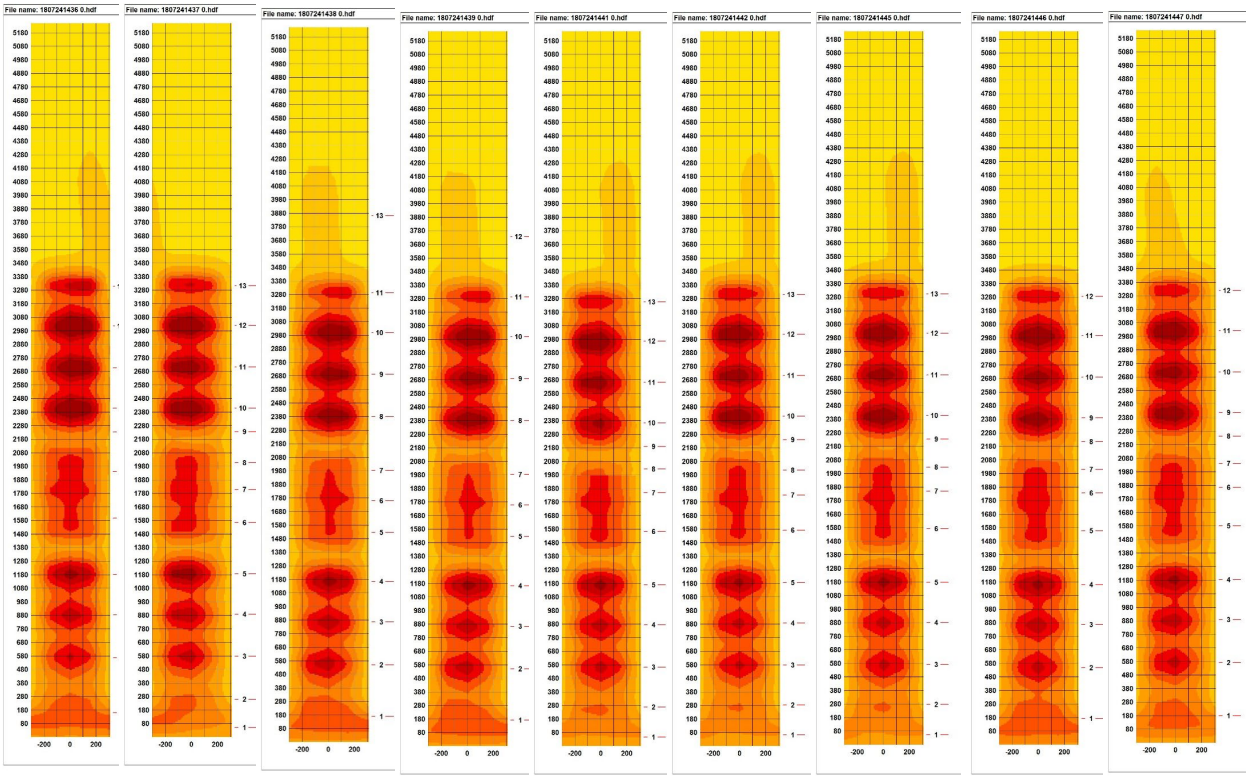
Compressive Strength

Average Compressive Strength			
	1-1	2-1	3-1
1 Day	1725		
2 Day	2375		
3 Day	2885		
5 Day	3268		
7 Day	3415	4062	4037
28 Day	5062	5423	5230
56 Day	5638	5760	5788

Surface Resistivity Data

ID	Cast Date	Days	0	90	180	270	0	90	180	270	AVG	AVG * 1.1
#1-1	7/16	7	12.9	13.1	13.4	11.6	12.9	13.3	13.3	11.5	12.8	14.0
#2-1	7/18	7	13.4	13.5	13.3	14.5	13.3	13.6	13.4	14.5	13.7	15.1
#2-3	7/18	7	11.2	10.3	10.2	10.6	11.2	10.4	10.0	10.6	10.6	11.6
#3-1	7/19	7	11.4	11.2	10.4	10.6	11.2	11.3	10.5	10.4	10.9	12.0
#3-3	7/19	7	12.3	10.9	11.9	12.6	12.4	11.0	11.7	12.3	11.9	13.1
#1-1	7/16	28	21.5	21.8	22.6	19.9	21.2	22.1	22.6	19.9	21.5	23.6
#2-1	7/18	28	24.6	24.7	24.0	26.4	24.9	24.9	24.1	26.6	25.0	27.5
#2-3	7/18	28	17.4	18.3	19.3	18.5	17.4	18.1	19.1	18.2	18.3	20.1
#3-1	7/19	28	18.2	18.2	16.9	16.9	18.2	18.2	16.8	16.9	17.5	19.3
#3-3	7/19	28	19.4	17.3	18.8	20	19.4	17.2	18.8	20	18.9	20.7
#1-1	7/16	56	33	32.9	34.2	30	32.8	32.4	34	30.5	32.5	35.7
#2-1	7/18	56	33.9	33.5	32.6	34.4	34	33.6	32.6	34.6	33.7	37.0
#2-3	7/18	56	23.7	25.4	25.7	25.2	23.6	25.6	25.9	25	25.0	27.5
#3-1	7/19	56	24	25.8	23.1	22.6	23.9	25.8	23.1	22.6	23.9	26.2
#3-3	7/19	56	26.3	23.1	25.4	26.8	26.4	23	25.5	26.6	25.4	27.9

Dowel Scan Data (MIT Scan 2)



Pavement Thickness

S. No	AVG, Inches	Design Thickness, Inches
1	8.1	8.0
2	8.7	8.0
3	8.3	8.0
4	8.6	8.0
5	8.3	8.0
Average	8.4	