United States
Department of Transportation

SUMMARY REPORT

US 20 Expansion

Holstein, IA

July, 2018

FHWA MCT Project # IA1802

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

BUCKLE UP AMERICA

MCT Field Report – Iowa Visit

Summary of the Visit

The Federal Highway Administration (FHWA) Mobile Concrete Trailer (MCT) visited the US-20 expansion project in Holstein, IA from July 8 to 13 and July 29 to Aug 3 at the request of Todd Hanson with Iowa 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.

The MCT Open House was conducted in coordination with the PEM presentation and the event was very well attended. The Iowa Concrete Paving Association (ICPA) and the National Concrete Pavement Technology Center assisted with this event.

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 very workable. The pavement edge was straight and stood without slumping. The surface finished well. The mixture had an excellent combined gradation, as well as a paste content that met 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 and total air content tracked well. The first week of calorimetry data indicated very consistent concrete. The test results from the second week were a little more variable but as would be expected because of differences in initial concrete temperature.

Iowa does not base acceptance on concrete strengths. The 56-day strengths were well above what most states use in design, indicating strength was adequate. The permeability test results (Surface Resistivity) fell in the medium category. But, since the samples were taken at the plant where the concrete had a high air content, they would not be accurate representatives of the concrete in the pavement.

Maturity was used to measure opening strength, as has been done in Iowa of over 20 years. It was reached in three days but with the high air content of the sample, likely the pavement actually reached opening strength in less time than that. The MIT SCAN found dowels to be in the proper location and alignment.

Positive Observations

- Use of low cement content mixtures
- Utilizing optimized aggregate gradation
- Air specification 6-10%
- Achieving very good air characteristics
- Performing field trials with the Super Air Meter and Box Test
- Use of the MIT Scan T2

- Requiring vibrator checks
- Use of maturity
- Knowledgeable agency staff
- Committed contractor staff

Recommendations

- Consider adopting the use of Surface Resistivity

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 US 20 Project

The U.S. 20 corridor is a 308-mile east-west route across Iowa connecting Dubuque to Sioux City. The facility is currently 260 miles of four-lane highway and the remaining 78 miles are two lanes. Project cost for the remaining 78 miles between US 71 (Early) and Moville is estimated at $496,904,920. This stretch of U.S. 20 is divided into 6 construction segments. Section 4 of the overall project requires construction of two additional lanes of U.S. 20 between Early and Moville which began in 2014. This final section of the U.S. 20 expansion is scheduled for completion in fall 2018. Once completed, a four-lane U.S. 20 will span Iowa.

Project Details Pertaining to Section 4

- Project extends from East of Correctionville to West of Jct. US 59 (appx. 11 miles)
- General Contractor: Ames Construction Inc.
- Paving subcontractor: Cedar Valley Corp
- Total contract award: $62.9 million
- Eastbound lanes were completed and open to traffic in 2017
- Westbound lanes paved and completed in 2018
- Paving began in October 2017 and is expected to be completed by May 2018

Design Details

- Design called for 26' section with 12' inside lane and 14' outside lane.
- Shoulders are 4' on the inside and outside
- Concrete pavement thickness 10" over a 6" granular subbase.

Project Specifications for Paving Concrete on US 20

- Minimum 28 Day Flexural Strength: 500 lb/in2
- Air content range: 6-10%
- Maximum w/cm: 0.45

Concrete Plant, Aggregates, and Stockpiles

- Rexcon – Model-S
- Plant capacity: 12cy, batch loads: 8cy
- Plant located in the northeast quadrant of County Road L51 and U.S. 20
- Aggregate stockpiles were well managed and were on a foundation

Concrete Plant

MCT at the Concrete Plant

Coarse (1”)

Intermediate (3/8")

Fine (Concrete Sand)

Aggregate Stockpile Management

Mixture Designs

- Cement (80%)
- Fly Ash (20%)
- Total Cementitious Content: 565 lbs
- Cement – GCC, Pueblo PC2902
- Fly Ash – HW, Nebraska City
- Air Entraining Agent – Brett Admixture Eucon AEA92
- Water Reducer – Brett Admixture Eucon WR 91

Material	Source	Weight, lbs
Cement, I/II	GCC-Pueblo	449
Fly Ash, Class C	HW-Nebraska City	112
Coarse Aggregate	L.G. Everist-Crocker	1382
Intermediate Aggregate	L.G. Everist-Larrabee	378
Fine Aggregate	L.G. Everist-Washta	1361
Water		224
Water c/m		0.40
Total Air		6%

Paste Content

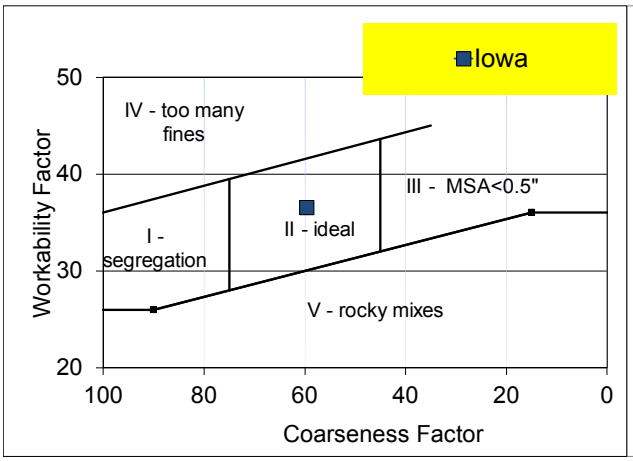
	Batch Weights wt.cu/yd	Specific Gravity	Absolute Volume cu,yd	Percent of Total Volume	
Cement	449.0	3.14	2.292	8.49	
Fly Ash	112.0	2.57	0.698	2.59	
Fine Agg.	1361.0	2.64	8.262	30.61	60.98
Inter Agg.	378.0	2.67	2.269	8.40	
Coarse Agg.	1382.0	2.68	8.264	30.61	
Water	224.0	1.00	3.590	13.30	
w/c ratio					0.40
% Air	6.0	0.00	1.620	6.00	

PERCENT PASTE

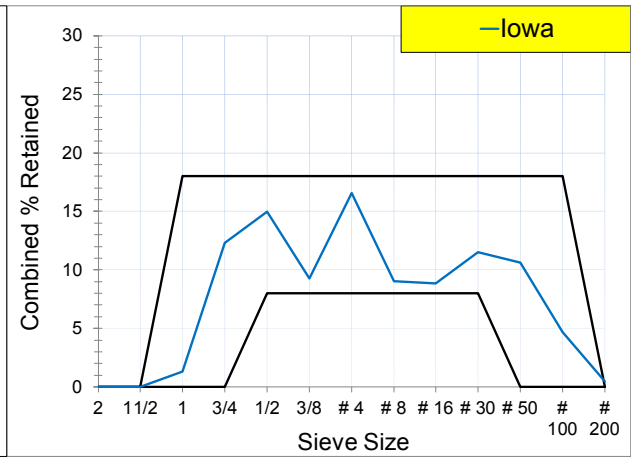
% Paste = 24.4

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

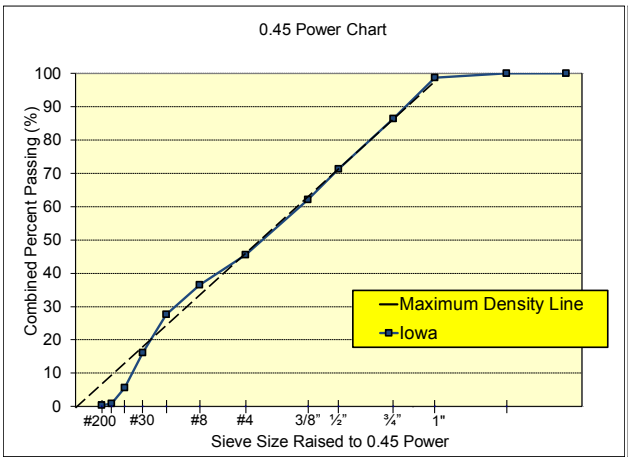
Mixture Design Gradations



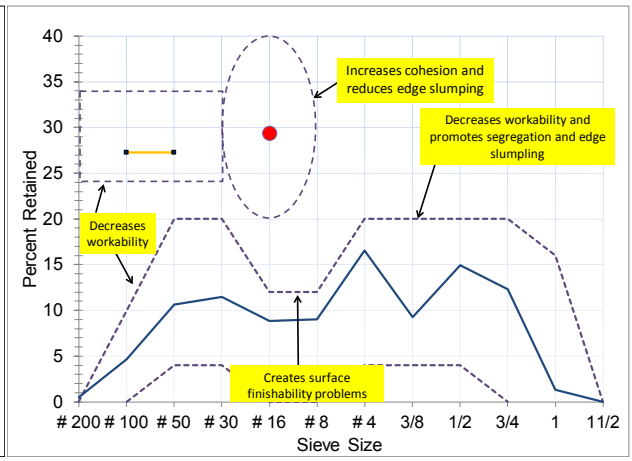
Coarseness Factor Chart



Percent of Aggregate Retained



FHWA 0.45 Power Chart



Tarantula Curve

Paving Operations

- Stringline paving, daytime paving
- Dowel baskets, pins used to anchor dowel baskets
- Dump truck used to transport concrete
- Joints were sealed
- The pavement was longitudinal tined for texture
- The MIT Scan T2 was used to measure pavement thickness












Sampling and Testing Locations

QC/QA on the grade

MCT Sampling at the plant

MCT Fresh Concrete Testing Matrix

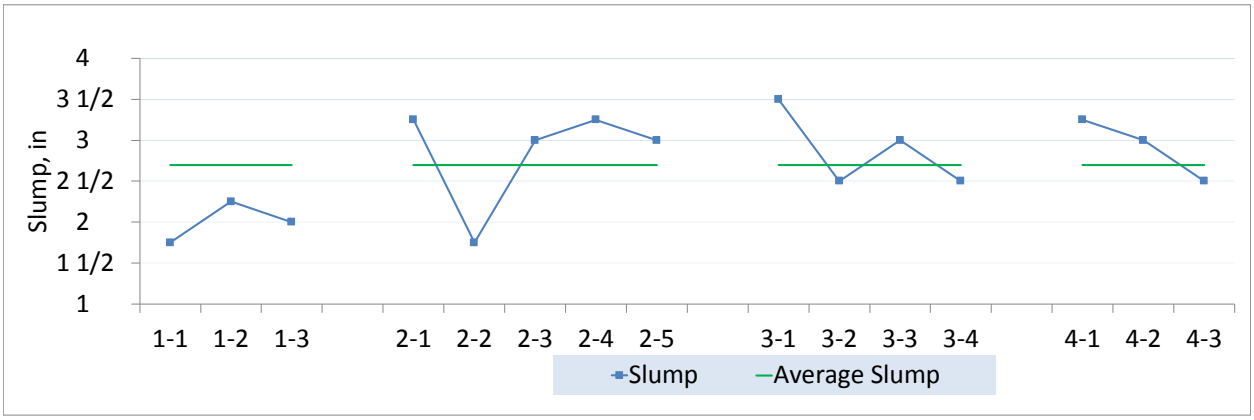
Section	Mixture Type	Date	Sample ID
Mainline	Regular	7/10	1-1,1-2, 1-3
Mainline	Regular	7/11	2-1, 2-2, 2-3, 2-4, 2-5
Mainline	Regular	7/12	3-1, 3-2, 3-3,3-4
Mainline	Regular	7/30	4-1, 4-2, 4-3, 4-4(F*), 4-5(F*), 4-6(F*), 4-7(F*)

*Field sample

TEST RESULTS

Slump

- Fifteen tests were taken at the plant
- Average Slump: 2.7”, Standard deviation: 0.6"

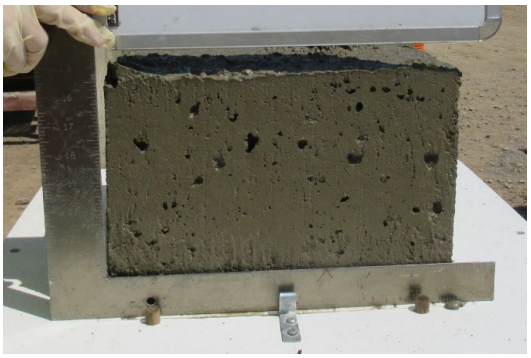


Box Test

- Four box tests were performed
- No edge slump or consolidation issues noticed

Sample 1-3

Sample 2-3



Sample 3-3

Sample 4-3

Edge and Finish

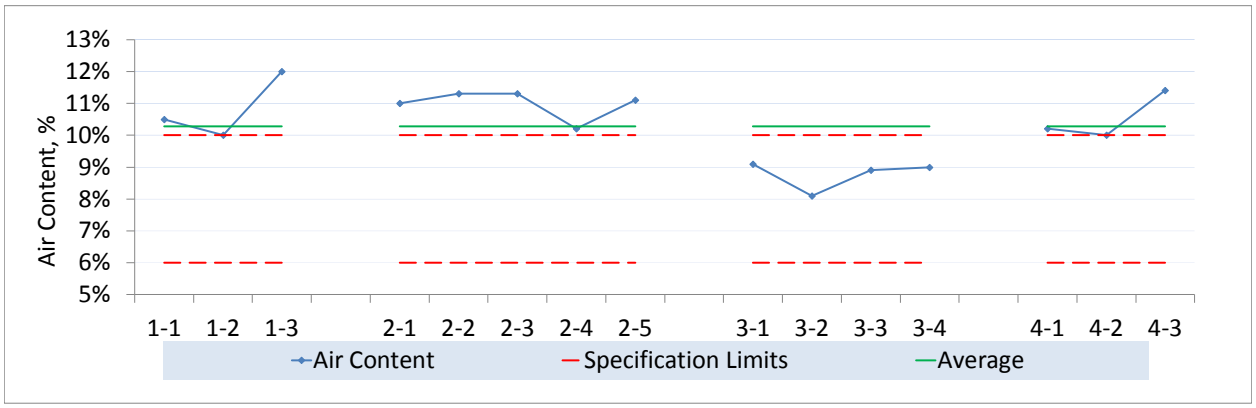
- Identical to the Box Test

Air Content and Air Void System

- Total Air is different than Air Void System

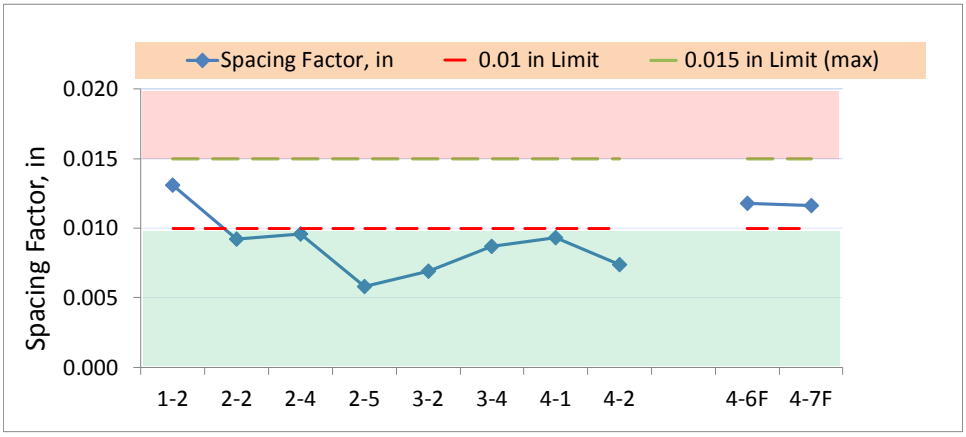
Total Air Content

- Fifteen air tests performed, all of them at the plant
- Average air content: 10.3%, Standard Deviation: 1.1%
- Limited variability observed. The high air content is due to testing performed at the plant.



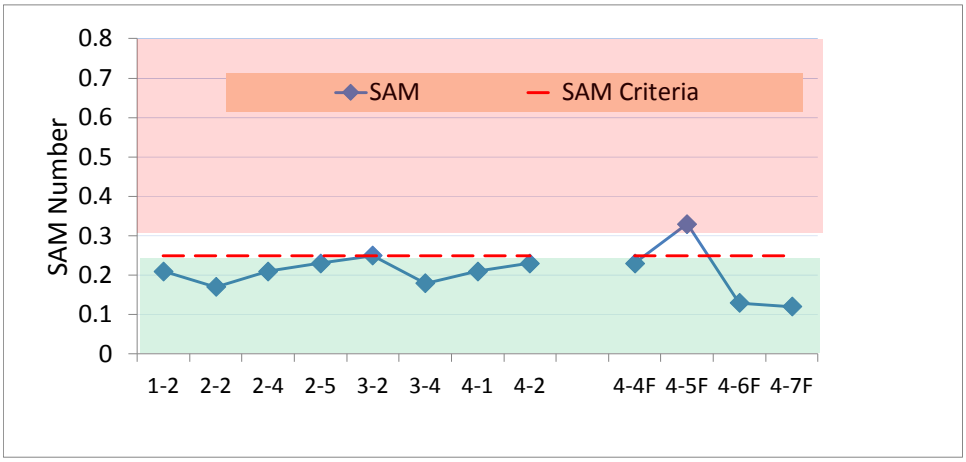
Air Void System Measured by the Air Void Analyzer (AVA)

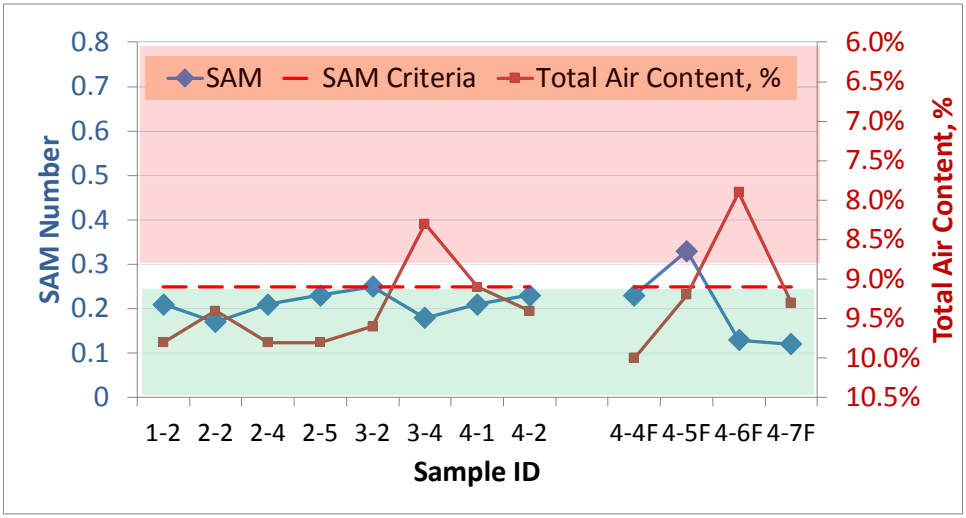
- Eight tests performed from samples taken at the plant and two tests from samples taken in the field
- Results indicate excellent spacing factor for seven of the eight samples. Two of the field tests indicate good spacing factor.



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

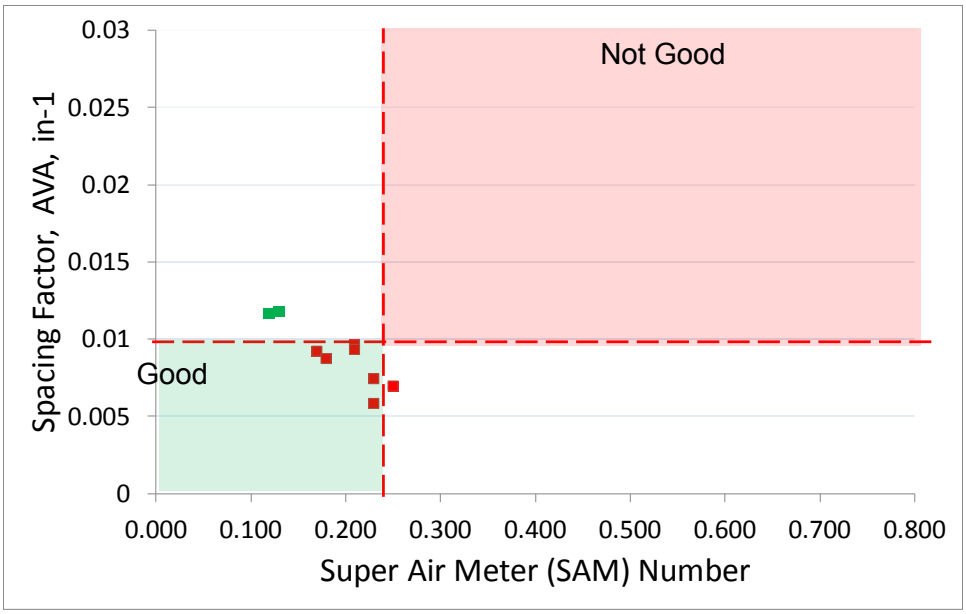
- Eight SAM tests performed at the plant and four in the field.
- Results indicate excellent air void characteristics (SAM numbers <0.25) in all but one field sample
- Total air content and SAM number did not correlate for the 12 tests





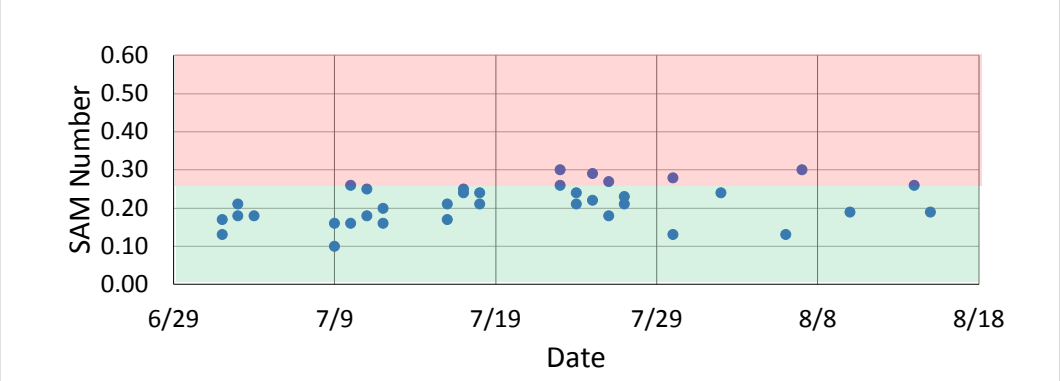
Super Air Meter versus the Air Void Analyzer

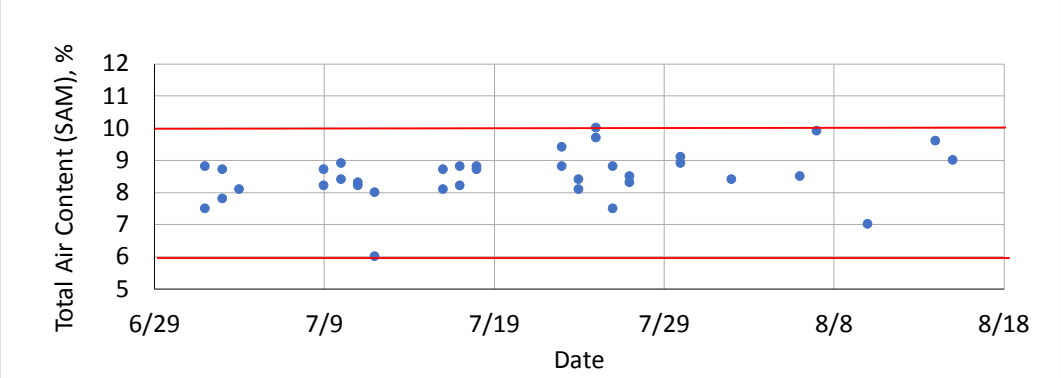
- Correlation between SAM and AVA data is excellent for the plant samples (red data markers). The correlation for field samples (green data markers) was fair (SAM indicated excellent air characteristics, while AVA indicated good/fair air characteristics.

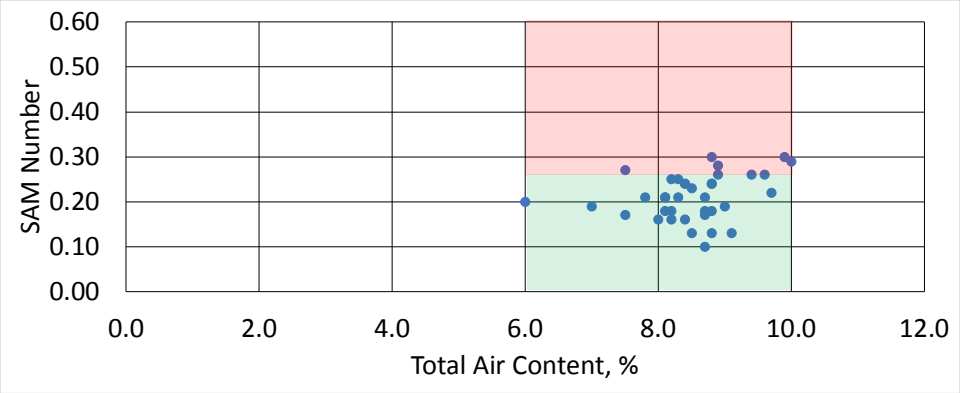


Contractor's (Cedar Valley) SAM Data

- Contractor performed 37 SAM tests in the field
- Average SAM number: 0.20 with a standard deviation of 0.05
- Total air content averaged 8.5% with a standard deviation of 0.8%







	SAM	Total Air (from the SAM)
Total Tests	37	37
Average	0.20	8.50%
Standard Deviation	0.05	0.80%
Coefficient of Variation	24%	9%

Air Loss During the Paving Process

- Significant number of tests were performed in the field before and after the paving the paver.
- Average air loss: 1.4%, standard deviation: 0.4%

In front of the paver

Behind the paver

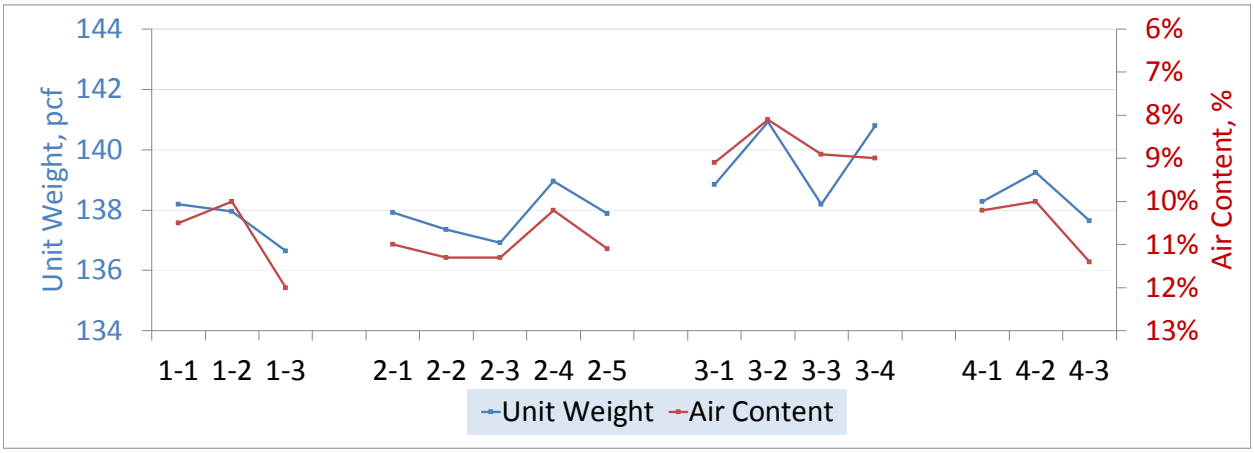
	Before Paver	After Paver	Difference
Total Tests	209	36	
Average	8.4%	7.2%	1.4%
Standard Deviation	0.7%	0.6%	0.4%
Coefficient of Variation	8%	9%	28%

Unit Weight

- Simple test to check uniformity: weight and volumetric proportions
- Fifteen tests performed. Limited variability observed.
- Average unit weight: 138.4 pcf, Standard Deviation: 1.2 pcf

Unit Weight and Air Content / Slump

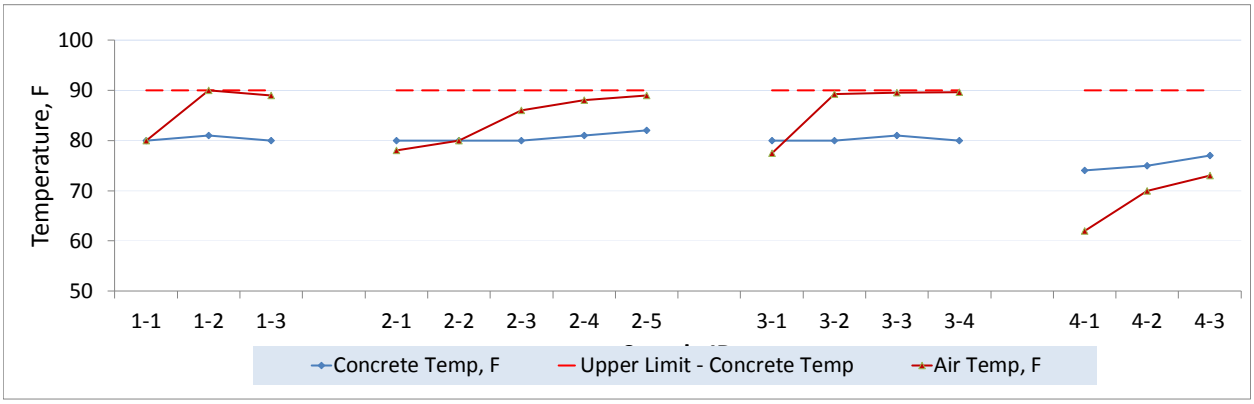
- Normally unit weight and air content will run parallel
  - Unit weight changes if air content changes
  - Unit weight changes if water (slump) changes
- When they diverge it indicates change in materials or proportions.
- Test Results: Unit weight and air content tracked



Concrete Temperature

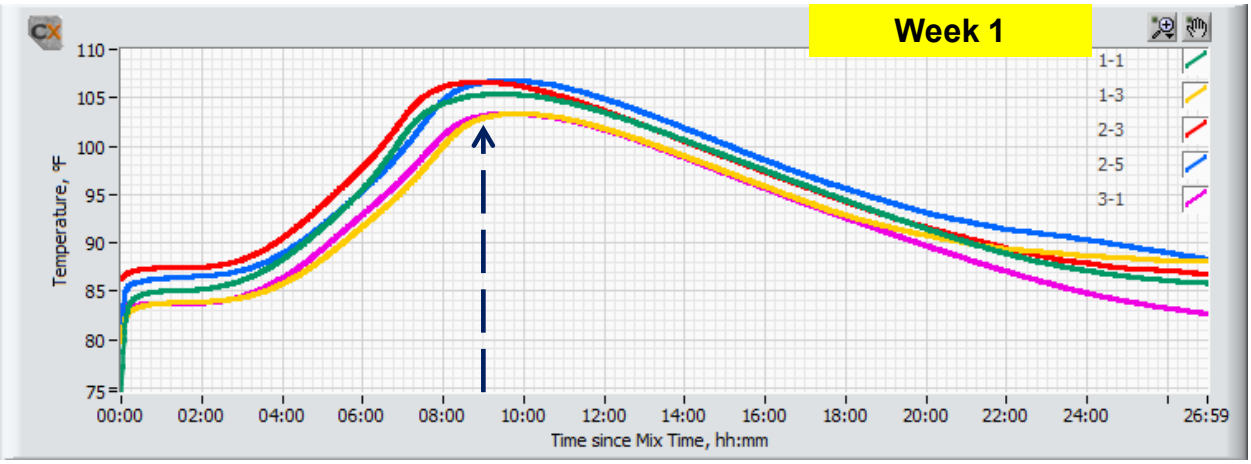
- Concrete temperature affects hydration rate which can impact workability and compatibility
- Air temperature stayed between 80 and 90˚F except on the last sample day.

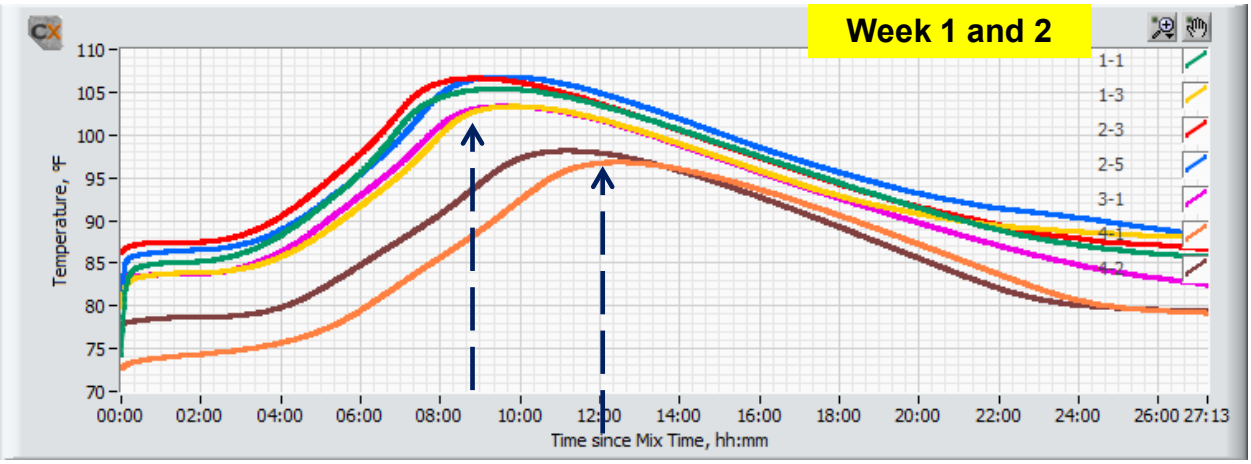
- Concrete temperature stayed consistent (low 80's), except for samples on the last day (mid-70s).



Heat Signature / Semi-Adiabatic Calorimetry

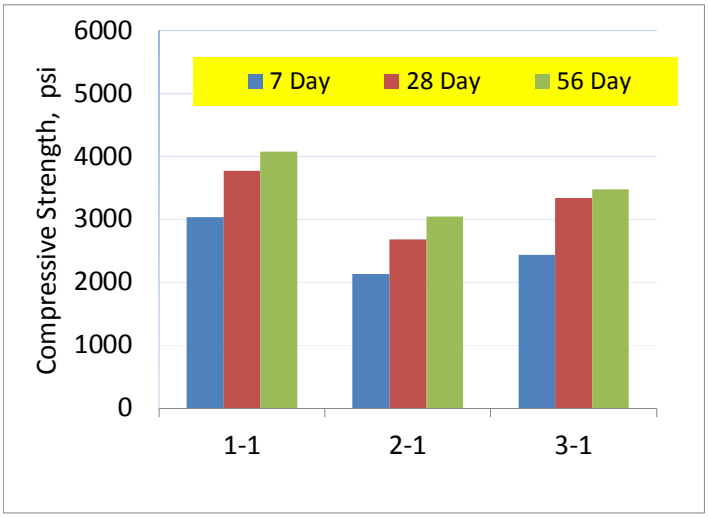
- Identifies changes in cementitious hydration due to cement, SCMs and admixtures
- Data indicated consistent heat signature curves during the first week.
- Heat signature curves were also consistent the second week. However, due to the low initial concrete temperature, the peak heat of hydration was lower and delayed by 2-3 hours compared to the first week.





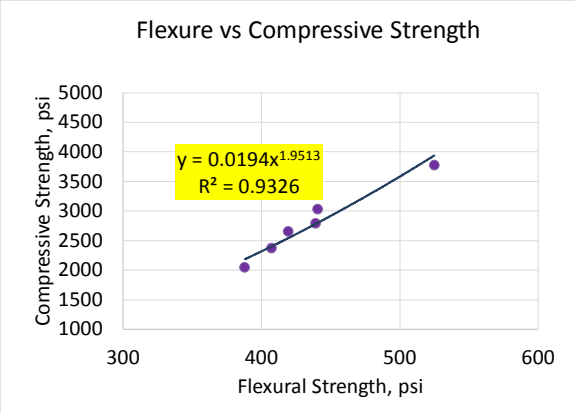
Concrete Strength

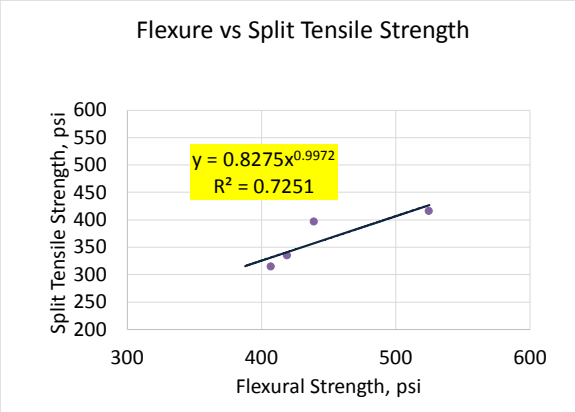
- Iowa does not base acceptance on concrete strengths. The 56-day strengths were well above what most states use in design, indicating strength was acceptable.
- Specimens for strength cylinders were cast at the plant with an average air content of 10.3%. The high air content contributes to the low strength results



Relationship between Flexural and Split Tensile / Compressive Strengths

- Flexural tests performed at 1, 2, 3, 5, 7 and 28 days of age
- Split tensile tests performed at 2, 3, 5 and 28 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

	56 Day	
	Modulus of Elasticity, E	Poisson's Ratio, μ
Run 1	3,464,928	0.18
Run 2	3,457,967	0.18
AVG	3,461,447	0.18

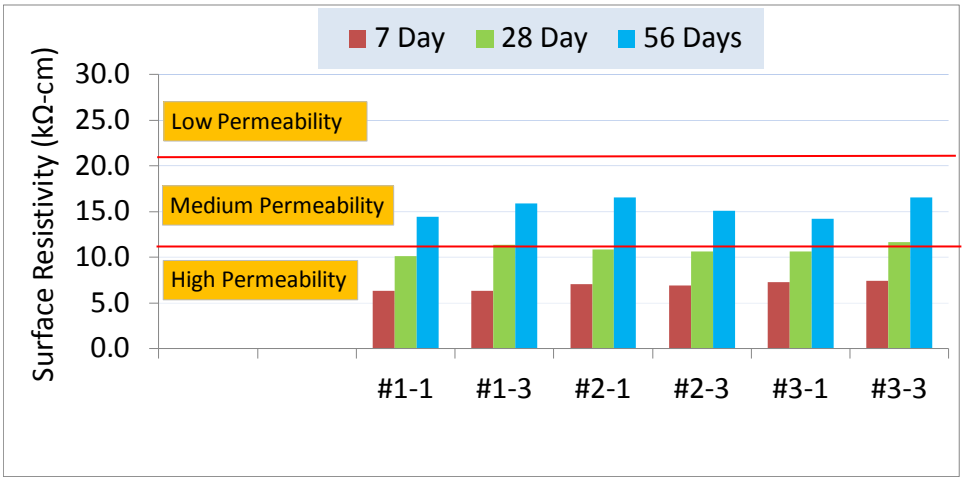
Coefficient of Thermal Expansion (CTE)

- 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
1-2	56	5.2
1-4	57	5.2
2-2	50	5.4
4-2	49	5.3

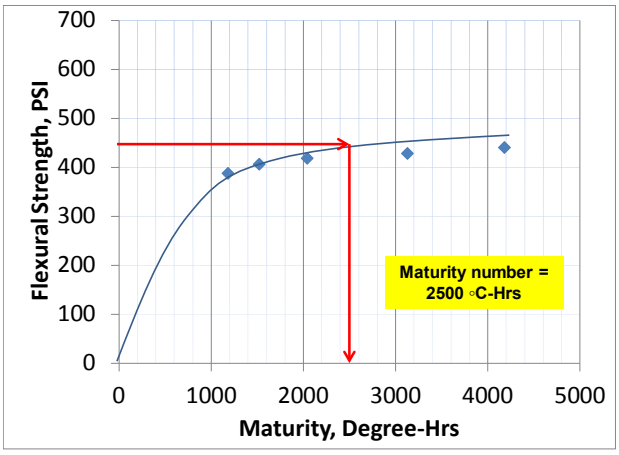
Surface Resistivity

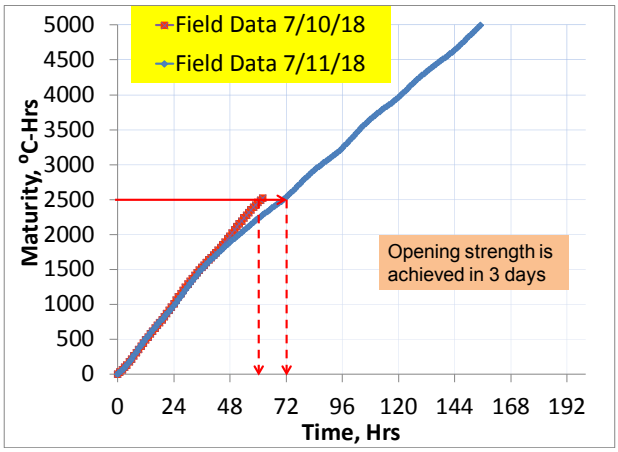
- Easy and quick test compared to the traditional Rapid Chloride Test
- Relates to the permeability of the concrete, which in turn influence durability
- At 56 days, all the specimens were in the medium permeability category



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



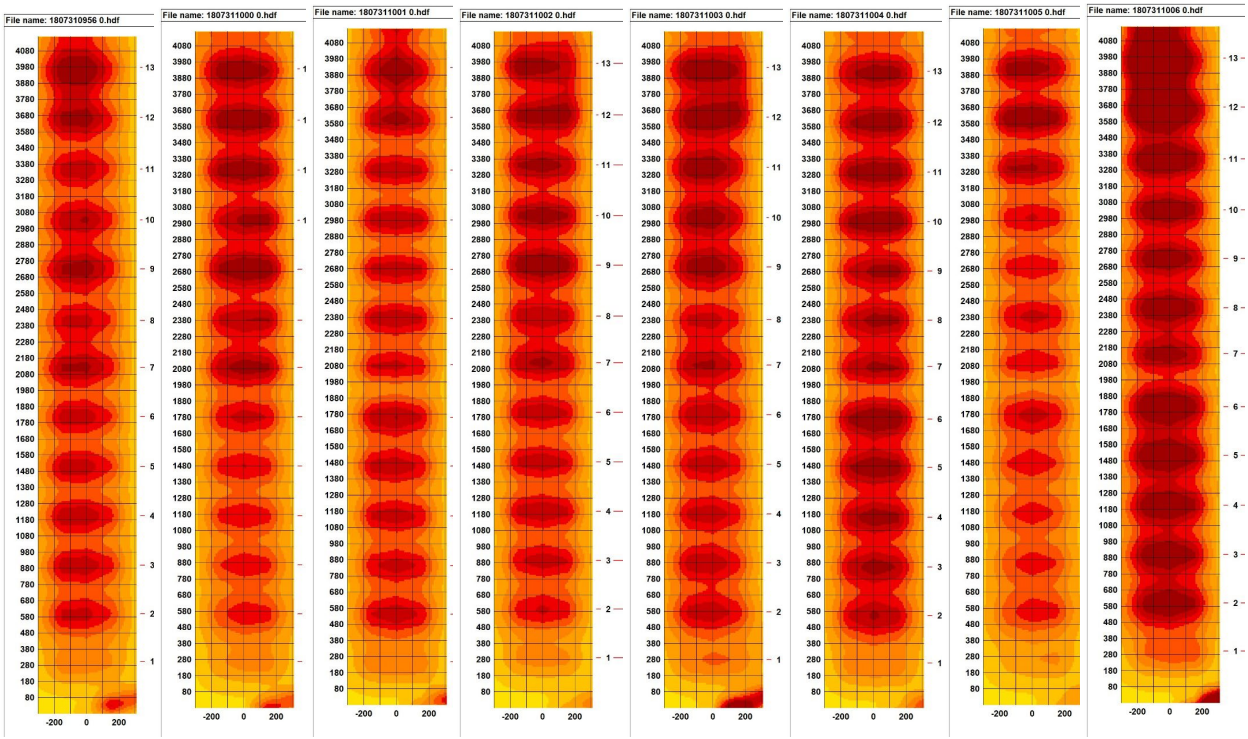


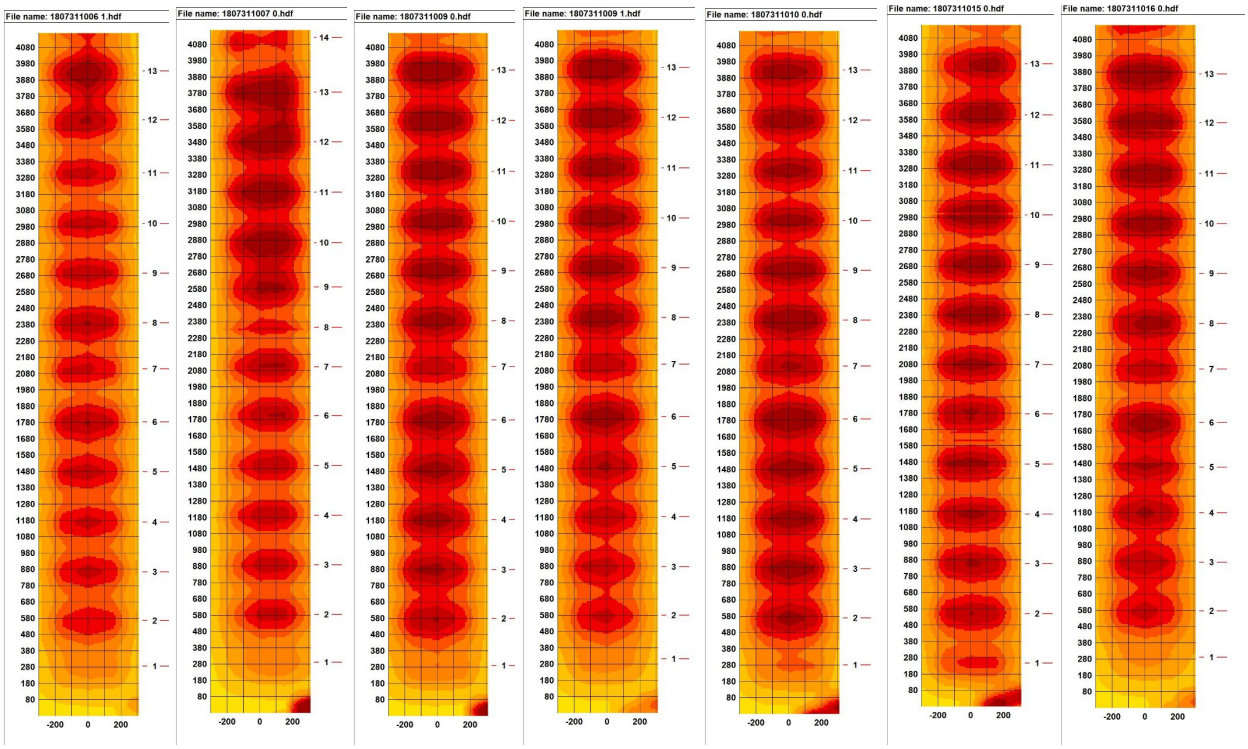
- Opening strength for construction traffic at this project is 500 psi flexural. For illustration purposes, 450 psi flexural strength is used as opening strength.
- The above curve (on the left) was built using specimens cast from concrete produced on 7/10/18. For the flexural strength of 450 psi, the maturity number for the regular mix was 2500˚C-Hrs
- In the field (curve on the right), opening strength is reached in three days or less.

Dowel Bar Alignment (MIT Scan 2)

- Magnetic Tomography used to determine dowel alignment at 15 consecutive joints
- Nondestructive approach
- Date of scan: 7/17/2018
- No major dowel alignment issues were found

Dowel Bar Scans





Positive Observations

Adequate saws for joint sawing

Safety Conscientious Contractor

Other MCT Activities

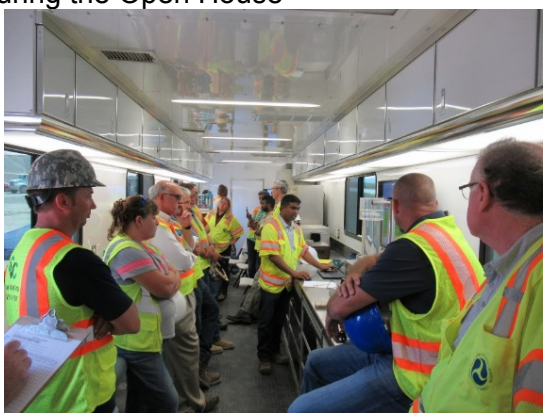
- Kick-Off Meeting and PEM / MCT Open House
- Close-Out Meeting (Iowa DOT, FHWA Division Office, Iowa Concrete Pavement Association and Contractor)
- Data collection for PEM initiative
- Additional data collection for Resistivity research by Dr. Jason Weiss
- SAM meter comparison testing with the contractor

Open House Presentations

Attendees during the Open House

Equipment Demonstrations during the Open House

Scan T2 Discs in the Field



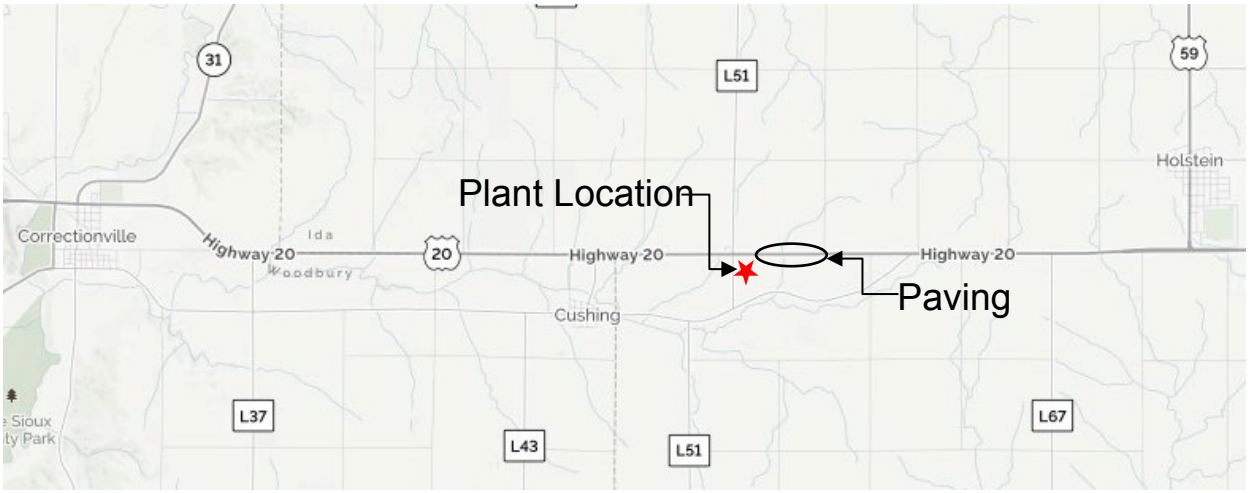
Close-Out Meeting

Acknowledgments

- Todd Hanson (Iowa DOT)
- Steve Mcelmeel (Iowa DOT)
- Lisa McDaniel (FHWA Division Office)
- Craig Hughes (Cedar-Valley Corp)
- John Quandahl (Cedar-Valley Corp)
- Greg Mulder (ICPA)
- Dan King (ICPA)
- Gordon Smith (CP Tech Center)
- Jarod Gross (Snyder & Associates)
- Rabi Pariyar (Snyder & Associates)

APPENDIX

Plant and Paving Location

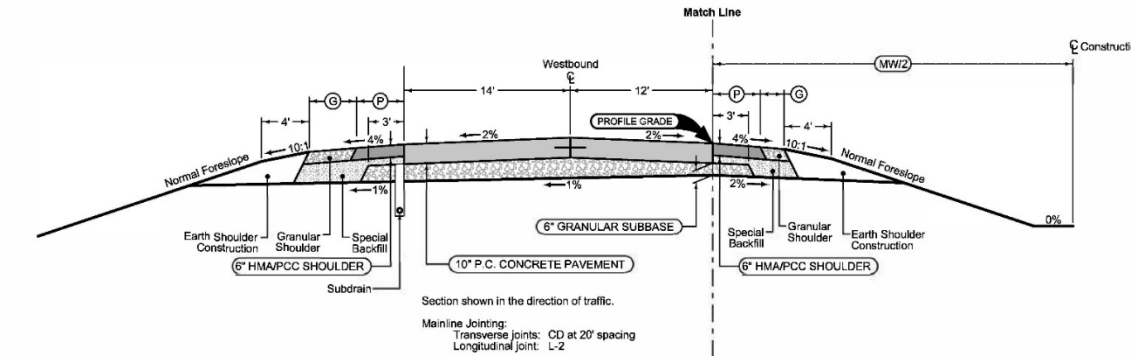


Fresh Concrete Properties

Sample ID	Date	Time, Local	Slump, inch	Conc Temp, ˚F	Air Temp, ˚F	Unit Weight, pcf	Air Content
1-1	7/10	9:06 a.m.	1.75	80	80.0	138.2	10.5%
1-2	7/10	10:30 a.m.	2.25	81	90.0	138.0	10.0%
1-3	7/10	2:00 p.m.	2.00	80	89.0	136.6	12.0%
2-1	7/11	8:56 a.m.	3.25	80	78.0	137.9	11.0%
2-2	7/11	10:35 a.m.	1.75	80	80.0	137.4	11.3%
2-3	7/11	11:40 a.m.	3.00	80	86.0	136.9	11.3%
2-4	7/11	12:50 p.m.	3.25	81	88.0	139.0	10.2%
2-5	7/11	3:05 p.m.	3.00	82	89.0	137.9	11.1%
3-1	7/12	8:18 a.m.	3.50	80	77.5	138.8	9.1%
3-2	7/12	10:36 a.m.	2.50	80	89.2	140.9	8.1%
3-3	7/12	11:42 a.m.	3.00	81	89.5	138.2	8.9%
3-4	7/12	12:13 p.m.	2.50	80	89.6	140.8	9.0%
4-1	7/30	8:35 a.m.	3.25	74	62.0	138.3	10.2%
4-2	7/30	9:46 a.m.	3.00	75	70.0	139.2	10.0%
4-3	7/30	11:07 a.m.	2.50	77	73.0	137.6	11.4%
Specification Limits				**90**			**6-10%***

*All the above samples were taken at the plant, while the point of acceptance was in the field

Pavement Design



Air Void Characteristics

		AVA				SAM		
Sample ID	Date	Spacing Factor, in	Max Rec*	Specific Surface, 1/in	Min Rec	SAM Number	Max Rec*	SAM Air
1-2	7/10/2018	0.0131	0.0100	410	600.00	0.21	0.25	9.8%
2-2	7/10/2018	0.0092	0.0100	538	600.00	0.17	0.25	9.4%
2-4	7/11/2018	0.0096	0.0100	548	600.00	0.21	0.25	9.8%
2-5	7/11/2018	0.0058	0.0100	600	600.00	0.23	0.25	9.8%
3-2	7/12/2018	0.0069	0.0100	679	600.00	0.25	0.25	9.6%
3-4	7/12/2018	0.0087	0.0100	581	600.00	0.18	0.25	8.3%
4-1	7/30/2018	0.0093	0.0100	515	600.00	0.21	0.25	9.1%
4-2	7/30/2018	0.0074	0.0100	659	600.00	0.23	0.25	9.4%
4-4F	7/30/2018		0.0100		600.00	0.23	0.25	10.0%
4-5F	7/30/2018		0.0100		600.00	0.33	0.25	9.2%
4-6F	7/30/2018	0.0118	0.0100	459	600.00	0.13	0.25	7.9%
4-7F	7/30/2018	0.0116	0.0100	451	600.00	0.12	0.25	9.3%

*Maximum Recommended Number

Average Compressive Strengths

Average Compressive Strength, psi			
Age	1-1	2-1	3-1
1 Day	2040		
2 Day	2370		
3 Day	2654		
5 Day	2791		
7 Day	3032	2135	2440
28 Day	3773	2685	3339
56 Day	4075	3048	3480

Maturity Data

Flexural Strength, psi	Maturity (flexural beam), ˚C-Hrs
388	1181
407	1523
419	2041
439	3131
441	4181

Strength Relationships

Age	Compressive Strength, psi	Flexural Strength, psi	Split Tensile Strength, psi
Day 1	2040	388	
Day 2	2370	407	314
Day 3	2654	419	334
Day 5	2791	439	396
Day 7	3032	441	
Day 28	3773	525	415
Day 56	4075		447
Day 90			

Surface Resistivity Data

ID	Cast Date	Days	0	90	180	270	0	90	180	270	AVG	AVG * 1.1
#1-1	7/10	7	5.6	5.7	5.8	5.8	5.7	5.7	5.7	5.8	5.7	6.3
#1-3	7/10	7	5.9	5.8	5.8	5.7	5.8	5.7	5.8	5.7	5.8	6.4
#2-1	7/11	7	6.3	6.3	6.6	6.2	6.5	6.3	6.7	6.3	6.4	7.0
#2-3	7/11	7	6.2	6.8	5.9	6.3	6.2	6.6	5.9	6.4	6.3	6.9
#3-1	7/12	7	6.9	6.6	6.3	6.5	6.9	6.6	6.3	6.5	6.6	7.2
#3-3	7/12	7	6.4	6.8	6.9	6.9	6.4	6.8	6.8	6.9	6.7	7.4
#1-1	7/10	28	9.5	9.1	9.7	8.6	9.4	9.1	9.6	8.7	9.2	10.1
#1-3	7/10	28	11.3	10.1	10.1	9.9	11.2	10.1	10.0	10.0	10.3	11.4
#2-1	7/11	28	9.7	9.9	10.2	9.6	9.9	9.9	10.2	9.6	9.9	10.9
#2-3	7/11	28	9.3	10.3	9.2	9.7	9.5	10.1	9.3	9.7	9.6	10.6
#3-1	7/12	28	9.3	9.1	10.5	9.6	9.3	9.1	10.7	9.6	9.7	10.6
#3-3	7/12	28	10	10.5	10.9	10.9	10.2	10.6	10.6	10.8	10.6	11.6
#1-1	7/10	56	13.3	13.4	11.2	14.2	13.6	12.7	13.4	13.3	13.1	14.5
#1-3	7/10	56	15.9	14.5	13.6	14.2	15.8	14.4	13.2	14.2	14.5	15.9
#2-1	7/11	56	15.3	15.8	13.7	15.6	15.5	15.8	13.1	15.8	15.1	16.6
#2-3	7/11	56	13.3	14.8	13.2	13.7	13.6	14.3	13.4	13.6	13.7	15.1
#3-1	7/12	56	12.6	12.1	14.2	12.9	12.5	12	14.2	12.6	12.9	14.2
#3-3	7/12	56	15.8	15	14.8	14.7	15.8	15	14.8	14.7	15.1	16.6
#1-3	7/10	71	16.4	15.3	14.5	15	16.4	15.4	14.6	15	15.3	16.9
#2-1	7/10	70	15.5	15.9	14	15.8	15.9	15.9	14.1	16	15.3	16.8
#2-3	7/11	70	13.8	15	13.6	14	13.9	13.8	13.7	13.9	14.0	15.4
#3-1	7/11	69	13.3	13.1	14.9	13.7	13.3	13.1	14.9	13.8	13.8	15.1
#3-3	7/12	69	16.5	15.5	15.4	15.3	16.4	15.5	15.3	15.4	15.7	17.2

Surface Resistivity and Rapid Chloride Penetrability Data

Sample ID	Cast Date	Age	Surface Resistivity, kΩ-cm		Rapid Chloride Penetrability Test, coulombs	
#1-3	7/10/2018	73	16.9	Moderate	2378	Moderate
#2-1	7/11/2018	72	16.8	Moderate	2577	Moderate
#2-3	7/11/2018	72	15.4	Moderate	2939	Moderate
#3-1	7/12/2018	71	15.1	Moderate	2821	Moderate
#3-3	7/12/2018	71	17.2	Moderate	2221	Moderate