IMPLEMENTATION OF PERFORMANCE ENGINEERED MIXTURES, AASHTO PP 84-18

TH-60 Westbound, Watonwan County, Minnesota

INTERIM REPORT

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EXECUTIVE SUMMARY

The Minnesota Department of Transportation (MnDOT), as a participant in the Federal Highway Administration Pooled Fund TPF-5(368), "Performance Engineered Concrete Paving Mixtures," specified the use of Performance Engineered Mixture (PEM) concrete mixture designs for two paving projects constructed in Minnesota. The first project involved the construction of an unbonded concrete overlay of an existing jointed plain concrete pavement along Trunk Highway TH-60 in Watonwan County, Minnesota (MnDOT S.P. 8309-52).

CHAPTER 1 INTRODUCTION

1.1 Background

The Federal Highway Administration Pooled Fund TPF-5(368), "Performance Engineered Concrete Paving Mixtures," is a collaborative effort among many state transportation agencies to deploy performance engineered mixtures in highway paving projects. As a participant in this study, the Minnesota Department of Transportation (MnDOT) has worked to implement Performance Engineered Mixture (PEM) designs in paving projects constructed in Minnesota in fulfilling Work Task 5 of TPF-5(368). The first implementation of PEM in fulfillment of Work Task 5 is MnDOT S.P. 8309-52, an unbonded concrete overlay of an existing jointed plain concrete pavement along Trunk Highway TH-60 in Watonwan County, Minnesota.

1.2 Scope and objectives

This portion of the Work Task 5 effort focused on the following objectives.

- On-site training and support for contractor use of Super Air Meter (SAM)
- Collect and compile all contractor construction QA/QC test data related to PEM
- Complete PEM Pooled Fund Administrator data collection spreadsheet

In addition, the fulfillment of the Work Task 5 objectives includes the production of this post-construction report summarizing the project and data collection.

1.3 Overview of report

This report provides general information on tests performed and a summary of test results related to the use of PEM for the unbonded overlay of TH-60. Appendices to the report include MnDOT mix design development documents, laboratory mix testing results, field testing results, and a unpublished article describing the Phoenix test, respectively.

Figure 1. Overview of paving operations along TH-60 near St. James, MN

CHAPTER 2 PROJECT INFORMATION

The project was located along TH-60 near St. James, MN. The project area is illustrated in Figure 2 and Figure 3.

Figure 2. Location of paving project along TH-60 near St. James, MN

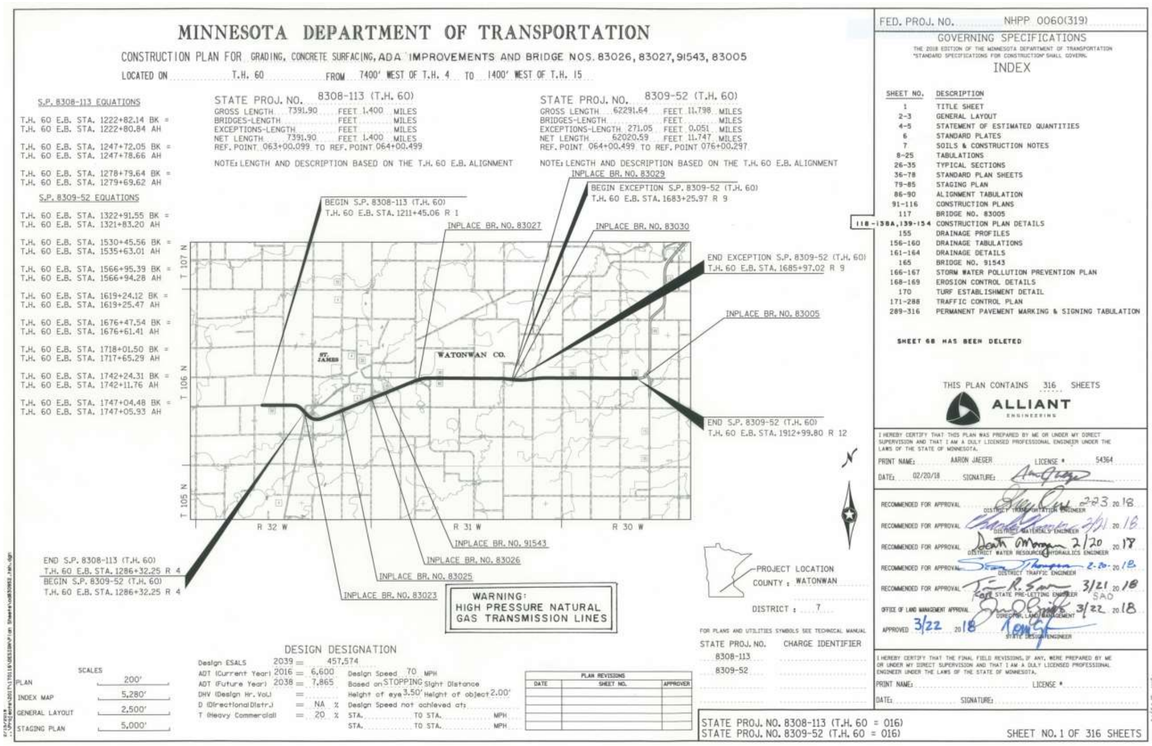


Figure 3. MnDOT construction plans for S.P. 8308-113 and S.P. 8309-52

2.1 Paving project details

Details relating to the use of PEM and the paving project include the following items.

- An unbonded concrete overlay was placed along a 12-mile stretch of TH-60 during June 6 - July 18, 2019.
- The 7.5-inch unbonded concrete overlay was placed on a 1.5-inch permeable asphalt stabilized stress relief course (PASSRC) interlayer (Figure 4). The existing jointed plain concrete pavement (JPCP) was 9 inches in thickness.

- The paving contractor was PCi Roads of St. Michael, MN.
- The contractor established a mobile concrete plant near the intersection of TH-60 and County Road CR-12. The mobile plant was certified by MnDOT prior to paving.
- At MnDOT's request, the contractor performed additional pre-paving tests of the concrete paving mix (Appendix B) and cast additional field specimens during paving.

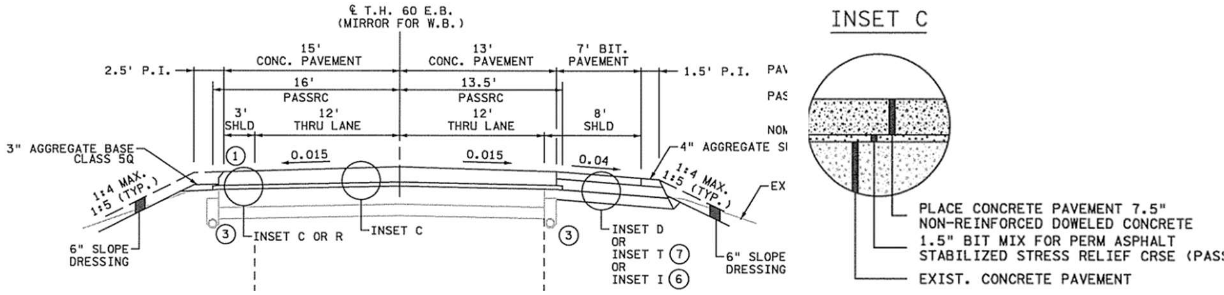


Figure 4. TH-60 design plans for unbonded overlay on a PASSRC interlayer

2.2 Concrete paving mix design

The initial concrete mixture used for the overlay was designated MnDOT 3A21-13; a revised mix was requested by the paving contractor to improve workability and finish. This mix – the mix used for paving – was designated as 3A21-2. Details of both 3A21-13 and 3A21-2, as tested and reported in Work Task 1 of the Pooled Fund effort for this project, are summarized in Table 1 below and in Appendix A to this report. Gradations performed on the mix aggregates are represented in Figure 5 using the tarantula curve.

Table 1. Mix design summary for initial and final designs used for TH-60 paving mix

	Amount per yd^3	
Material	**3A21-13**	**3A21-2**
Type I/II Continental Davenport Cement (lbs)	412	400
Boral, Headwaters Coal Creek Type F (lbs)	203	200
Coarse Agg., 1-1/2" Minus, Pit #52003 (lbs)	586	595
Coarse Agg., 3/4" Minus, Pit #52003 (lbs)	1,173	1,191
Fine Agg., Pit #52007 (lbs)	1,159	1,177
Water (lbs)	240	228
Air Entrainer, Mapei Polychem SA (oz/cwt)	2.0	2.0
Mid-Range Water-Reducer, Mapei Paver Plus (oz/cwt)	4.0	4.0
HRWR, Dynamon SX (oz/cwt)	2.0	--

PEM-specific tests of 3A21-13 were performed in the laboratory immediately after batching, at 15 minutes after batching, and at 30 minutes after batching. These results are summarized in Chapter 3 and in Appendix B.

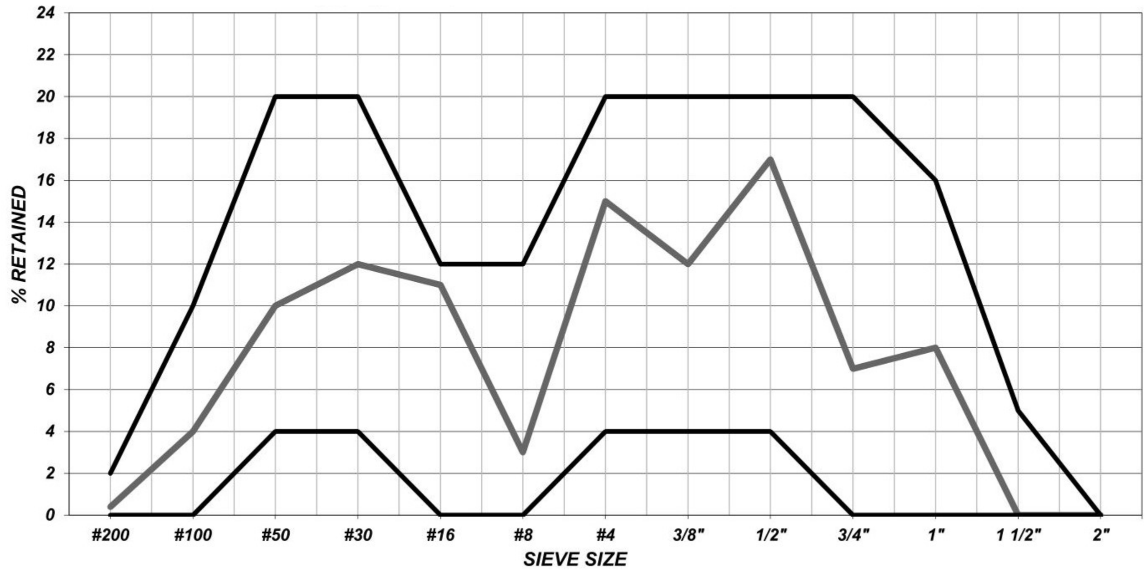


Figure 5. Tarantula curve for paving mix (MnDOT 3A21-2)

CHAPTER 3 TESTS PERFORMED

3.1 Tests performed

In addition to conventional tests to characterize fresh mix and hardened concrete performance in the laboratory and field, MnDOT and the paving contractor oversaw tests described in AASHTO PP 84-18 to characterize the performance of PEM for concrete paving. These tests include the following procedures, which are either unconventional or otherwise unfamiliar to most paving contractors.

Super air meter. The Super Air Meter (SAM) method assesses the volume of air and characterizes the air void system using a measure known as the SAM number. Laboratory and field tests using SAM followed the procedure outlined in AASHTO TP 118.

Vibrating Kelly ball (VKelly). The vibrating Kelly ball test evaluates the flow and workability of placed mix in terms of the penetration rate of a probe (in millimeters per root-seconds). Laboratory VKelly tests were performed according to AASHTO TP 129.

Box test. The box test assesses the flow and workability of a given concrete paving mix. This test is presented as an alternative to VKelly in AASHTO PP 84-18. Laboratory box tests were performed on 3A21-2 according to the procedure outlined in Appendix X3 of AASHTO PP 84-18. Box test results include (A) a qualitative measure to estimate the deformed surface relative to reference photographs and (B) a measure of edge slump (in inches) using a straightedge.

Bucket test. The bucket test assesses the resistivity of concrete cylinders to chloride ion penetration after soaking in a five-gallon bucket containing a chloride solution. The resistivity indirectly evaluates the formation factor (or "F Factor") of the concrete. The formation factor can be used in place of other measures to understand the long-term durability of paving concretes. The bucket test procedure, as performed in this study, is outlined in AASHTO TP 119.

Phoenix test. The laboratory tests also included the Phoenix test to assess water/cementitious ratio (w/c). This test uses rapid heating of a concrete sample to induce water loss and quickly determine the water-to-cementitious ratio. The determination of w/c is based on an understanding of the mix design, the volume and mass of the sample, and the total mass loss, which is assumed in the procedure to be water.

As the Phoenix test is not included in AASHTO PP 84-18 nor described in a current AASHTO or ASTM standard, the basic procedure is outlined below.

- Prepare test apparatus – this step is important as the test materials are unusual (Pan, cylinder mold, heating element, scale)
- Obtain air content
- Mold sample using 4x8 cylinder (i.e. sample has known volume)
- Empty sample into pre-heated pan on heating element (which are all located on the scale for regular mass measurements)
- Heat sample, apply searing iron, for anywhere between 10-30 minutes
- Record mass until mass remains constant over a period of 3-5 minutes

The procedure above summarizes more extensive detail from the unpublished article, “Determining the Water to Cement Ratio of Fresh Concrete by Evaporation,” by Robertson and Ley of Oklahoma State University (OSU). This article, which is reproduced in full in Appendix D, was provided to MnDOT to assist in scoping and performing the Phoenix test.

Figure 6. Phoenix test apparatus [Photo provided by Robertson and Ley of Oklahoma State University]

3.2 Results in summary

Full results of the field and lab tests are reported in Appendix A and recorded in the PEM Pooled Fund Administrator data collection spreadsheet ("MNDOT_TH60_Watanwon_Co_State-Data-Entry-Form.xlsx").

3.2.1 Super air meter

SAM test results are summarized in Table 2 and Table 3 for field and laboratory results, respectively. The average SAM number of field tests was 0.21. The average SAM number from laboratory tests was 0.19. Laboratory tests of 3A21-13 also included an ASTM C457 (Procedure A) assessment of hardened air, which estimated the spacing factor as 0.003 inches.

3.2.2 Box test

Laboratory box tests were performed at 0 minutes, 15 minutes, and 30 minutes after batching. Results for box tests are reported in Table 3.

Table 2. Results of field tests using SAM (Mix 3A21-2)

Station	1654+00	1619+50	1600+15	155+90	1537+32	1239+56	1265+17	1303+87
Test Date	6/13/2019	6/14/2019	6/14/2019	6/17/2019	6/17/2019	6/19/2019	6/19/2019	6/24/2019
Test Time	1:50	8:25	11:45	8:37	11:42	10:00	14:43	11:12
SAM Number	0.23	0.23	0.27	0.19	0.07	0.18	0.17	0.24

Station	1323+18	1340+37	1358+62	1440+18	1468+50	1499+25	1512+68	1275+17
Test Date	6/24/2019	6/24/2019	6/26/2019	6/28/2019	6/28/2019	6/29/2019	6/29/2019	7/1/2019
Test Time	15:00	17:20	9:02	10:55	14:57	7:15	9:55	11:17
SAM Number	0.23	0.2	0.17	0.27	0.19	0.34	0.05	0.18

Station	1296+55	1518+88	1508+08	1418+73	1878+08	1721+37	1595+65
Test Date	7/2/2019	7/3/2019	7/8/2019	7/8/2019	7/9/2019	7/10/2019	7/11/2019
Test Time	9:16	10:40	8:15	14:14	15:28	11:52	9:46
SAM Number	0.16	0.19	0.23	0.17	0.31	0.3	0.12

Table 3. Laboratory results for tests of fresh mix (3A21-13)

Minutes after batching	0	15	30
Unit Weight (pcf)	143.6	142.8	143.2
Slump (in)	2.8	2.50	2.25
Air Content (%)	6.3	6.0	5.8
Super Air Meter (SAM) Number	0.16	0.19	0.21
Box Test, Vertical Surface Ratings	2, 2, 2, 1	2, 2, 2, 1	1, 2, 2, 1
Box Test, Edge Slump (in)	0.00	0.00	0.25

3.2.3 Vibrating Kelly ball (VKelly)

Results of laboratory VKelly tests on Mix 3A21-13 are summarized in Figure 7, which is excerpted directly from the laboratory report in Appendix B. These results were measured in the laboratory using inches instead of millimeters. The results in Figure 7 are reported (in inches) at 0 minutes, 15 minutes, and 30 minutes after batching. These results, when converted to millimeters, correspond with VKelly values of 9.9, 10.6, and 12.1 mm/√s. These values are below AASHTO PP 84-18 specifications of 15-30 mm/√s. As noted in Section 3.1, no VKelly tests were performed on the field mix (3A21-2).

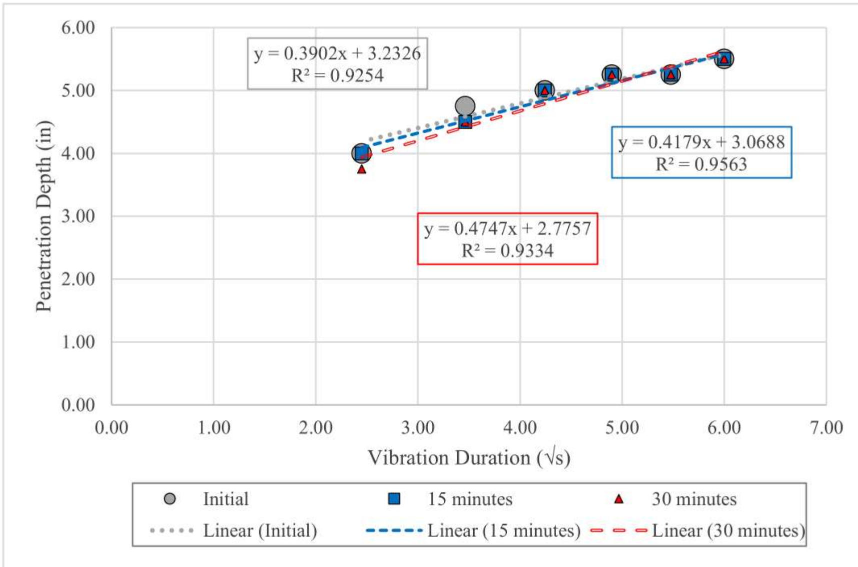


Figure 7. Results of vibrating Kelly ball test (3A21-13)

3.2.4 Bucket test and formation factor

MnDOT collected field samples for bucket tests, which were performed in the laboratory. Field bucket tests were not performed.

Summary bucket test results from laboratory testing of 3A21-2 are reported in Table 4 and Figure 8. Measured surface resistivity results (i.e. raw test data) are provided in Appendix B of this report. The calculated formation factor of 1270 is also reported in Table 4.

Effective surface resistivity was calculated automatically in the worksheet provided to MnDOT by Oregon State University for bucket test data entry. Those calculations consider measured surface resistivity, specimen dimensions, specimen temperature, and surface probe sensor spacing. Equations and other assumptions describing the calculations for effective surface resistivity and formation factor are provided in AASHTO TP 119 and AASHTO PP 84, respectively.

Table 4. Effective surface resistivity results and formation factor from bucket tests (AASHTO TP 119) of laboratory batched mix (MnDOT 3A21-13)

Age (d)	1	3	5	7	14	28	56	91
Average Effective Surface Resistivity (kOhm-cm)	2.28	2.43	2.70	2.89	3.97	6.79	11.09	12.70
							Formation Factor	1270

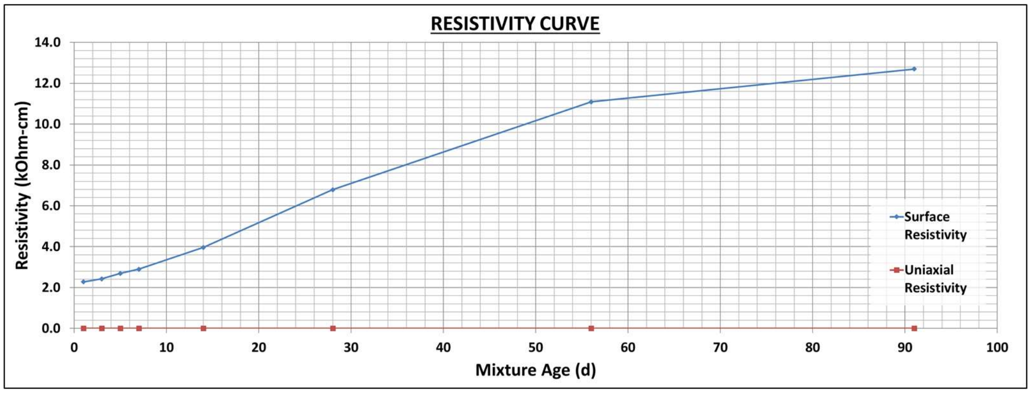


Figure 8. Effective surface resistivity results from bucket tests (AASHTO TP 119) of laboratory batched mix (MnDOT 3A21-13)

3.2.5 Phoenix test

Phoenix testing was performed in the laboratory on concrete batched at a w/c ratio of 0.39. Phoenix testing of this mix estimated the w/c ratio to be 0.38. This value was calculated from the total lost mass through heating (water loss, shown in Figure 9); the volume and mass of the concrete sample; and the amount of cementitious products (binder) in the mix design. More detail on the Phoenix test procedure, test data, and w/c calculation is provided in Appendix D.

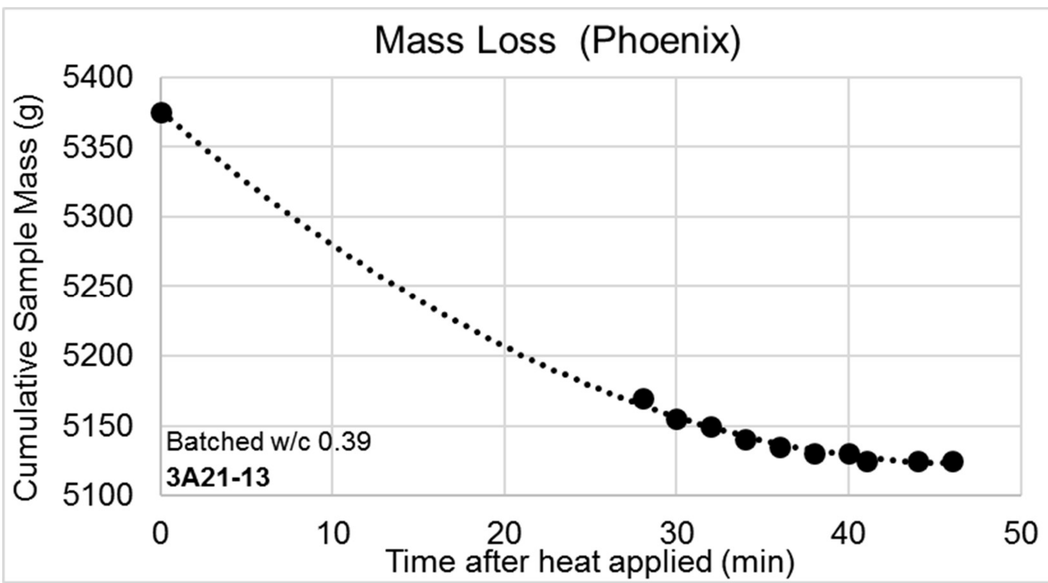
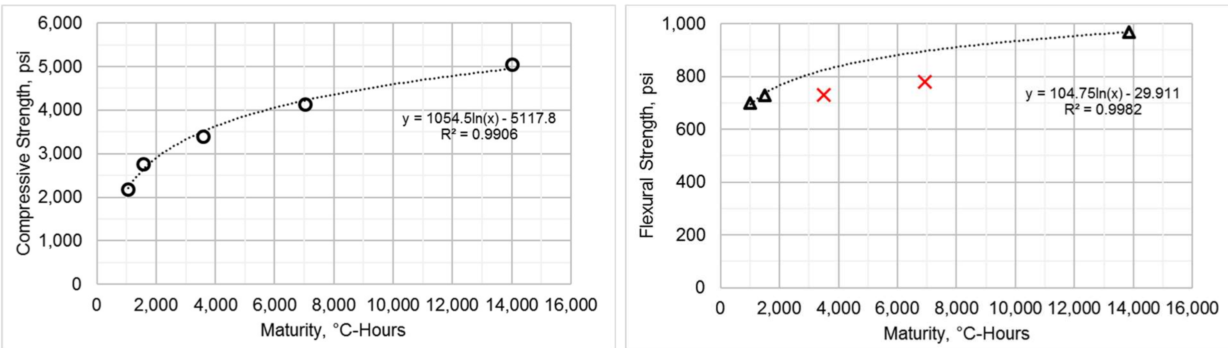


Figure 9. Laboratory Phoenix test results for lost mass over time (3A21-13)

Due to issues with test equipment, Phoenix testing in the field was not performed for the TH-60 paving project.

3.2.6 Laboratory maturity curve and field maturity beams

Initial maturity testing for the TH-60 paving used compressive and flexural strength test specimens to develop strength-maturity curves for 3A21-13 (Figure 10). Appendix B summarizes the results and test procedures followed. These curves are consulted when using a maturity meter to evaluate beams cast in the field. The flexural strength laboratory test samples for 7 days and 14 days produced results that did not agree with trends normally observed for flexural strength development. Therefore, these points are excluded when developing a logarithmic regression equation relating maturity and flexural strength (inset in each subfigure of Figure 10).



(a) **(b)**

Figure 10. MnDOT 3A21-13 (a) compressive strength-maturity curve and (b) flexural strength-maturity curve (red marks denote beam data at 7 and 14 days, discussed in text)

3.2.7 Field maturity data and maturity curve

As discussed above, 3A21-2 was adopted as the final paving mix for this project; as a result, the lab-developed maturity information for 3A21-13 was not considered to be a reliable basis for field maturity testing. Additional maturity testing was performed using field-produced mix (3A21-2) to develop revised maturity-strength correlation curves (Figure 11). Additional field maturity results are reported in Table 5 and Appendix C.

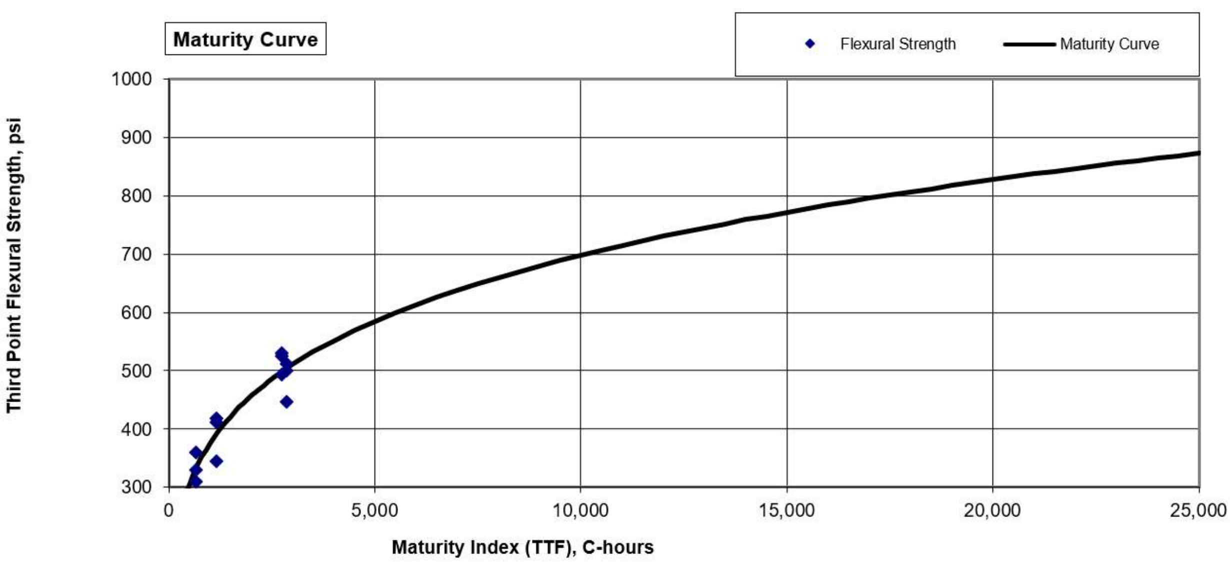


Figure 11. MnDOT 3A21-2 flexural strength-maturity curve

Table 5. Maturity meter test results from field beams (includes interpreted third-point flexural strength, calculated using relationship in Figure 10)

Station	1683+26	1626+74	1626+74	1565+52	1565+52	1565+52	1291+35	1291+35	1291+35	1291+35	1291+35	1344+08
Age (d)	4.8	3.8	4.5	1.7	2.7	3.6	2.0	2.2	3.5	4.1	4.5	2.1
Maturity (C-h)	2735	2166	2627	1107	1681	2135	1066	1430	1863	2254	2455	1166
MR (psi)	*501*	*470*	*495*	*389*	*438*	*468*	*385*	*419*	*451*	*475*	*486*	*395*

Station	1344+08	1344+08	1419+91	1419+91	1419+91	1493+58	1493+58	1523+40	1515+57	1515+57	n/a	n/a
Age (d)	2.5	4.5	1.5	3.5	4.5	2.8	3.9	4.8	1.9	2.5	5.5	4.5
Maturity (C-h)	1371	2753	1816	2374	3001	2063	2724	3311	1280	1651	3688	3071
MR (psi)	*414*	*502*	*448*	*482*	*514*	*464*	*500*	*527*	*406*	*436*	*543*	*517*

CHAPTER 4 CONCLUSIONS AND DISCUSSION

The implementation of PEM on this project was an opportunity to familiarize MnDOT and contractor personnel with PEM testing, especially the SAM and maturity testing. One accomplishment not shown in test data is the level of collaboration – everyone involved worked well together in training and performing the tests and collecting the test data. Overall, the PEM testing went well on this project. The effort helped to educate MnDOT personnel and the contractor on the use and effectiveness of PEM. The following items discuss individual tests related to PEM.

4.1 Super air meter

MnDOT required the contractor to perform the SAM testing for this project. The contractor was trained to use the SAM by American Engineering Testing (AET) at their facility and at the project site.

- The measured percent air using SAM did not correlate well with ASTM measurements of air on several of the tests. It was determined that the SAM was likely leaking. MnDOT asked the contractor to perform leak tests on the SAM daily – thereafter, we observed better agreement between SAM and the ASTM standard for air.
- SAM tests results that were run correctly indicated that we had freeze thaw durable concrete (SAM numbers of 0.25 or less).
- Hardened air tests have not been conducted to date on the SAM samples. They will be sent to Oklahoma State University (OSU) for testing in 2020.
- With more experience and training, MnDOT believes that the SAM can provide real-time results regarding the freeze thaw durability of the concrete pavement.

4.2 Maturity and strength

This project was contractor's first experience using maturity to estimate the strength of the concrete.

- The contractor first used the maturity curve that was developed in the lab. The lab maturity curve did not match well with the concrete that was batched at the plant, as the contractor adjusted the mix design from 3A21-13 to 3A21-2 to get better workability and finish.
- A strength-maturity curve using the on-site batch plant mix was instead developed and applied. Once the new curve was established, maturity testing provided better estimates of strength performance.

4.3 Box test

The Box Test was only conducted during the lab testing and not in the field. MnDOT did not require the box test during the paving process.

4.4 Bucket test

Bucket test samples for the formation factor were made by MnDOT personnel and delivered the next day to AET for testing in the laboratory. MnDOT elected to use laboratory bucket tests to avoid field training for project personnel on this test (for the time being).

4.5 Phoenix test

The Phoenix test was supposed to be conducted on this project but after equipment issues it was removed from the scope of work. MnDOT has been using this device on several other paving projects with very good results, and MnDOT has been relaying our experiences to Oklahoma State University as they further refine the test apparatus and procedure.

REFERENCES

AASHTO PP 84-18 (2018). *Developing Performance Engineered Concrete Pavement Mixtures*. American Association of State Highway and Transportation Officials, Washington D.C.

AASHTO TP 118. *Characterization of the Air-Void System of Freshly Mixed Concrete by the Sequential Pressure Method*. American Association of State Highway and Transportation Officials, Washington D.C.

AASHTO TP 119. *Electrical Resistivity of a Concrete Cylinder Tested in a Uniaxial Resistance Test*. American Association of State Highway and Transportation Officials, Washington D.C.

AASHTO TP 129. *Vibrating Kelly Ball (VKelly) Penetration in Fresh Portland Cement Concrete*. American Association of State Highway and Transportation Officials, Washington D.C.

Robertson, B. and M. T. Ley (2019). *Determining the Water to Cement Ratio of Fresh Concrete by Evaporation.* Unpublished Article Provided to MnDOT in Spring 2019, Oklahoma State University, Stillwater, OK.

APPENDIX A

MnDOT 3A21-2 Mix Design Summary

Minnesota Department of Transportation (7/25/18)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Continental - Davenport	CONDAIA	I/II	3.15
Fly Ash	Haedwaters - Coal Creek	COCUNND	F	2.50
Slag				
Other CM				
Admx#1	GRT - Polychem SA	GRTPOLYSA	AEA	2-12/cy
Admx#2	GRT - Paver Plus	AGRTPLYPP	A	2-8/cwt
Admx#3				
Admx#4				
Admx#5				
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

	Pit #	Size	Class	SP.G.	ABS.
FA#1	52007	Sand		2.60	0.013
FA#2					
CA#1	52003	1.5" Minus	A	2.63	0.003
CA#2	52003	3/4" Minus	A	2.63	0.005
CA#3					

SP Number	8309-52
Requested By	Steve Gerster
Company	PCiRoads.com
Phone	612-868-0662
Email	sgerster@pciroads.com
Agency Contact	Bob Williams
Agency Phone	507-822-0806
Agency Email	bob.williams@state.mn.us
Plant Name	PCIRoads - St. James
Plant #	
Contractor	PCiRoads.com
JMF Number	**18-125**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range
% Aggregate Proportion by Volume													40		20	40					
3A21-1	7.0	224	400	190			32				590	0.38	1185		600	1199		27.0	140.7	25.3	
3A21-2	7.0	228	400	200			33				600	0.38	1177		595	1191		27.0	140.4	25.8	
3A21HE-3	7.0	270	600	110			15				710	0.38	1105		559	1118		27.0	139.3	29.9	
3A41-4	7.0	228	400	200			33				600	0.38	1177		595	1191		27.0	140.4	25.8	
3A41HE-5	7.0	270	600	110			15				710	0.38	1105		559	1118		27.0	139.3	29.9	

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments:

Submit to: conc1off.dot@state.mn.us

Minnesota Department of Transportation (7/25/18)

Contractor Mix Design - Job Mix Formula (JMF)

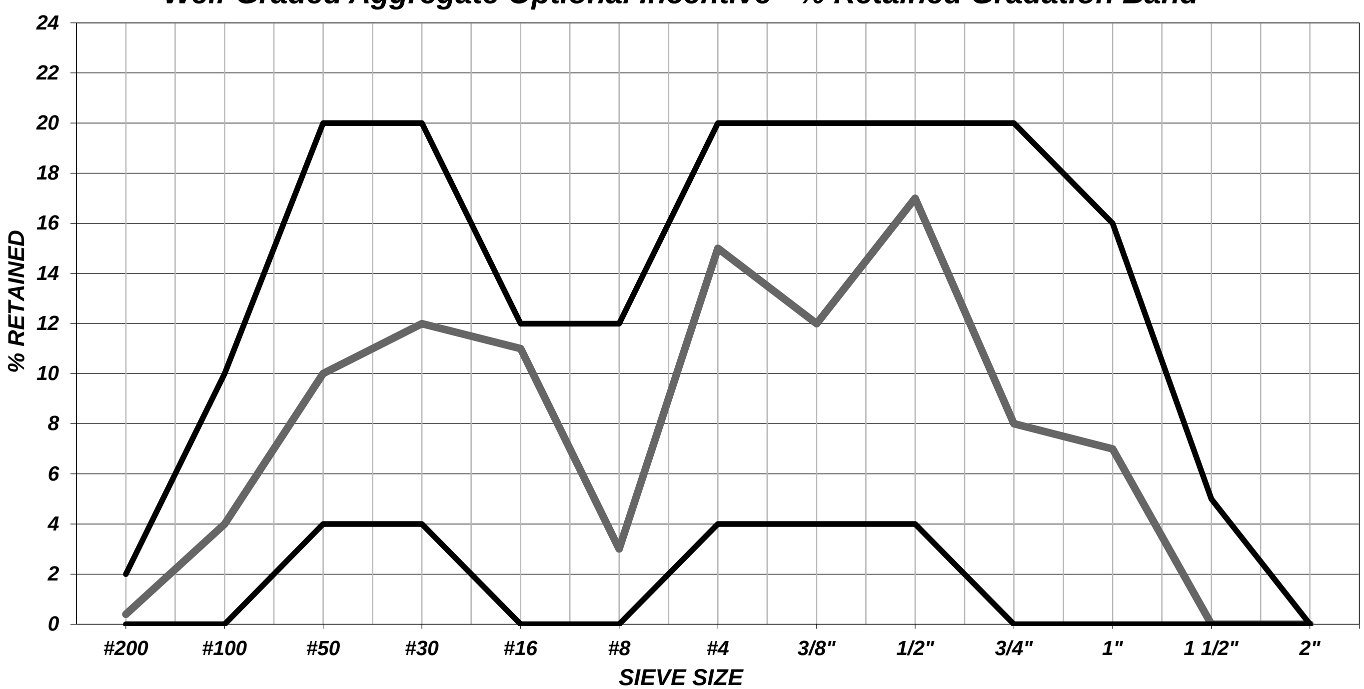
JMF **18-125**

SP 8309-52

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING 100%	WORKING RANGE LIMITS	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	Sand		1.5" Minus	3/4" Minus						
Prop. %	40		20	40						
2"	100.0		100.0	100.0		**100**	± 5	95	100	**0**
1 1/2"	100.0		100.0	100.0		**100**	± 5	95	100	**0**
1"	100.0		63.0	100.0		**93**	± 5	88	98	**7**
3/4"	100.0		25.0	100.0		**85**	± 5	80	90	**8**
1/2"	100.0		3.0	69.5		**68**	± 5	63	73	**17**
3/8"	100.0		2.0	38.0		**56**	± 5	51	61	**12**
#4	100.0		2.0	1.3		**41**	± 5	36	46	**15**
#8	92.0		2.0	1.0		**38**	± 4	34	42	**3**
#16	67.0		1.0	0.7		**27**	± 4	23	31	**11**
#30	37.0		1.0	0.5		**15**	± 4	11	19	**12**
#50	12.0		0.7	0.3		**5**	± 3	2	8	**10**
#100	2.9		0.5	0.2		**1**	± 2	0	3	**4**
#200	1.1		0.4	0.1		**0.6**	≤ 1.6	0.0	1.6	**0**

Mix #
3A21-1
3A21-2
3A21HE-3
3A41-4
3A41HE-5

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
26
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
26
Between 24-34%, generally enhances workability of the mix.

Minnesota Department of Transportation (7/25/18)

Project Specific Paving Mix Design (JMF)

Use for:
Paving Projects 3,500 CY or greater

SP Number	8309-52
Requested By	Steve Gerster
Company	PCiRoads.com
Phone	612-868-0662
Email	sgerster@pciroads.com
Agency Contact	Bob Williams
Agency Phone	507-822-0806
Agency Email	bob.williams@state.mn.us
Plant Name	PCIRoads - St. James
Plant #	
Contractor	PCiRoads.com
JMF Number	**18-126**

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Continental - Davenport	CONDAIA	I/II	3.15
Fly Ash	Haedwaters - Coal Creek	COCUNND	F	2.50
Slag				
Other CM				
Admx#1	GRT - Polychem SA	GRTPOLYSA	AEA	2-12/cy
Admx#2	GRT - Paver Plus	AGRTPLYPP	A	2-8/cwt
Admx#3	GRT - Dynamon SX	FGRTDYNSX	F	3-5/cwt
Admx#4				
Admx#5				
Fiber				
Color				

	Pit #	Size	Class	SP.G.	ABS.
FA#1	52007	Sand		2.60	0.013
FA#2					
CA#1	52003	1.5" Minus	A	2.63	0.003
CA#2	52003	3/4" Minus	A	2.63	0.005
CA#3					

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range
% Aggregate Proportion by Volume													40		20	40					
3A21-13	7.0	240	412	203			33				615	0.39	1159		586	1173		27.0	139.8	26.8	1/2-3"
3A41-14	7.0	240	412	203			33				615	0.39	1159		586	1173		27.0	139.8	26.8	2-5"

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments:

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

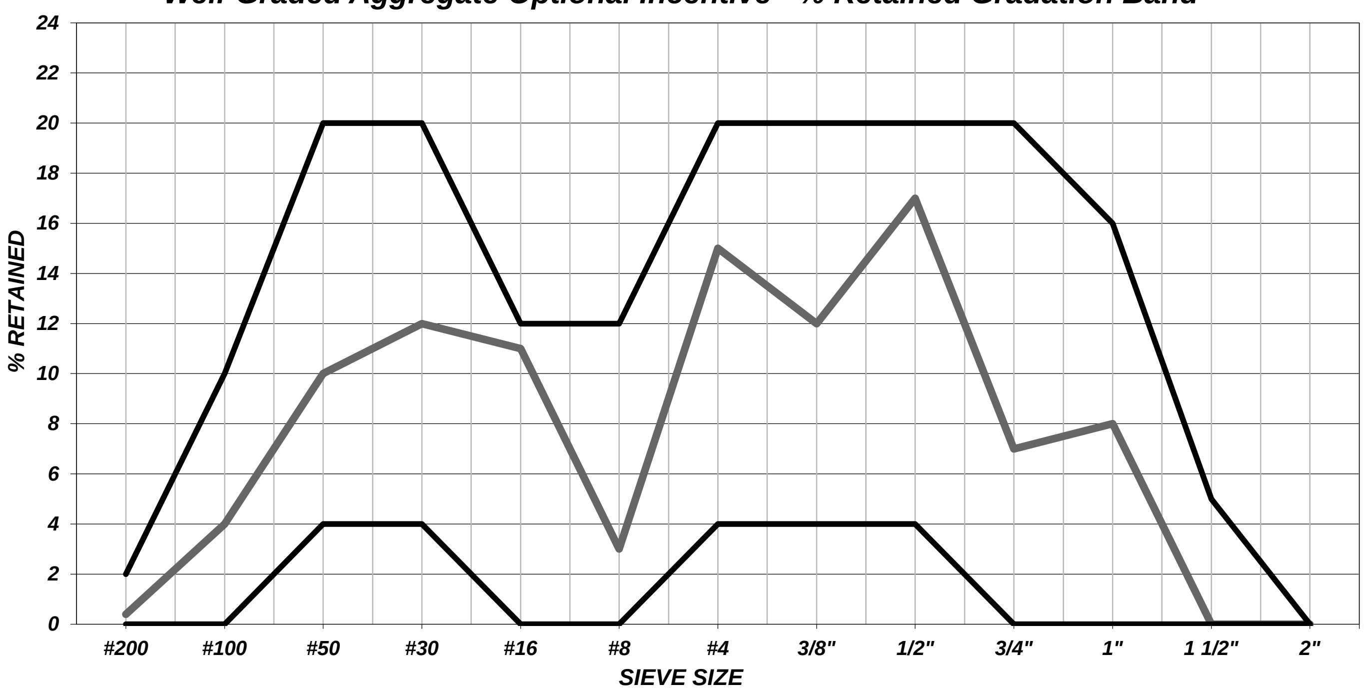
JMF 18-126

SP 8309-52

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE LIMITS	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	Sand		1.5" Minus	3/4" Minus						
Prop. %	40		20	40		100%				
2"	100.0		100.0	100.0		**100**	± 5	95	100	**0**
1 1/2"	100.0		100.0	100.0		**100**	± 5	95	100	**0**
1"	100.0		61.0	100.0		**92**	± 5	87	97	**8**
3/4"	100.0		25.0	100.0		**85**	± 5	80	90	**7**
1/2"	100.0		3.0	69.5		**68**	± 5	63	73	**17**
3/8"	100.0		2.0	38.0		**56**	± 5	51	61	**12**
#4	100.0		2.0	1.3		**41**	± 5	36	46	**15**
#8	92.0		2.0	1.0		**38**	± 4	34	42	**3**
#16	67.0		1.0	0.7		**27**	± 4	23	31	**11**
#30	37.0		1.0	0.5		**15**	± 4	11	19	**12**
#50	12.0		0.7	0.3		**5**	± 3	2	8	**10**
#100	2.9		0.5	0.2		**1**	± 2	0	3	**4**
#200	1.1		0.4	0.1		**0.6**	≤ 1.6	0.0	1.6	**0**

Mix #
3A21-13
3A41-14

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
26
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
26
Between 24-34%, generally enhances workability of the mix.

APPENDIX B
Laboratory Mix Testing

June 7, 2019

Mr. Todd Callahan
PCI Roads
14123 42nd St NE
St. Michael, MN 55376

Re: MnDOT TH60 Paving Project in St. James
MnDOT Work Task #1 – Materials Performance Test Results
AET Project No. 29-20087

Dear Mr. Callahan,

Attached are the final test results for the referenced project. One mix design that you provided and identified as Mix 3A21-13 was used to cast various concrete test specimens at American Engineering Testing, Inc. (AET) on April 10, 2019 in accordance with the required test matrix identified as MnDOT Task #1. You submitted and identified all materials for the concrete mix. Six buckets labeled PCI Roads TH 60 Davenport Cement arrived at AET on August 29, 2018. The remainder of the materials arrived at AET in early April 2019.

Basic and additional required plastic properties were obtained after mixing.

The requested testing was conducted in accordance with the following standard test methods:

- ASTM C192/C192M – 16a, “Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory” Plastic Tests: Air Content, SAM Number, Slump, Unit Weight
- Box Test
- Vibrating V-Kelly Ball Test
- AASHTO T 22-17, “Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens"
- AASHTO T 97-18, "Standard Method of Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)"
- AASHTO T 358-19, "Standard Method of Test for Surface Resistivity Indication of Concrete’s Ability to Resist Chloride Ion Penetration
- AASHTO TP 119-19, "Modified Standard Method of Test for Electrical Resistivity of a Concrete Cylinder Tested in a Uniaxial Resistance Test" (Bucket Test)
- ASTM C29/C29M – 17a, “Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

- ASTM C457/C457M – 16, “Standard Test Method for Microscopical Determination of Parameters of the Air Void System in Hardened Concrete”
- ASTM C136/136M – 14, “Standard Test Method for Sieve Analysis of Fine and Coarse Aggregate”
- ASTM C1074 – 17, “Standard Practice for Estimating Concrete Strength by the Maturity Method”

Any remaining test samples will be retained for a period of 30 days from the date of this report. Unless we are informed otherwise, the specimens will then be discarded. The results represent specifically the samples tested and the methods specified.

Please contact us should you have any questions or need additional information.

American Engineering Testing, Inc.

Willy Morrison
Manager, Concrete Materials Laboratory
Phone: 651-659-1333
wmorrison@amengtest.com

AMERICAN ENGINEERING TESTING, INC.

CONSULTANTS
· ENVIRONMENTA
· GEOTECHNICAL
· MATERIALS
· FORENSICS

AET Project No.: 29-20087
Project: MnDOT Work Task #1
Client: PCI Roads
Contact: Mr. Todd Callahan

AET Project Mgr.: W. Morrison
Approved: P. Barnhouse
Date: June 7, 2019

Mix Design (lb/yd^3)

	Mix 3A21-13
Type I/II Continental Davenport Cement (lbs)	412
Boral, Headwaters Coal Creek Type F (lbs)	203
Coarse Agg., 1-1/2" Minus, Pit #52003 (lbs)	586
Coarse Agg., 3/4" Minus, Pit #52003 (lbs)	1,173
Fine Agg., Pit #52007 (lbs)	1,159
Water (lbs)	240
Air Entrainer, Mapei Polychem SA (oz/cwt)	2.0
Mid-Range Water-Reducer, Mapei Paver Plus (oz/cwt)	4.0
HRWR, Dynamon SX (oz/cwt)	2.0
Water to Cement Ratio	0.39

Fresh Properties:

Unit Weight (pcf)	143.6
Slump (in)	2.8
Air Content (%)	6.3
Super Air Meter (SAM) Number	0.16
Box Test, Ratings, Edge Slump	2,2,2,1/0.0"
V-Kelly Ball Index, (in/√s)	0.390
15 Minutes	
Unit Weight (pcf)	142.8
Slump (in)	2.50
Air Content (%)	6.0
Super Air Meter (SAM) Number	0.19
Box Test, Ratings, Edge Slump	2,2,2,1/0.0"
V-Kelly Ball Index, (in/√s)	0.418
30 Minutes	
Unit Weight (pcf)	143.2
Slump (in)	2.25
Air Content (%)	5.8
Super Air Meter (SAM) Number	0.21
Box Test, Ratings, Edge Slump	1,2,2,1/0.25"
V-Kelly Ball Index, (in/√s)	0.475

(2) Concrete fabricated at AET on April 10, 2019.

550 Cleveland Avenue North | Saint Paul, MN 55114
Phone (651) 659-9001 | (800) 972-6364 | Fax (651) 659-1379 | www.amengtest.com | AA/EEO

Project No: 29-20087
Project: MnDOT Work Task #1
Client: PCI Roads
Contact: Mr. Todd Callahan

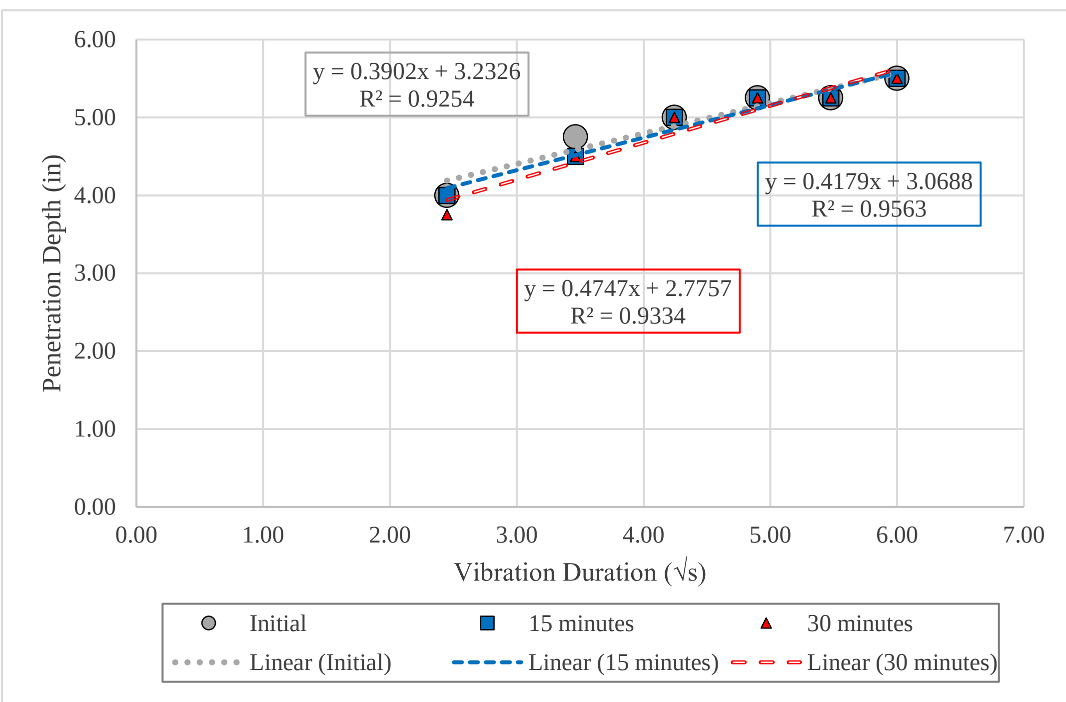
AET Project Mgr.: W. Morrison
AET Engineer: P. Barnhouse
Approved: W. Morrison
Date: June 7, 2019

Fresh Property Data Sheet

Mix ID - 3A21-13

V-Kelly Ball Test Results

Initial			15 minutes			30 minutes		
Time (s)	Depth (in)		Time (s)	Depth (in)		Time (s)	Depth (in)	
Initial	2.25		Initial	2.00		Initial	1.75	
At Rest	2.50		At Rest	2.50		At Rest	2.25	
6	4.00		6	4.00		6	3.75	
12	4.75		12	4.50		12	4.50	
18	5.00		18	5.00		18	5.00	
24	5.25		24	5.25		24	5.25	
30	5.25		30	5.25		30	5.25	
36	5.50		36	5.50		36	5.5	
VKelly Index (in/√s)		0.390	VKelly Index (in/√s)		0.418	VKelly Index (in/√s)		0.475



AMERICAN ENGINEERING TESTING, INC.

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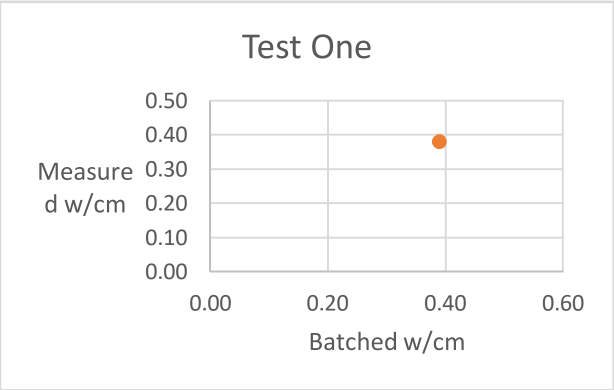
AET Project No.:	29-20087	AET Project Mgr.:	W. Morrison
Project:	MnDOT Task #1	Approved:	P. Barnhouse
Client:	PCI Roads	Date:	June 7, 2019
Contact:	Mr. Todd Callahan		

Specific Gravities		Absorptions		Batch Masses	
Cement SG	3.15	CAI	0.3	Cement	76.3
Fly Ash SG	2.5	CAII	0.5	Fly Ash	37.6
CAI	2.63	CAIII		CAI	108.6
CAII	2.63	FAI	1.3	CAII	218
CAIII		FAII		CAIII	
FAI	2.6			FAI	224.2
FAII				FAII	
				Water	44.4
				Batched Volume (ft^3)	5
				Batched Concrete Air Volume	

Air Volume		Total Water Absorbed		Binder and Absorbed Water Cylinder	
Cylinder Density (g/ft^3)	65463.9	CAI Abs	0.33	Volume Ratio	0.011545376
Total Batched Mass	709.1	CAII Abs	1.09	Cylinder Binder	1.315018286
Absolute Volume Batched (Air Free)	4.7	CAIII Abs		Cylinder Abs Water	0.049996095
Air Content (%)	6.3	FAI Abs	2.91		
		FAII Abs			
		Total Absorbed Water	4.33		

Absolute Volume Batched	5.03
Batched Density	141.04
Water Loss Mass (lbs)	0.55



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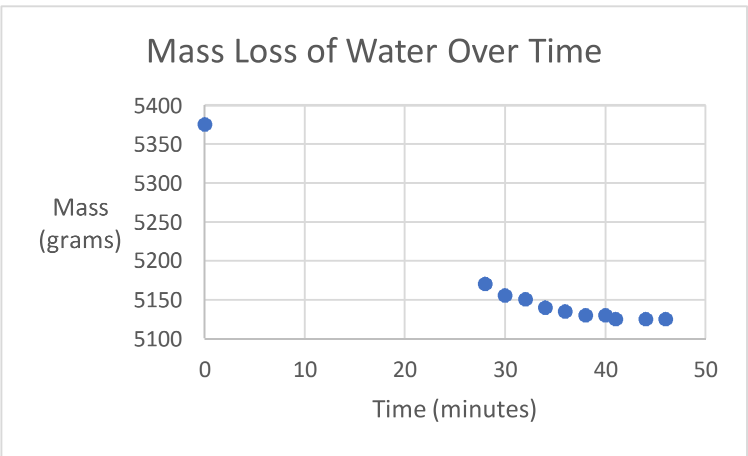
AET Project No.:	29-20087	AET Project Mgr.:	W. Morrison
Project:	MnDOT Task #1	Approved:	P. Barnhouse
Client:	PCI Roads	Date:	June 7, 2019
Contact:	Mr. Todd Callahan		

Phoenix Masses			lbs	Mass loss of water over time	
				Mass (g)	Time (min)
Tare Cylinder (g)	110		0.24	5375	0
Mass Cylinder Filled (g)	3920		8.64	5170	28
Mass Cylinder Emptied (g)	120		0.26	5155	30
Volume Cylinder (ft^3)	0.06			5150	32
Mass of Pan Fresh Concrete (g)	5375			5140	34
Mass of Pan Dried Concrete (g)	5125			5135	36
				5130	38
Cylinder Volume Tested (g/ft^3)	0.06	(lbs/ft^3)	0.06	5130	40
				5125	41
				5125	44
w/cm Calculations				5125	46
Measure w/cm	0.38				
Batched w/cm	0.39				



AMERICAN ENGINEERING TESTING, INC.

CONSULTANTS
· ENVIRONMENTAL
· GEOTECHNICAL
· MATERIALS
· FORENSICS

AET Project No:	29-20087	**AET Project Mgr.:**	W. Morrison
Project:	MnDOT Work Task #1	**AET Engineer:**	P. Barnhouse
Client:	PCI Roads	**Approved:**	W. Morrison
Contact:	Mr. Todd Callahan	**Report Date:**	June 7, 2019

Test Result Summary of Hardened Properties

Concrete Mix 3A21-13

Cast Date: April 10, 2019 **Specification**

ASTM C78, Flexural Strength, psi	Specimen 1	Specimen 2	Specimen 3	**Average**	
2 days, psi	730	665	710	**700**	
3 days, psi	710	675	805	**730**	
7 days, psi	750	650	785	**730**	
14 days, psi	750	810	780	**780**	
28 days, psi	1040	945	930	**970**	

ASTM C39, Compressive Strength, psi	Specimen 1	Specimen 2	Specimen 3	**Average**	
2 days, psi	2,290	2,080	2,190	**2,190**	
3 days, psi	2,700	2,780	2,800	**2,760**	
7 days, psi	3,120	3,620	3,460	**3,400**	
14 days, psi	4,350	3,890	4,150	**4,130**	
28 days, psi	5,200	4,980	4,960	**5,050**	

ASTM C457, Air Void Analysis

	Total Air Voids, %	Specific Surface, in^2/in^3	Spacing Factor, in
Mix 3A21-13	5.7	1310	0.003

Notes:

1. The test results represent the specimens tested and the methods specified.
2. The test specimens could not be demolded at 24 hours due to incomplete hydration. The test specimens were demoded after 48 h
   One day test results were requested, however 2 days tests were conducted instead.

AET Project No: 29-20087 **AET Project Mgr.:** W. Morrison
Project: Work Task #1 **AET Engineer:** P. Barnhouse
Client: PCI Roads **Cast Date:** April 10, 2019

AASHTO T 358 Wenner Probe Surface Resistivity Results

3A21-3

Day 28 **5/8/19**

	Sealed 1	Sealed 2
Mass (g)	3,803.1	3,790.2

Sealed	0°	90°	180°	270°	0°	90°	180°	270°
Sample 1	26.7	25.4	25.6	29.4	25.7	24.5	24.9	29.6
Sample 2	23.3	23.8	23.2	23.6	22.6	24.7	23.0	23.2

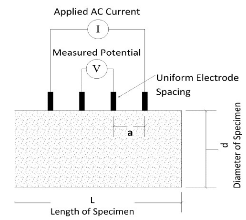
	Average Surface Resistivity (kΩ-cm)
Sample 1	26.5
Sample 2	23.4
Average	**25.0**

RESISTIVITY TESTING - CURVE DEVELOPMENT

Contractor: Lab Mixture

Mixture ID: 3A21-13
Location:

Curve No.: 1
Cast Date/Time: 4/10/2019



Sample Geometry

	Diameter (mm)	Length (mm)
1	100.0	200.0
2	100.0	200.0
3	100.0	200.0

Sponge Resistances

Measured with Plates

TOP	0.0
BOTTOM	0.0

* put 0 for values off-scale (too low)

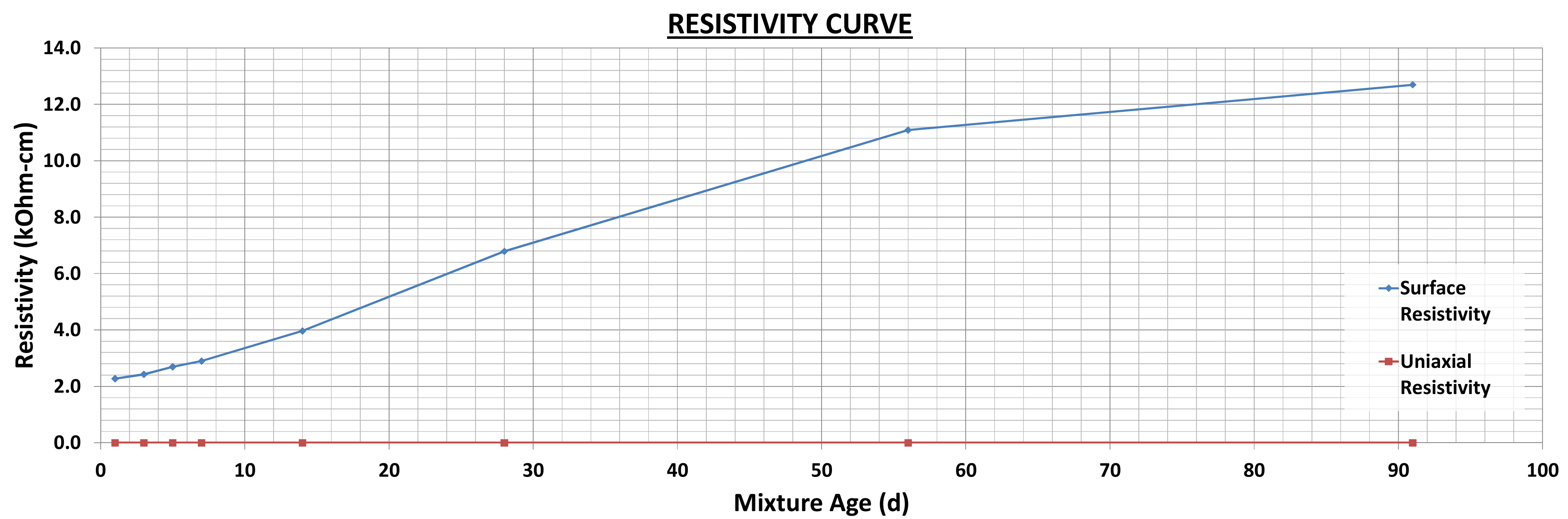
Temperature

Activation Energy of Conduction 15
Default Approximation 15 kJ/mol

Factors

	a (mm)	SR	Meter (cm)	DR (cm)
1	38.0	1.95	24	4
2	38.0	1.95	24	4
3	38.0	1.95	24	4

Specimen Number	Date	Specimen Temperature (C)	Temperature Factor	Surface Configuration (kOhm-cm)								Uniaxial Configuration (kOhm-cm)	Effective Surface Resistivity (kOhm-cm)	Uniaxial Resistivity (kOhm-cm)	Testing Age (d)	Effective Surface Resistivity (kOhm-cm)	Uniaxial Resistivity (kOhm-cm)
	4/11/2019	22.0	0.98	4.00	4.60	4.50	5.30	4.50	4.60	4.50	5.30		2.39		1	2.28	
		22.0	0.98	3.90	4.30	4.40	4.20	4.10	4.30	4.20	4.30		2.16				
	4/13/2019	22.0	0.98	4.50	4.80	5.10	4.90	4.70	4.90	5.10	4.90		2.49		3	2.43	
		22.0	0.98	4.40	4.50	4.70	4.90	4.50	4.50	4.70	4.60		2.36				
	4/15/2019	22.0	0.98	5.00	5.50	5.50	5.40	5.30	5.60	5.50	5.50		2.78		5	2.70	
		22.0	0.98	4.90	4.90	5.40	5.00	5.20	5.00	5.30	5.10		2.62				
	4/17/2019	22.0	0.98	5.50	5.70	5.90	5.70	5.90	6.00	6.00	5.70		2.97		7	2.89	
		22.0	0.98	5.00	5.30	5.80	5.60	5.60	5.10	5.70	5.80		2.81				
	4/24/2019	22.0	0.98	7.50	9.10	8.00	7.70	8.60	8.30	8.50	8.20		4.14		14	3.97	
		22.0	0.98	7.00	7.40	7.60	7.80	7.80	7.40	7.90	7.50		3.79				
	5/8/2019	22.0	0.98	14.60	14.80	15.30	15.10	15.10	15.10	11.30	15.60		7.34		28	6.79	
		22.0	0.98	10.20	10.40	12.20	12.80	12.20	12.90	14.00	14.60		6.24				
	6/5/2019	22.0	0.98	25.40	25.40	26.40	27.80	20.60	25.00	24.80	23.90		12.52		56	11.09	
		22.0	0.98	17.50	17.90	19.50	20.40	18.70	19.20	21.50	19.10		9.66				
	7/10/2019	22.0	0.98	37.50	33.20	22.60	26.20	28.00	27.70	31.90	33.60		15.12		91	12.70	
		22.0	0.98	18.30	19.10	18.60	21.20	19.50	22.80	22.40	21.70		10.27				



AIR VOID ANALYSIS

PROJECT:

MNDOT TH PAVING PROJECT IN ST. JAMES
WORK TASK #1 – MATERIALS PERFORMANCE TESTING
ST JAMES, MN

AET PROJECT NO: 29-20087

REPORTED TO:

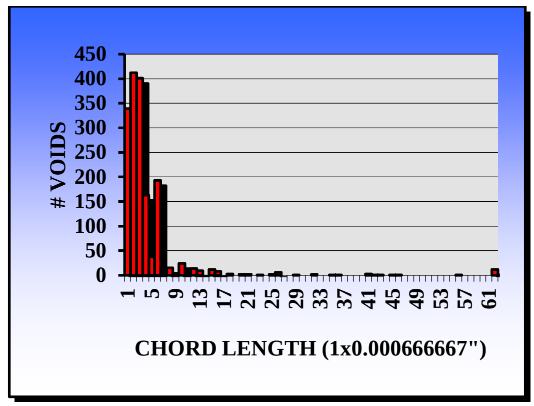
PCI ROADS LLC
14123 – 42ND STREET NE
ST. MICHAEL, MN 55376-9564

ATTN: TODD CALLAHAN

DATE: MAY 8, 2019

Sample ID: Mix 3A21-13

Conformance: The concrete contains an air void system which is consistent with current American Concrete Institute (ACI) recommendations for freeze-thaw resistance.



Sample Data

Description:	Hardened Concrete Cylinder
Dimensions:	102 mm (4”) diameter x 203 mm (8”) length

Test Data: By ASTM C457, Procedure A

Air Void Content %	5.7
Entrained, % < 0.040"(1mm)	4.6
Entrapped, %> 0.040"(1mm)	1.1
Air Voids/inch	18.5
Specific Surface, in^2/in^3	1310
Spacing Factor, inches	0.003
Paste Content, % estimated	22
Magnification	75x
Traverse Length, inches	90
Test Date	5/8/2019
Test Performed By	W. Reely

Magnification: 15x
Description: Hardened air void system.

Report Prepared By:
American Engineering Testing, Inc.

Blake M. Lemcke, PG
Geologist/Petrographer
MN License #50337

DETERMINING CONCRETE STRENGTH USING THE MATURITY METHOD

Below are the results of maturity calculations conducted on the concrete mixture identified as 3A21-13. Compressive and flexural strength specimens were cast at the AET laboratory on April 10, 2019, and stored at our laboratory in St. Paul, MN, for strength testing. At the same time, a companion compressive and companion flexural specimen were cast and were used to monitor and record concrete temperature and maturity. All specimens were stored in a 100% relative humidity curing room at 23 °C until testing in accordance with ASTM C39 and ASTM C78. The temperature-time factor (i.e., maturity) was determined from the companion specimens in accordance with the method in ASTM C1074.

- Table 1 presents the temperature-time factor and compressive strengths at various ages for the given mix design.
- Figure 1 illustrates the relationship between estimated maturity and compressive strength through 28 days of curing in our laboratory.
- Table 2 presents the temperature-time factor and flexural strengths at various ages for the given mix design.
- Figure 2 illustrates the relationship between estimated maturity and flexural strength through 28 days of curing in our laboratory.

Table 1. Maturity and compressive strength results from laboratory-cured cylinders (3A21-13)

Age, days	Maturity (°C-Hours)	Compressive Strength (psi)
2	1,048	2,190
3	1,554	2,760
7	3,580	3,400
14	7,012	4,130
28	14,018	5,050

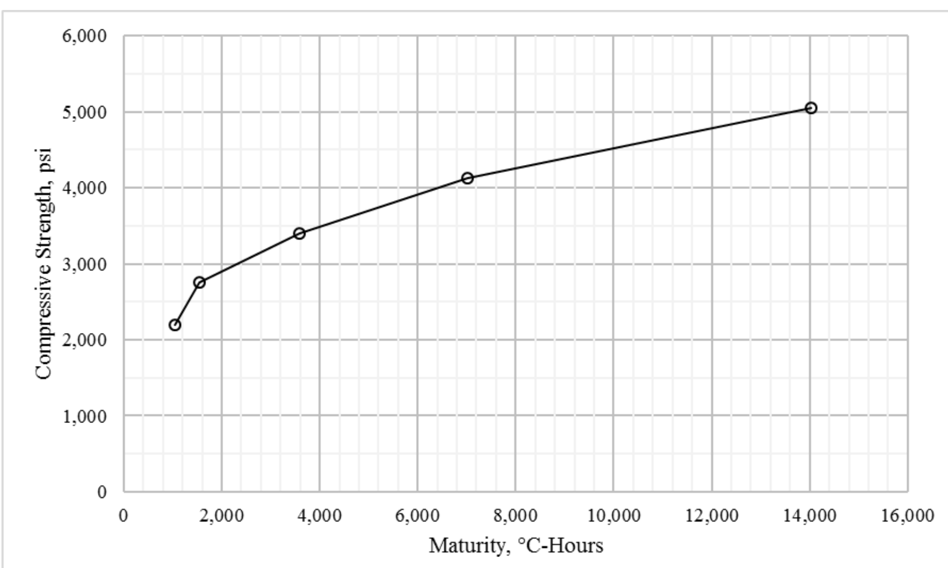


Figure 1. Compressive strength-maturity relationship (3A21-13)

Table 2. Maturity and flexural strength results from laboratory-cured cylinders (3A21-13)

Age, days	Maturity (°C-Hours)	Flexural Strength (psi)
2	1,006	700
3	1,509	730
7	3,515	730
14	6,922	780
28	13,850	970

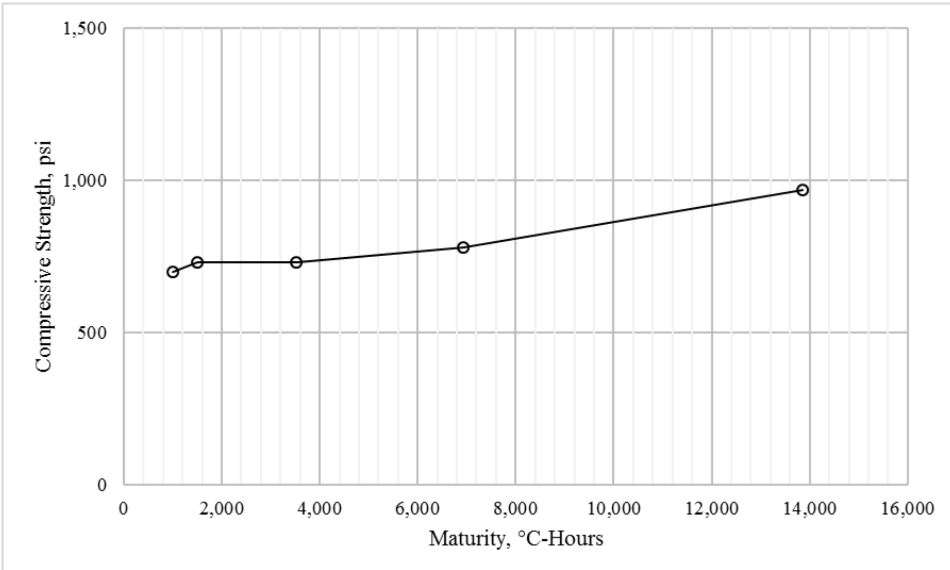


Figure 2. Flexural strength-maturity relationship (3A21-13)

APPENDIX C

Field Test Results

Date	Test No.	Station	Before/ After	Regular Air Pot	Super Air Meter		Concrete Temp
					SAM	Air	
6/13/2019	1	1654+00	Before	8.8%	0.23	11.10	73
6/13/2019	2	1654+00	After	8.2%	0.33	10.00	73
6/14/2019	3	1619+50	Before	N/A	0.23	8.70	68
6/14/2019	4	1619+50	After	N/A	0.04	7.70	68
6/14/2019	5	1600+15	Before	7.2%	0.27	8.80	70
6/14/2019	6	1600+15	After	6.5%	0.74	8.20	70
6/17/2019	7	1555+90	Before	6.5%	Error	8.20	73
6/17/2019	7.1	1555+90	Before	6.5%	0.19	8.00	73
6/17/2019	8	1537+32	Before	7.5%	Error	10.80	70
6/17/2019	8.1	1537+32	Before	7.5%	0.07	12.80	70
6/17/2019	9	1537+32	After	8.0%	0.07	8.70	70
6/19/2019	10	1239+56	Before	7.2%	Error	9.80	68
6/19/2019	10.1	1239+56	Before	7.2%	0.18	8.70	68
6/19/2019	11	1265+17	Before	6.8%	0.17	9.10	71
6/19/2019	12	1265+17	After	6.2%	Error	7.40	71
6/19/2019	12.1	1265+17	After	6.2%	0.08	8.40	71
6/24/2019	13	1303+87	Before	7.5%	0.24	8.50	73
6/24/2019	14	1303+87	After	7.2%	Error	10.30	73
6/24/2019	14.1	1303+87	After	7.2%	Error	9.70	73
6/24/2019	15	1323+18	Before	8.0%	0.23	8.90	70
6/24/2019	16	1323+18	After	8.1%	0.19	8.40	70
6/26/2019	17	1358+62	Before	8.0%	0.17	9.80	67
6/26/2019	18	1385+36	Before	7.0%	Error	8.40	70
6/26/2019	18.1	1385+36	Before	7.0%	0.18	9.30	70
6/26/2019	19	1385+36	After	6.9%	Error	7.10	70
6/26/2019	19.1	1385+36	After	6.9%	0.23	7.10	70
6/28/2019	20	1440+18	Before	6.0%	0.27	8.20	76
6/28/2019	21	1468+50	Before	8.2%	0.19	12.10	74
6/28/2019	22	1468+50	After	7.5%	0.29	10.40	74
6/29/2019	23	1499+25	Before	7.8%	0.34	9.60	75
6/29/2019	24	1499+25	After	7.0%	0.23	8.30	75
6/29/2019	25	1512+75	Before	8.8%	0.05	10.30	75
7/1/2019	26	1275+17	Before	7.6%	0.18	10.20	76
7/1/2019	27	1275+17	After	7.0%	0.28	8.10	76
7/2/2019	28	1296+55	Before	8.8%	Error	9.20	76
7/2/2019	28.1	1296+55	Before	8.8%	0.16	10.40	76
7/2/2019	29	1296+55	After	7.8%	0.25	8.40	76
7/3/2019	30	1518+88	Before	7.6%	0.19	8.40	78
7/3/2019	31	1518+88	After	6.8%	0.18	7.00	78
7/8/2019	32	1508+08	Before	8.8%	0.23	10.90	75
7/8/2019	33	1418+73	Before	8.4%	0.17	9.20	77
7/8/2019	34	1418+73	After	7.5%	0.13	7.60	77
7/9/2019	35	1878+08	Before	7.8%	0.31	9.30	76
7/9/2019	36	1878+08	After	6.5%	0.19	7.30	76

Date	Test No.	Station	Before/ After	Regular Air Pot	Super Air Meter		Concrete Temp
					SAM	Air	
7/10/2019	37	1721+37	Before	7.0%	0.3	7.70	75
7/10/2019	38	1721+37	After	5.5%	0.36	6.90	75
7/11/2019	39	1595+65	Before	7.2%	0.12	8.10	77
7/11/2019	40	1595+65	After	6.0%	0.24	6.70	77
8/1/2019	41	1408+50	Before	6.80%	0.19	6.7	7.9
8/1/2019	42	1408+50	After	6.80%	0.25	6.9	7.9

Date		6/13/2019	6/13/2019	6/14/2019	6/14/2019	6/14/2019	6/14/2019	6/17/2019	6/17/2019	6/17/2019	6/17/2019	6/17/2019	19-Jun
Location		1654+00	1654+00	1619+50	1619+50	1600+15	1600+15	1555+90	1555+90	1537+32	1537+32	1537+32	1239+56
Test No.		1	2	3	4	5	6	7	7.1	8	8.1	9	10
First Run	14.5 psi	4.85	5.21	5.66	6.08	5.61	5.84	5.83	5.94	4.92	4.40	5.62	5.25
	30 psi	13.51	14.29	15.02	16.08	15.77	15.90	15.55	15.52	14.14	13.64	14.62	14.57
	45 psi	24.18	25.36	26.31	27.65	27.71	27.98	27.18	27.04	25.32	24.74	25.65	25.80
Second Run	14.5 psi	4.97	5.38	5.67	6.12	5.67	5.75	5.76	6.04	4.86	4.43	5.71	5.26
	30 psi	13.69	14.56	15.15	15.95	15.96	16.25	15.43	15.63	14.03	13.68	14.71	14.58
	45 psi	24.41	25.69	26.54	27.68	27.98	28.71	27.00	27.21	25.13	24.80	25.72	25.82
Air Content (%)		11.10	10.00	8.70	7.70	8.80	8.20	8.20	8.00	10.80	12.80	8.70	9.80
SAM @ 14.5 psi		0.12	0.17	0.01	0.04	0.06	-0.09	-0.07	0.10	-0.06	0.03	0.09	0.01
SAM @ 30 psi		0.18	0.27	0.13	-0.13	0.19	0.35	-0.12	0.11	-0.11	0.04	0.09	0.01
SAM @ 45 psi		0.23	0.33	0.23	0.03	0.27	0.73	-0.18	0.17	-0.19	0.06	0.07	0.02
SAM's Chance		0.73	0.80	0.95	0.96	0.91	1.00	0.09	0.75	0.05	0.52	0.23	0.45
Result:		**Likely Correct**	**Likely Correct**	**Likely Correct**	*Ran Incorrect*	**Likely Correct**	*Ran Incorrect*	*Ran Incorrect*	**Likely Correct**	*Ran Incorrect*	**Likely Correct**	*Ran Incorrect*	*Ran Incorrect*
Fresh Prop.	slump [in]												
	temp. [F]	73.00	73.0	68.00	68.0	70.0	70	73	73	70	70	70	68
	Unit Weight [pcf]	135.90	135.90	135.40	135.40	135.40	135.40	138.8	138.8	138.8	138.8	138.8	137.7
	w/c ratio	0.37	0.37	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.38	0.38	0.36
Mix Design [lb/yd^3]	Coarse 1	595	595	595	595	595	595	595	595	595	595	595	595
	Coarse 2	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198
	Fine	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185
	Cement	400	400	400	400	400	400	400	400	400	400	400	400
	Fly Ash	200	200	200	200	200	200	200	200	200	200	200	200
	Water	228	228	228	228	228	228	228	228	228	228	228	228
	AEA												
	WR												
	SP												
What was done to the concrete before the test?													
How long was it mixed?													
How was it mixed?													
Does it have a stable air void system?													
Did you sample from the same location at the same time?													
Did you leak check the meter before running?													
Comments		3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2

Date		6/19/2019	6/19/2019	6/19/2019	6/19/2019	6/24/2019	6/24/2019	6/24/2019	6/24/2019	6/24/2019	6/26/2019	6/26/2019	6/26/2019
Location		1239+56	1265+17	1265+17	1265+17	1303+87	1303+87	1303+87	1323+18	1323+18	1358+62	1385+36	1385+36
Test No.		10.1	11	12	12.1	13	14	14.1	15	16	17	18	18.1
First Run	14.5 psi	5.61	5.48	6.20	5.84	5.72	5.07	5.26	5.55	5.75	5.22	5.77	5.30
	30 psi	14.74	15.15	16.19	15.90	18.05	14.69	14.91	14.57	15.06	14.13	15.31	15.15
	45 psi	25.88	26.67	28.14	27.84	26.34	26.32	26.43	25.61	26.32	25.05	26.75	26.69
Second Run	14.5 psi	5.77	5.55	6.13	5.84	5.81	5.81	5.28	5.59	5.80	5.27	5.69	5.44
	30 psi	14.92	15.28	16.16	16.16	15.23	15.23	14.90	14.72	15.18	14.25	15.10	15.28
	45 psi	26.07	26.84	28.00	27.91	26.59	26.59	26.44	25.84	26.51	25.22	26.46	26.98
Air Content (%)		8.70	9.10	7.40	8.40	8.50	10.30	9.70	8.90	8.40	9.80	8.40	9.30
SAM @ 14.5 psi		0.16	0.07	-0.07	0.00	0.09	0.74	0.02	0.04	0.05	0.05	-0.08	0.14
SAM @ 30 psi		0.18	0.13	-0.03	0.26	-2.82	0.54	-0.01	0.15	0.12	0.12	-0.21	0.13
SAM @ 45 psi		0.19	0.17	-0.14	0.07	0.25	0.27	0.01	0.23	0.19	0.17	-0.29	0.29
SAM's Chance		0.40	0.69	0.04	0.01	1.00	0.00	0.48	0.90	0.85	0.77	0.04	0.98
Result:		*Ran Incorrect*	**Likely Correct**	*Ran Incorrect*	*Ran Incorrect*	*Ran Incorrect*	*Ran Incorrect*	*Ran Incorrect*	**Likely Correct**	**Likely Correct**	**Likely Correct**	*Ran Incorrect*	**Likely Correct**
Fresh Prop.	slump [in]												
	temp. [F]	68	71	71	71	73	73	73	70	70	67	70	70
	Unit Weight [pcf]	137.7	137.7	137.7	137.7	134.3	134.3	134.3	134.3	134.3	135.8	135.8	135.8
	w/c ratio	0.36	0.36	0.36	0.36	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Mix Design [lb/yd^3]	Coarse 1	595	595	595	595	595	595	595	595	595	595	595	595
	Coarse 2	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198
	Fine	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185
	Cement	400	400	400	400	400	400	400	400	400	400	400	400
	Fly Ash	200	200	200	200	200	200	200	200	200	200	200	200
	Water	228	228	228	228	228	228	228	228	228	228	228	228
	AEA												
	WR												
	SP												
What was done to the concrete before the test?													
How long was it mixed?													
How was it mixed?													
Does it have a stable air void system?													
Did you sample from the same location at the same time?													
Did you leak check the meter before running?													
Comments		3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2

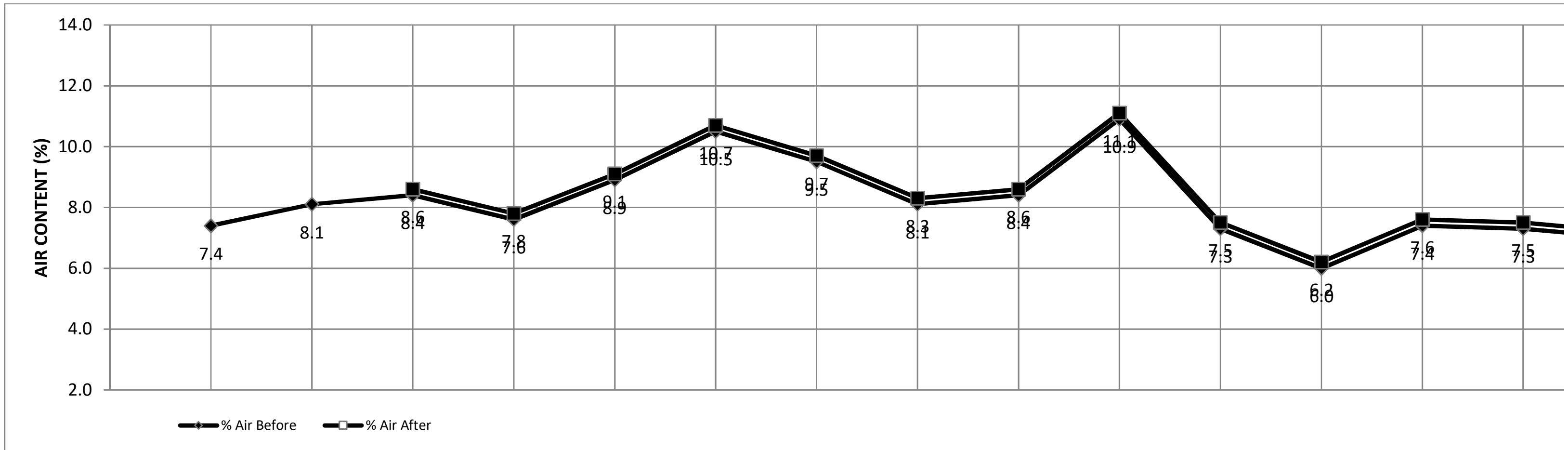
Date		6/26/2019	6/26/2019	6/28/2019	6/28/2019	6/28/2019	6/29/2019	6/29/2019	6/29/2019	7/1/2019	7/1/2019	7/2/2019	7/2/2019
Location		**1385+36**	**1385+36**	**1440+18**	**1468+50**	**1468+50**	**1499+25**	**1499+25**	**1512+75**	**1275+17**	**1275+17**	**1296+55**	**1296+55**
Test No.		**19**	**19.1**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**28.1**
First Run	**14.5 psi**	6.33	6.33	5.83	4.53	5.04	5.28	5.78	5.06	5.11	5.87	5.46	5.05
	30 psi	19.91	16.28	16.05	13.87	14.49	14.58	15.43	13.52	14.76	15.94	14.29	14.19
	45 psi	28.87	28.14	28.05	25.10	26.03	25.80	26.99	23.99	26.26	27.84	25.15	25.29
Second Run	**14.5 psi**	6.21	6.45	5.95	4.62	5.18	5.45	5.90	5.02	5.16	5.97	5.44	5.12
	30 psi	16.12	16.46	16.26	14.03	14.82	14.82	15.59	13.51	14.87	16.14	14.29	14.30
	45 psi	27.89	28.37	28.32	25.29	26.32	26.14	27.22	24.04	26.44	28.12	25.17	25.45
Air Content (%)		7.10	7.10	8.20	12.10	10.40	9.60	8.30	10.30	10.20	8.10	9.20	10.40
SAM @ 14.5 psi		-0.12	0.12	0.12	0.09	0.14	0.17	0.12	-0.04	0.05	0.10	-0.02	0.07
SAM @ 30 psi		-3.79	0.18	0.21	0.16	0.33	0.24	0.16	-0.01	0.11	0.20	0.00	0.11
SAM @ 45 psi		-0.98	0.23	0.27	0.19	0.29	0.34	0.23	0.05	0.18	0.28	0.02	0.16
SAM's Chance		1.00	0.73	0.81	0.63	0.28	0.91	0.81	0.81	0.85	0.89	0.56	0.73
Result:		*Ran Incorrect*	**Likely Correct**	**Likely Correct**	**Likely Correct**	*Ran Incorrect*	**Likely Correct**	**Likely Correct**	*Ran Incorrect*	**Likely Correct**	**Likely Correct**	*Ran Incorrect*	**Likely Correct**
Fresh Prop.	**slump [in]**												
	temp. [F]	70	70	76	74	74	75	75	75	76	76	76	76
	Unit Weight [pcf]	135.8	135.8	136	136	136	137	137	137	134.5	134.5	134.5	134.5
	w/c ratio	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.38	0.38	0.37	0.37
Mix Design [lb/yd^3]	**Coarse 1**	595	595	595	595	595	595	595	595	595	595	595	595
	Coarse 2	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198
	Fine	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185
	Cement	400	400	400	400	400	400	400	400	400	400	400	400
	Fly Ash	200	200	200	200	200	200	200	200	200	200	200	200
	Water	228	228	228	228	228	228	228	228	228	228	228	228
	AEA												
	WR												
	SP												
What was done to the concrete before the test?													
How long was it mixed?													
How was it mixed?													
Does it have a stable air void system?													
Did you sample from the same location at the same time?													
Did you leak check the meter before running?													
Comments		3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2

Date		7/2/2019	7/3/2019	7/3/2019	7/8/2019	7/8/2019	7/8/2019	7/9/2019	7/9/2019	7/10/2019	7/10/2019	7/11/2019	7/11/2019
Location		1296+55	1518+88	1518+88	1508+08	1418+73	1418+73	1878+08	1878+08	1721+37	1721+37	1595+65	1595+65
Test No.		29	30	31	32	33	34	35	36	37	38	39	40
First Run	14.5 psi	5.27	5.64	6.39	4.87	5.45	6.09	5.39	6.25	6.06	6.42	5.88	6.55
	30 psi	15.29	14.92	16.29	13.38	14.49	15.71	14.16	16.07	15.62	16.69	15.27	16.94
	45 psi	26.73	26.20	28.07	23.89	25.51	27.28	24.96	27.80	27.13	28.77	26.62	29.11
Second Run	14.5 psi	5.88	5.67	6.41	4.98	5.48	6.12	5.49	6.32	6.19	6.57	5.88	6.64
	30 psi	15.47	15.06	16.40	13.54	14.59	15.81	14.37	16.21	15.85	16.95	15.34	17.12
	45 psi	26.98	26.39	28.25	24.12	25.68	27.41	25.26	27.98	27.43	29.13	26.74	29.36
Air Content (%)		8.40	8.40	7.00	10.90	9.20	7.60	9.30	7.30	7.70	6.90	8.10	6.70
SAM @ 14.5 psi		0.61	0.03	0.02	0.11	0.03	0.03	0.10	0.07	0.13	0.15	0.00	0.09
SAM @ 30 psi		0.18	0.14	0.11	0.16	0.10	0.10	0.21	0.14	0.23	0.26	0.07	0.18
SAM @ 45 psi		0.25	0.19	0.18	0.23	0.17	0.13	0.30	0.18	0.30	0.36	0.12	0.25
SAM's Chance		0.15	0.81	0.87	0.82	0.86	0.66	0.92	0.70	0.85	0.93	0.78	0.85
Result:		*Ran Incorrect*	Likely Correct	Likely Correct	Likely Correct	Likely Correct	Likely Correct	Likely Correct	Likely Correct	Likely Correct	Likely Correct	Likely Correct	Likely Correct
Fresh Prop.	slump [in]												
	temp. [F]	76	78	78	75	77	77	76	76	75	75	77	77
	Unit Weight [pcf]	134.5	136.6	136.6	131.7	131.7	131.7	138.6	138.6	137.9	137.9	136.6	136.6
	w/c ratio	0.37	0.38	0.38	0.36	0.36	0.36	0.38	0.38	0.38	0.38	0.38	0.38
Mix Design [lb/yd^3]	Coarse 1	595	595	595	595	595	595	595	595	595	595	595	595
	Coarse 2	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198
	Fine	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185
	Cement	400	400	400	400	400	400	400	400	400	400	400	400
	Fly Ash	200	200	200	200	200	200	200	200	200	200	200	200
	Water	228	228	228	228	228	228	228	228	228	228	228	228
	AEA												
	WR												
	SP												
What was done to the concrete before the test?													
How long was it mixed?													
How was it mixed?													
Does it have a stable air void system?													
Did you sample from the same location at the same time?													
Did you leak check the meter before running?													
Comments		3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2	3A21-2

Date		8/1/2019	8/1/2019										
Location		**1408+50**	**1408+50**										
Test No.		**41**	**42**										
First Run	**14.5 psi**	6.55	6.45										
	30 psi	16.78	16.34										
	45 psi	28.83	28.12										
Second Run	**14.5 psi**	6.61	6.53										
	30 psi	16.92	16.51										
	45 psi	29.01	28.37										
Air Content (%)		6.70	6.90										
SAM @ 14.5 psi		0.06	0.08										
SAM @ 30 psi		0.14	0.17										
SAM @ 45 psi		0.18	0.25										
SAM's Chance		0.72	0.89										
Result:		**Likely Correct**	**Likely Correct**	Insert Pressure Steps Above	Insert Pressure Steps Above	Insert Pressure Steps Above	Insert Pressure Steps Above	Insert Pressure Steps Above	Insert Pressure Steps Above	Insert Pressure Steps Above	Insert Pressure Steps Above	Insert Pressure Steps Above	Insert Pressure Steps Above
Fresh Prop.	**slump [in]**												
	temp. [F]	NA	NA										
	Unit Weight [pcf]	NA	NA										
	w/c ratio	NA	NA										
Mix Design [lb/yd^3]	**Coarse 1**	595	595										
	Coarse 2	1198	1198										
	Fine	1185	1185										
	Cement	400	400										
	Fly Ash	200	200										
	Water	228	228										
	AEA												
	WR												
	SP												
What was done to the concrete before the test?													
How long was it mixed?													
How was it mixed?													
Does it have a stable air void system?													
Did you sample from the same location at the same time?													
Did you leak check the meter before running?													
Comments		3A21-2	3A21-2										

MnDOT

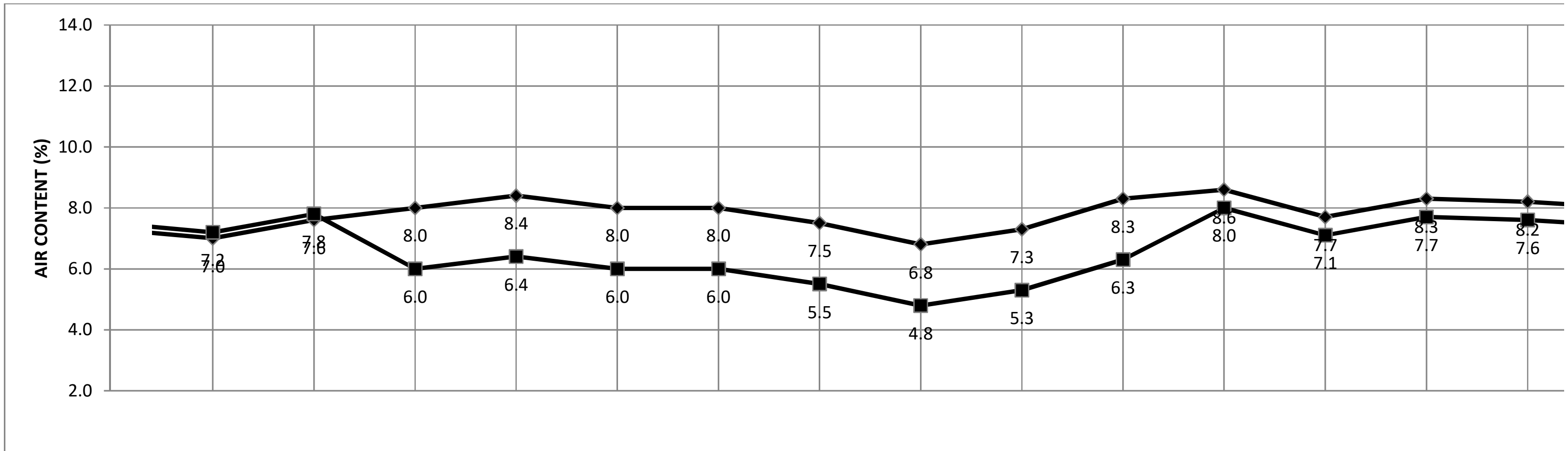
AIR CONTENT WORKSHEET/CHART



Project Number:						**Engineer:**					**Contractor:**				
Date		6/7/19	6/7/19	6/7/19	6/7/19	6/7/19	6/7/19	6/7/19	6/7/19	6/7/19	6/7/19	6/7/19	6/7/19	6/7/19	6/7/19
Before Consolidation	Time	6:32 AM	7:15 AM	8:40 AM	9:49 AM	10:25 AM	11:55 AM	12:10 PM	12:20 PM	1:10 PM	1:40 PM	2:15 PM	3:15 PM	4:10 PM	4:21 PM
	Station	1908+63	1907+07	1902+50	1898+23	1895+45	1886+85	1886+25	1884+95	1880+60	1877+85	1875+50	1870+60	1865+95	1865+95
	Concrete Temperature	75	76	74	73	73	75	75	75	75	75	75	75	75	75
	% Air Content [a]	7.4	8.1	8.4	7.6	8.9	***10.5***	***9.5***	8.1	8.4	***10.9***	7.3	6.0	7.4	7.3
	Agency Correlation % Air Content	**6.5**	8.1	8.2											
	SAM Number**														
After Consolidation	Time			9:00 AM											
	Concrete Temperature			74											
	% Air Content [b]			8.6											
	Air Loss Correction Factor [a-b]			-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
	% Air Content or Adjusted % Air Content			8.6	7.8	9.1	10.7	9.7	8.3	8.6	11.1	7.5	6.2	7.6	7.5
	Agency Correlation % Air Content			8.2											
	SAM Number**														
Additional Information or Comments															
Additional Information or Comments															

MnDOT

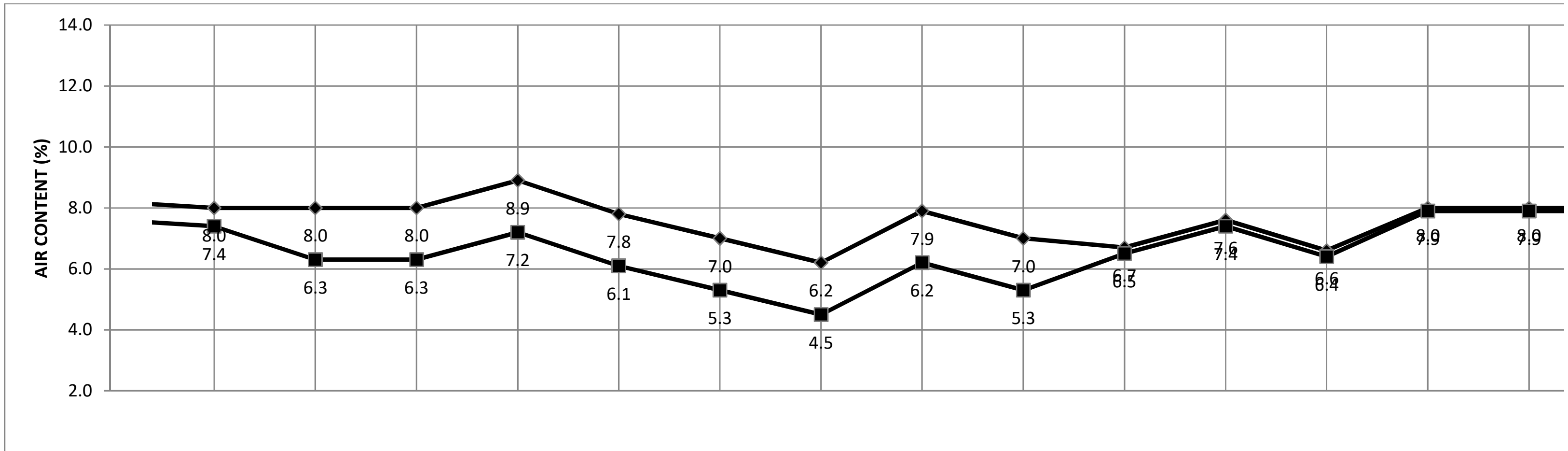
AIR CONTENT WORKSHEET/CHART



Project Number:					Engineer:			0			Contractor:			0	
Date		6/7/19	6/7/19	6/8/19	6/8/19	6/8/19	6/8/19	6/8/19	6/8/19	6/8/19	6/8/19	6/8/19	6/8/19	6/9/19	6/9/19
Before Consolidation	Time	5:15 PM	6:32 PM	6:40 AM	8:00 AM	9:00 AM	10:00 AM	11:10 AM	12:25 PM	1:35 PM	2:30 PM	3:35 PM	4:26 PM	6:30 AM	7:04 AM
	Station	1860+00	1853+00	1852+09	1852+09	1840+10	1834+25	1830+75	1826+10	1819+30	1813+95	1807+75	1802+65	1800+40	1798+68
	Concrete Temperature	75	75	70	68	70	69	72	73	73	72	73	74	67	66
	% Air Content [a]	7.0	7.6	8.0	8.4	8.0	8.0	7.5	6.8	7.3	8.3	8.6	7.7	8.3	8.2
	Agency Correlation % Air Content			7.8										8.0	
	SAM Number**														
After Consolidation	Time			7:00 AM								3:40 PM			
	Concrete Temperature			69								73			
	% Air Content [b]			6.0								8.0			
	Air Loss Correction Factor [a-b]	-0.2	-0.2	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.6	0.6	0.6	0.6
	% Air Content or Adjusted % Air Content	7.2	7.8	6.0	6.4	6.0	6.0	5.5	4.8	5.3	6.3	8.0	7.1	7.7	7.6
	Agency Correlation % Air Content			**6.0**											
	SAM Number**														
Additional Information or Comments															
Additional Information or Comments															

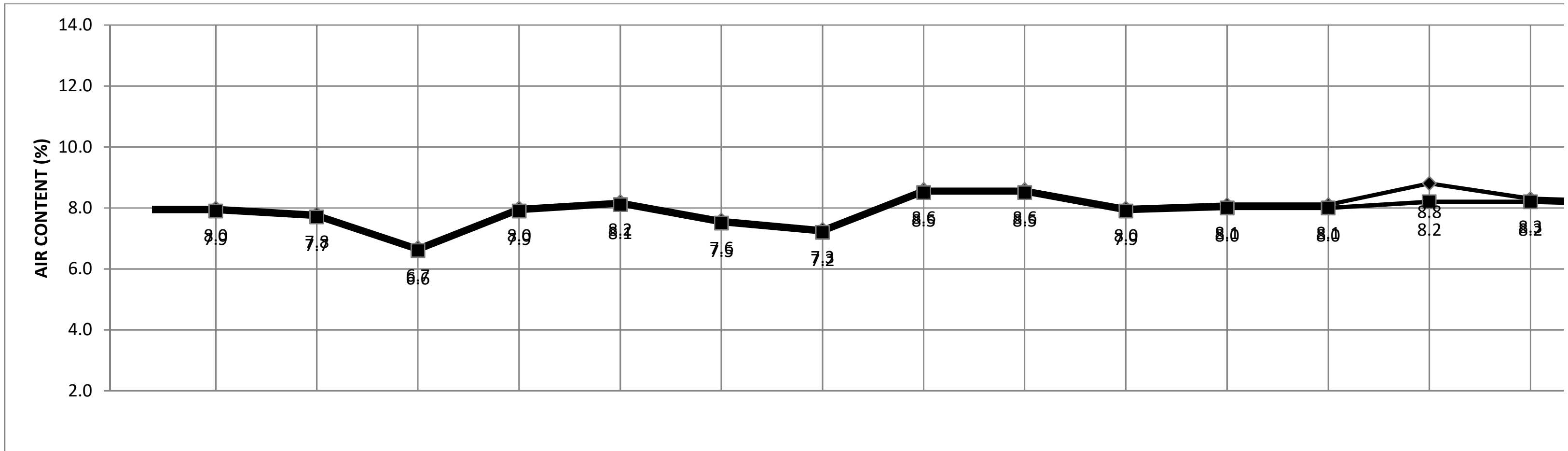
MnDOT

AIR CONTENT WORKSHEET/CHART



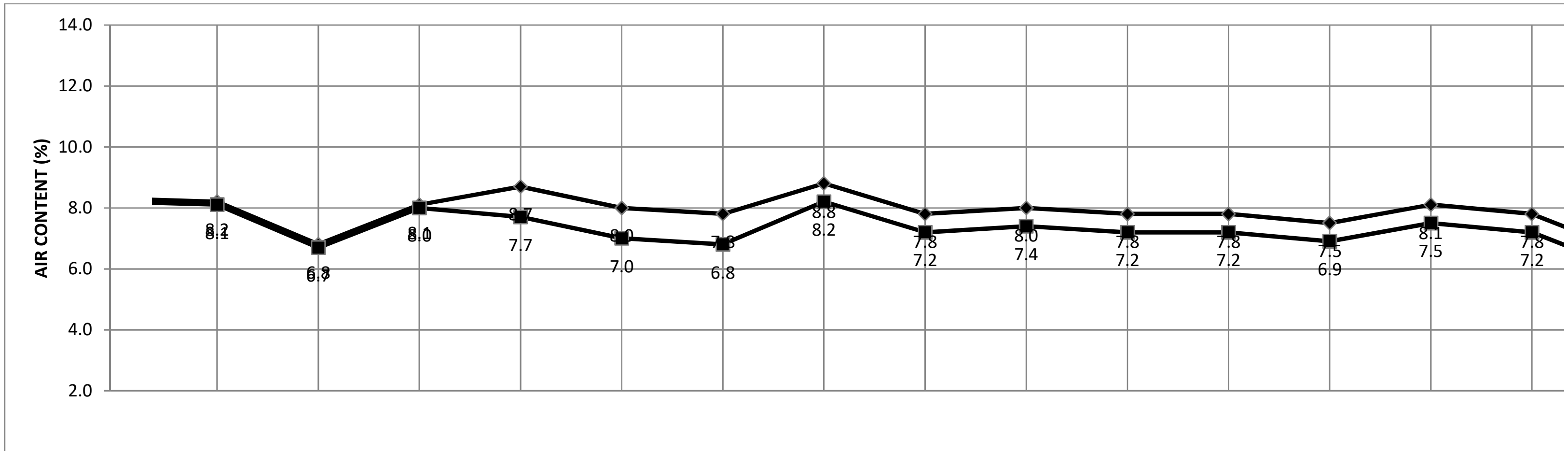
Project Number:							Engineer:		0			Contractor:		0	
Date		6/9/19	6/9/19	6/9/19	6/9/19	6/9/19	6/9/19	6/9/19	6/9/19	6/10/19	6/11/19	6/11/19	6/12/19	6/12/19	6/12/19
Before Consolidation	Time	7:20 AM	8:20 AM	9:45 AM	11:10 AM	12:15 PM	12:30 PM	1:35 PM	2:35 PM	3:35 PM	4:35 PM	5:27 PM	6:30 AM	8:15 AM	9:25 AM
	Station	1798+50	1793+25	1785+00	1779+25	1773+50	1772+10	1776+00	1760+35	1753+55	1746+48	1742+63	1741+30	1734+75	1728+50
	Concrete Temperature	66	66	68	72	73	73	72	72	73	71	71	68	66	66
	% Air Content [a]	8.0	8.0	8.0	8.9	7.8	7.0	6.2	7.9	7.0	6.7	7.6	6.6	8.0	8.0
	Agency Correlation % Air Content		7.2										**6.5**		
	SAM Number**														
After Consolidation	Time		8:27 AM								4:41 PM			8:19 AM	
	Concrete Temperature		66								71			66	
	% Air Content [b]		6.3								6.5			7.9	
	Air Loss Correction Factor [a-b]	0.6	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	0.2	0.2	0.2	0.1	0.1
	% Air Content or Adjusted % Air Content	7.4	6.3	6.3	7.2	6.1	5.3	4.5	6.2	5.3	6.5	7.4	6.4	7.9	7.9
	Agency Correlation % Air Content		**6.5**												
	SAM Number**														
Additional Information or Comments															
Additional Information or Comments															

AIR CONTENT WORKSHEET/CHART



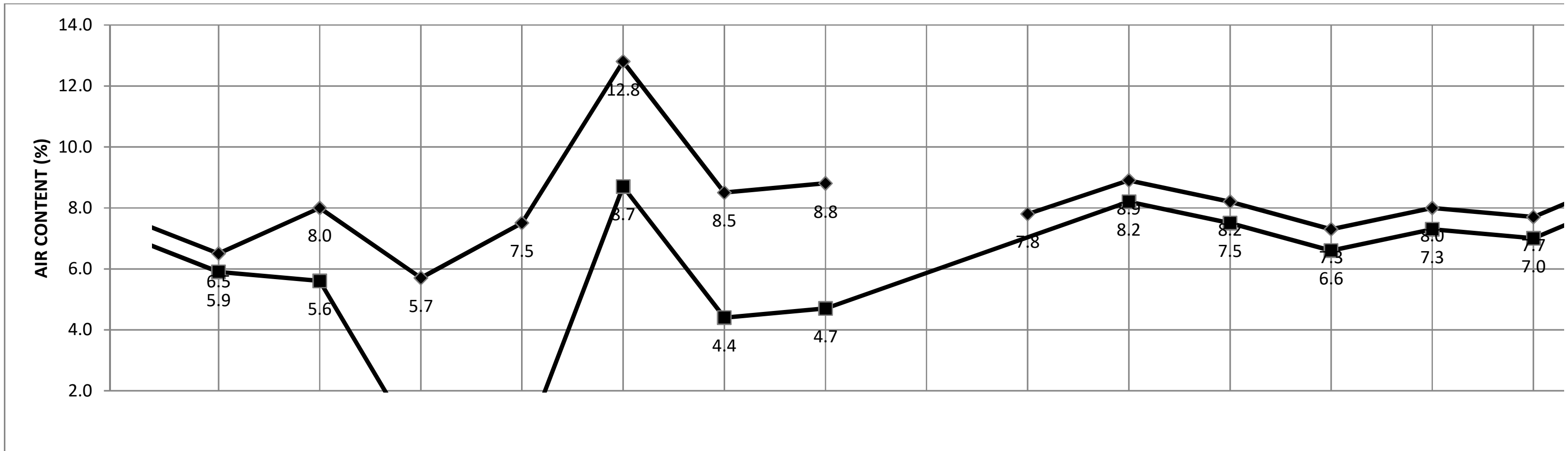
Project Number:						Engineer:		0			Contractor:		0	
Date	6/12/19	6/12/19	6/12/19	6/12/19	6/13/19	6/13/19	6/13/19	6/13/19	6/13/19	6/13/19	6/13/19	6/13/19	6/13/19	6/13/19
Before Consolidation														
Time	12:35 AM	1:35 AM	2:45 AM	4:00 AM	6:30 AM	7:36 AM	8:21 AM	9:20 AM	9:45 AM	10:20 AM	11:20 AM	12:20 AM	1:50 AM	3:09 PM
Station	1710+85	1707+55	1700+75	1693+25	1683+10	1678+95	1675+30	1670+10	1667+70	1666+00	1661+75	1658+00	1654+00	1643+65
Concrete Temperature	70	70	70	70	63	61	59	66	66	69	70	72	73	71
% Air Content [a]	8.0	7.8	6.7	8.0	8.2	7.6	7.3	8.6	8.6	8.0	8.1	8.1	8.8	8.3
Agency Correlation % Air Content					7.6								**8.8**	
SAM Number**													0.23	
After Consolidation														
Time													2:03 PM	3:15 PM
Concrete Temperature													73	71
% Air Content [b]													8.2	8.2
Air Loss Correction Factor [a-b]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.6	0.1
% Air Content or Adjusted % Air Content	7.9	7.7	6.6	7.9	8.1	7.5	7.2	8.5	8.5	7.9	8.0	8.0	8.2	8.2
Agency Correlation % Air Content													8.2	
SAM Number**													0.33	
Additional Information or Comments														
Additional Information or Comments														

AIR CONTENT WORKSHEET/CHART



Project Number:						Engineer:		0			Contractor:			0	
Date		6/13/19	6/13/19	6/14/19	6/14/19	6/14/19	6/14/19	6/14/19	6/14/19	6/14/19	6/14/19	6/14/19	6/14/19	6/14/19	6/17/19
Before Consolidation	Time	4:55 PM	6:38 PM	6:55 AM	8:25 AM	9:15 AM	10:30 AM	11:45 AM	1:17 PM	2:55 PM	3:45 PM	4:45 PM	5:55 PM	6:45 PM	6:38 AM
	Station	1636+25	1627+00	1626+74	1619+50	1614+65	1608+75	1600+15	1591+19	1887+35	1583+00	1577+20	1570+25	1566+17	1565+38
	Concrete Temperature	72	70	66	68	71	70	70	72	74	75	74	73	74	71
	% Air Content [a]	8.2	6.8	8.1	8.7	8.0	7.8	8.8	7.8	8.0	7.8	7.8	7.5	8.1	7.8
	Agency Correlation % Air Content			7.8											7.0
	SAM Number**				0.23			0.27							
After Consolidation	Time				8:37 AM			11:58 AM							
	Concrete Temperature				68			70							
	% Air Content [b]				7.7			8.2							
	Air Loss Correction Factor [a-b]	0.1	0.1	0.1	1.0	1.0	1.0	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	% Air Content or Adjusted % Air Content	8.1	6.7	8.0	7.7	7.0	6.8	8.2	7.2	7.4	7.2	7.2	6.9	7.5	7.2
	Agency Correlation % Air Content														
	SAM Number**				0.04			0.74							
Additional Information or Comments															
Additional Information or Comments															

AIR CONTENT WORKSHEET/CHART



Project Number:						Engineer:		0			Contractor:		0		
Date		6/17/19	6/17/19	6/17/19	6/17/19	6/17/19	6/17/19	6/17/19	6/19/19	6/19/19	6/19/19	6/19/19	6/19/19	6/19/19	6/19/19
Before Consolidation	Time	7:50 AM	8:37 AM	9:43 AM	10:45 AM	11:42 AM	1:32 PM	2:53 PM	6:44 AM	7:07 AM	8:10 AM	10:00 AM	10:42 AM	12:14 PM	1:08 PM
	Station	1560+10	155+90	1549+60	1544+30	1537+32	1523+38	1517+65	1224+00	1224+67	1234+50	1239+56	1243+95	1251+63	1257+25
	Concrete Temperature	71	73	69	70	69	70	69	70	70	69	69	70	71	73
	% Air Content [a]	6.5	8.0	5.7	7.5	***12.8***	8.5	8.8		7.8	8.9	8.2	7.3	8.0	7.7
	Agency Correlation % Air Content					7.5			7.0			7.2			
	SAM Number**		0.19			0.07						0.18			
After Consolidation	Time			9:47 AM		11:58 AM					9:14 AM				
	Concrete Temperature			73		69					69				
	% Air Content [b]			5.6		8.7					8.2				
	Air Loss Correction Factor [a-b]	0.6	***2.4***	#REF!	#REF!	***4.1***	***4.1***	***4.1***			0.7	0.7	0.7	0.7	0.7
	% Air Content or Adjusted % Air Content	5.9	5.6	#REF!	#REF!	8.7	***4.4***	4.7			8.2	7.5	6.6	7.3	7.0
	Agency Correlation % Air Content					8.0									
	SAM Number**					0.07									
Additional Information or Comments															
Additional Information or Comments															

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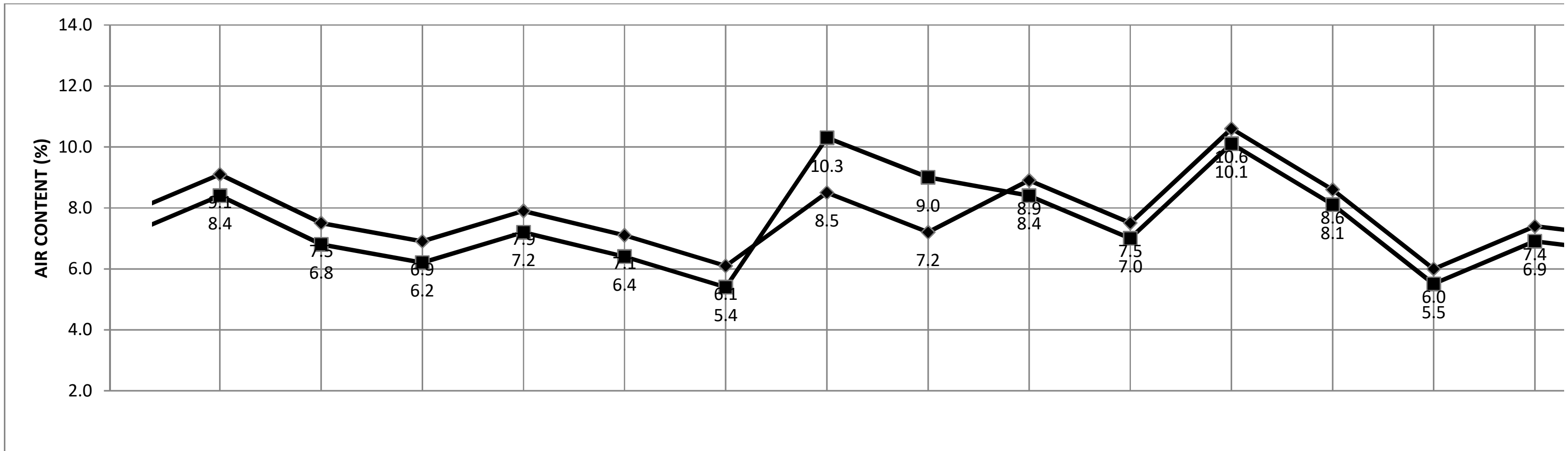
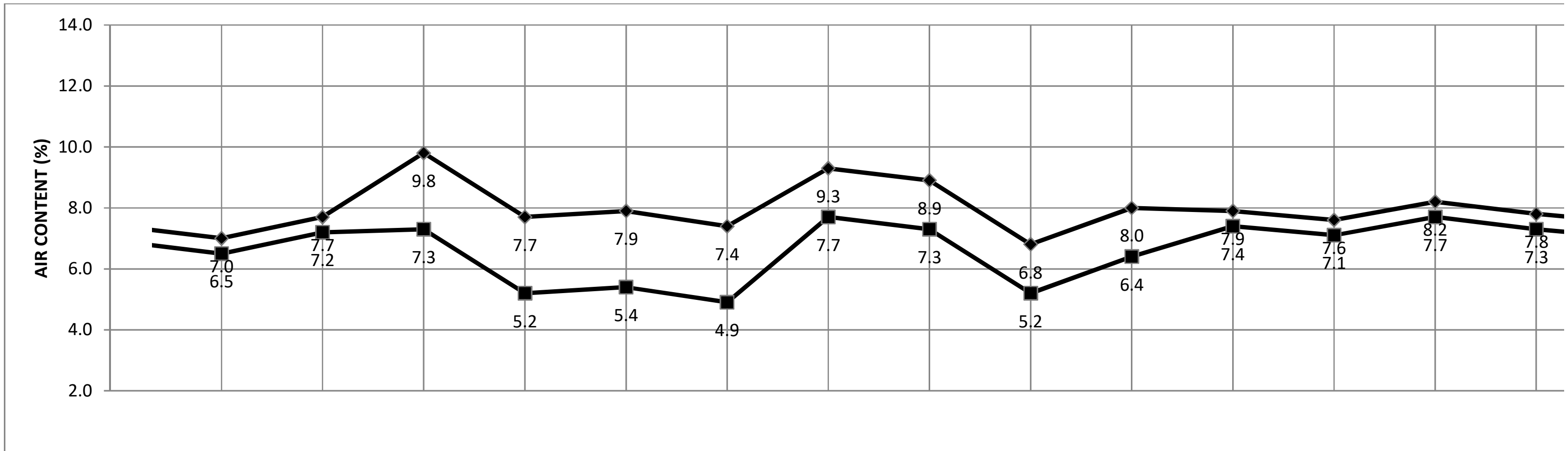
AIR CONTENT WORKSHEET/CHART



Project Number:						Engineer:		0			Contractor:			0	
Date		6/19/19	6/19/19	6/19/19	6/19/19	6/24/19	6/24/19	6/24/19	6/24/19	6/24/19	6/24/19	6/24/19	6/24/19	6/25/19	6/26/19
Before Consolidation	Time	2:43 PM	4:37 PM	6:12 PM	6:45 PM	8:42 AM	10:15 AM	11:12 AM	1:18 PM	3:00 PM	4:23 PM	5:20 PM	5:50 PM	10:43 AM	11:56 AM
	Station	1265+17	1265+17	1265+17	1265+17	1291+50	1297+85	1303+87	1311+90	1323+18	1333+64	1340+37	1343+00	1623+73	1640+99
	Concrete Temperature	71	71	71	71	70	73	73	70	70	71	70	68	73	73
	% Air Content [a]	***9.1***	7.5	6.9	7.9	7.1	6.1	8.5	7.2	8.9	7.5	***10.6***	8.6	6.0	7.4
	Agency Correlation % Air Content	6.8				**6.0**	**6.1**	7.5		8.0		8.1		**5.6**	
	SAM Number**	0.17						0.24		0.23		0.20			
After Consolidation	Time	2:59 PM						11:30 AM		3:09 PM					
	Concrete Temperature	71						73		70					
	% Air Content [b]	8.4						10.3		8.4					
	Air Loss Correction Factor [a-b]	0.7	0.7	0.7	0.7	0.7	0.7	-1.8	-1.8	0.5	0.5	0.5	0.5	0.5	0.5
	% Air Content or Adjusted % Air Content	8.4	6.8	6.2	7.2	6.4	5.4	10.3	9.0	8.4	7.0	10.1	8.1	5.5	6.9
	Agency Correlation % Air Content	**6.2**						7.2		8.1					
	SAM Number**	0.08								0.19					
Additional Information or Comments															
Additional Information or Comments															

AIR CONTENT WORKSHEET/CHART



Project Number:		Engineer:						0		Contractor:			0		
Date		6/26/19	6/26/19	6/26/19	6/26/19	6/26/19	6/26/19	6/26/19	6/26/19	6/26/19	6/28/19	6/28/19	6/28/19	6/28/19	6/28/19
Before Consolidation	Time	6:28 AM	7:42 AM	9:02 AM	10:49 AM	11:52 AM	12:56 PM	2:02 PM	4:30 PM	5:40 PM	6:23 AM	7:53 AM	9:07 AM	10:55 AM	11:56 AM
	Station	1344+22	1350+08	1358+62	1370+38	1377+88	1385+36	1393+75	1049+10	1415+95	1490+91	1427+54	1434+12	1440+18	1445+15
	Concrete Temperature	61	66	67	70	70	70	70	73	73	74	72	73	76	75
	% Air Content [a]	7.0	7.7	***9.8***	7.7	7.9	7.4	***9.3***	8.9	6.8	8.0	7.9	7.6	8.2	7.8
	Agency Correlation % Air Content	7.0		8.0				7.0			7.5			**6.0**	
	SAM Number**			0.17										0.27	
After Consolidation	Time			9:02 AM				2:20 PM				7:57 AM			
	Concrete Temperature			8.2				70				72			
	% Air Content [b]			7.3				7.7				7.4			
	Air Loss Correction Factor [a-b]	0.5	0.5	***2.5***	***2.5***	***2.5***	***2.5***	1.6	1.6	1.6	1.6	0.5	0.5	0.5	0.5
	% Air Content or Adjusted % Air Content	6.5	7.2	7.3	5.2	5.4	4.9	7.7	7.3	5.2	6.4	7.4	7.1	7.7	7.3
	Agency Correlation % Air Content							7.6							
	SAM Number**														
Additional Information or Comments															
Additional Information or Comments															

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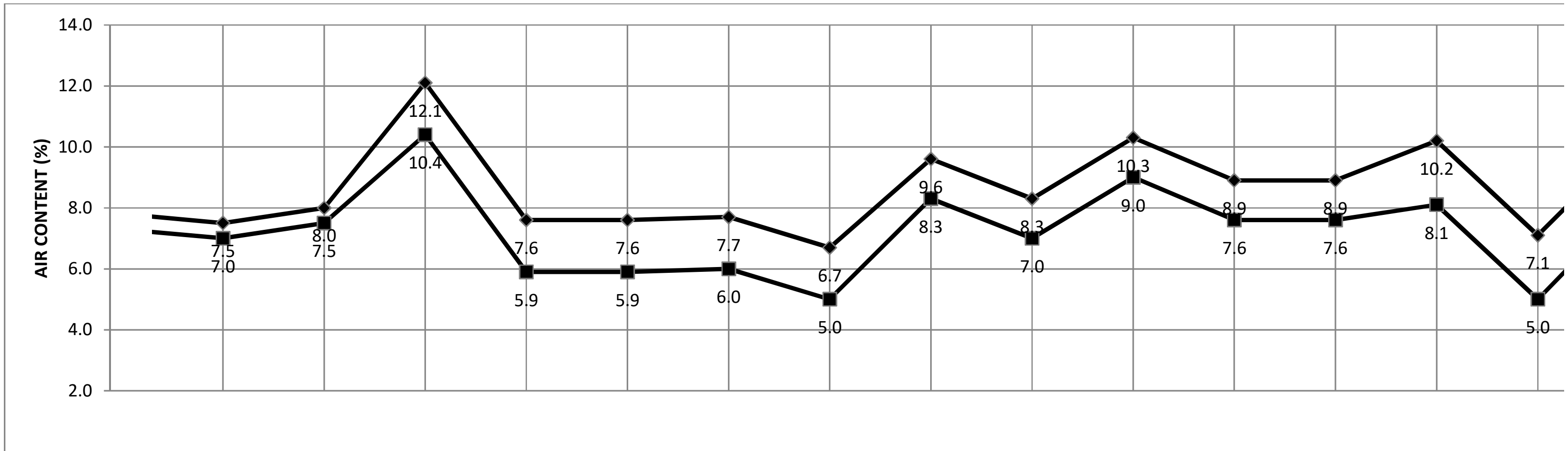
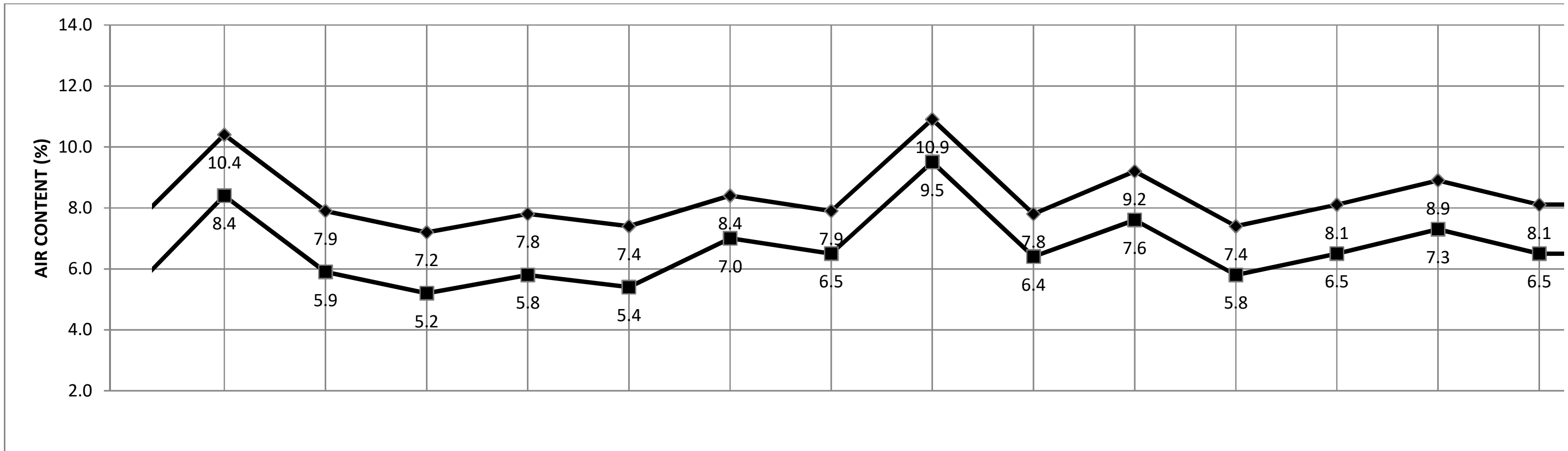
AIR CONTENT WORKSHEET/CHART



Project Number:						Engineer:		0			Contractor:		0		
Date		6/28/19	6/28/19	6/28/19	6/28/19	6/28/19	6/28/19	6/29/19	6/29/19	6/29/19	6/29/19	6/29/19	7/1/19	7/1/19	7/2/19
Before Consolidation	Time	1:02 PM	2:08 PM	2:57 PM	4:45 PM	5:47 PM	6:29 PM	6:15 AM	7:15 AM	9:09 AM	9:55 AM	10:35 AM	8:53 AM	11:17 AM	6:47 AM
	Station	1453+22	1462+55	1468+50	1468+50	1468+50	1468+50	1493+58	1499+25	1508+62	1512+68	1516+15	1266+10	1275+17	1285+34
	Concrete Temperature	76	74	77	73	75	75	75	75	74	75	73	79	77	75
	% Air Content [a]	7.5	8.0	***12.1***	7.6	7.6	7.7	6.7	***9.6***	8.3	***10.3***	8.9	8.9	***10.2***	7.1
	Agency Correlation % Air Content			8.2				**6.5**	7.8		**8.8**		**8.8**	7.6	6.8
	SAM Number**			0.19					0.34		0.05			0.18	
After Consolidation	Time			3:04 PM					7:30 AM					11:21 AM	
	Concrete Temperature			77					75					77	
	% Air Content [b]			10.4					8.3					8.1	
	Air Loss Correction Factor [a-b]	0.5	0.5	1.7	1.7	1.7	1.7	1.7	1.3	1.3	1.3	1.3	1.3	***2.1***	***2.1***
	% Air Content or Adjusted % Air Content	7.0	7.5	10.4	5.9	5.9	6.0	5.0	8.3	7.0	9.0	7.6	7.6	8.1	5.0
	Agency Correlation % Air Content			7.5					7.0					7.0	
	SAM Number**			0.29					0.23					0.28	
Additional Information or Comments															
Additional Information or Comments															

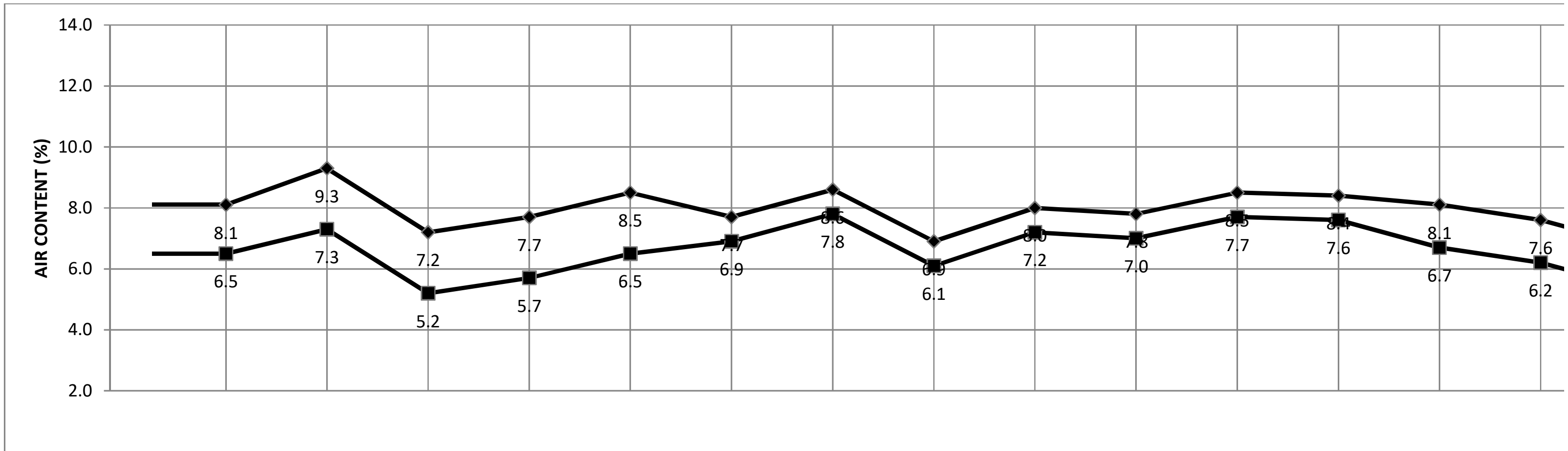
AIR CONTENT WORKSHEET/CHART

(1/2018)



Project Number:							Engineer:		0			Contractor:			0	
Date		7/2/19	7/2/19	7/2/19	7/3/19	7/3/19	7/3/19	7/8/19	7/8/19	7/8/19	7/8/19	7/9/19	7/9/19	7/9/19	7/9/19
Before Consolidation	Time	9:16 AM	12:00 PM	12:49 PM	6:42 AM	7:17 AM	10:40 AM	6:28 AM	8:15 AM	12:30 PM	2:14 PM	6:16 AM	9:14 AM	10:00 AM	1:34 PM
	Station	1296+55	1247+64	1244+04	1260+63	1257+55	1518+88	1515+40	1508+08	1427+70	1418+73	1716+21	1897+95	1902+67	1882+64
	Concrete Temperature	74	76	79	75	75	78	75	75	77	77	74	75	75	76
	% Air Content [a]	***10.4***	7.9	7.2	7.8	7.4	8.4	7.9	***10.9***	7.8	***9.2***	7.4	8.1	8.9	8.1
	Agency Correlation % Air Content	**8.8**			7.7		7.6	7.0	**8.8**		8.4	7.4			
	SAM Number**	0.16					0.19		0.23		0.17				
After Consolidation	Time	9:22 AM					10:47 AM				2:20 PM				
	Concrete Temperature	74					78				77				
	% Air Content [b]	8.4					7.0				7.6				
	Air Loss Correction Factor [a-b]	2.0	2.0	2.0	2.0	2.0	1.4	1.4	1.4	1.4	1.6	1.6	1.6	1.6	1.6
	% Air Content or Adjusted % Air Content	8.4	5.9	5.2	5.8	5.4	7.0	6.5	9.5	6.4	7.6	5.8	6.5	7.3	6.5
	Agency Correlation % Air Content	7.8					6.8				7.5				
	SAM Number**	0.25									0.13				
Additional Information or Comments															
Additional Information or Comments															

AIR CONTENT WORKSHEET/CHART



Project Number:						Engineer:		0		Contractor:			0		
Date		7/9/19	7/9/19	7/10/19	7/10/19	7/10/19	7/10/19	7/10/19	7/10/19	7/11/19	7/11/19	7/11/19	7/11/19	7/11/19	7/15/19
Before Consolidation	Time	2:47 PM	3:28 PM	6:28 AM	9:47 AM	10:22 AM	11:52 AM	4:57 PM	6:08 PM	6:17 AM	8:16 AM	8:38 AM	9:12 AM	9:46 AM	8:00 AM
	Station	1878+28	1878+08	1778+50	1283+15	1283+30	1721+37	1641+63	1273+09	1614+45	1614+88	1508+18	1591+24	1595+65	1511+40
	Concrete Temperature	76	76	74	75	75	75	79	78	72	75	75	77	77	82
	% Air Content [a]	8.1	***9.3***	7.2	7.7	8.5	7.7	8.6	6.9	8.0	7.8	8.5	8.4	8.1	7.6
	Agency Correlation % Air Content		7.8	7.2			7.0			8.0				7.2	
	SAM Number**		0.31				0.30							0.12	
After Consolidation	Time		3:35 PM				11:58 AM							9:52 AM	
	Concrete Temperature		76				75							77	
	% Air Content [b]		7.3				6.9							6.7	
	Air Loss Correction Factor [a-b]	1.6	2.0	2.0	2.0	2.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.4	1.4
	% Air Content or Adjusted % Air Content	6.5	7.3	5.2	5.7	6.5	6.9	7.8	6.1	7.2	7.0	7.7	7.6	6.7	6.2
	Agency Correlation % Air Content		**6.5**				**5.5**							**6.0**	
	SAM Number**		0.19				0.36							0.24	
Additional Information or Comments															
Additional Information or Comments															

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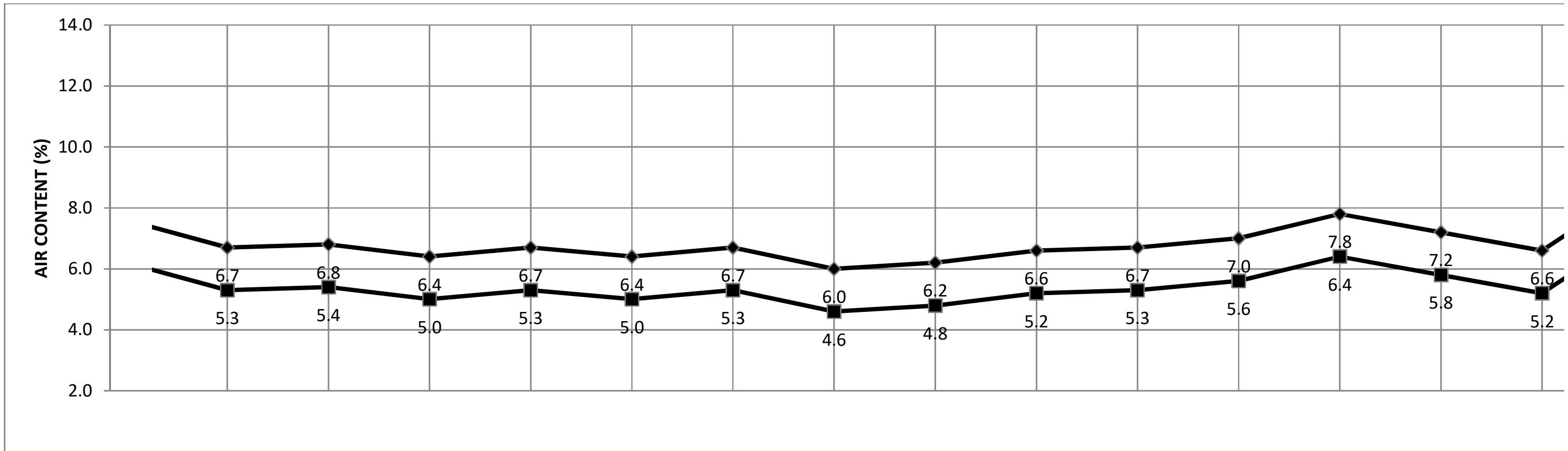
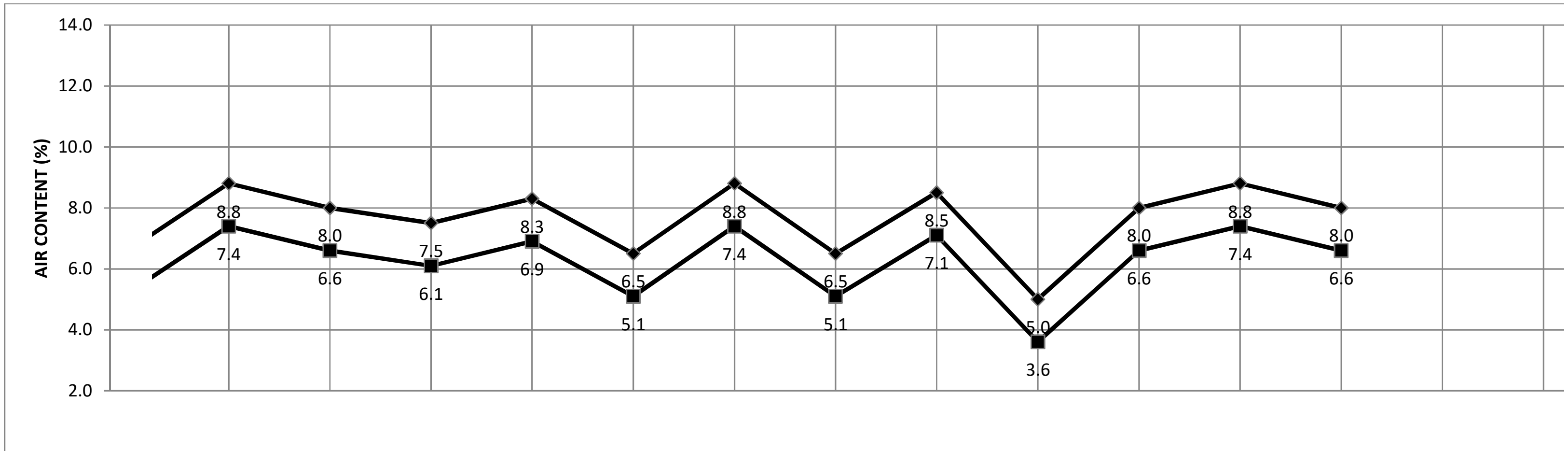
AIR CONTENT WORKSHEET/CHART



Project Number:					Engineer:			0			Contractor:		0	
Date	7/15/19	7/15/19	7/15/19	7/15/19	7/16/19	7/16/19	7/16/19	7/16/19	7/16/19	7/16/19	7/26/19	7/26/19	7/26/19	7/29/19
Before Consolidation – Time	11:14 AM	1:04 PM	2:58 PM	3:52 PM	7:09 AM	8:42 AM	10:28 AM	11:36 AM	2:08 PM	3:58 PM	8:20 AM	1:05 PM	2:45 PM	7:25 AM
Station	Rest Area	Rest Area	Rest Area	Rest Area	Rest Area	Rest Area	Rest Area	Rest Area	Rest Area	Rest Area	Median	Median	Median	Rest Area
Concrete Temperature	88	90	89	93	88	83	87	84	84	84	72	82	85	73
% Air Content [a]	6.7	6.8	6.4	6.7	6.4	6.7	6.0	6.2	6.6	6.7	7.0	7.8	7.2	6.6
Agency Correlation % Air Content					**6.5**						6.6			**6.4**
SAM Number**														
After Consolidation – Time														
Concrete Temperature														
% Air Content [b]														
Air Loss Correction Factor [a-b]	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
% Air Content or Adjusted % Air Content	5.3	5.4	5.0	5.3	5.0	5.3	4.6	4.8	5.2	5.3	5.6	6.4	5.8	5.2
Agency Correlation % Air Content														
SAM Number**														
Additional Information or Comments														
Additional Information or Comments														

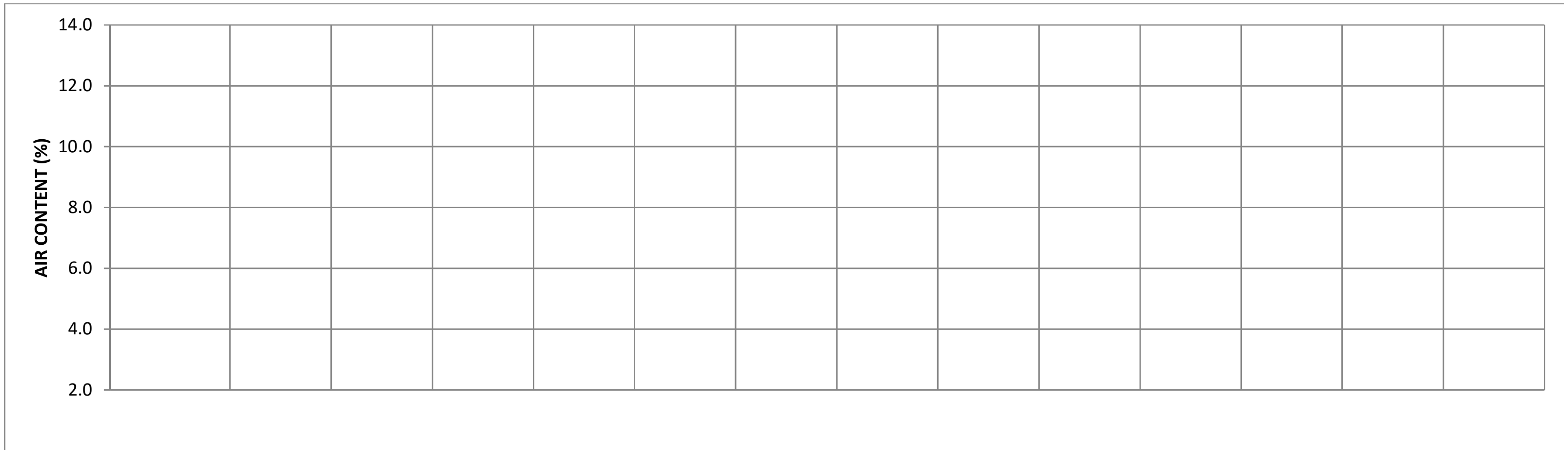
MnDOT

AIR CONTENT WORKSHEET/CHART



Project Number:						Engineer:		0			Contractor:			0	
Date		7/29/19	7/29/19	7/29/19	7/29/19	7/29/19	7/29/19	7/30/19	7/30/19	7/31/19	7/31/19	7/31/19	7/31/19		
Before Consolidation	Time	8:00 AM	8:15 AM	8:25 AM	8:45 AM	12:25 PM	2:20 PM	7:40 AM	2:35 PM	8:15 AM	8:30 AM	8:50 AM	3:10 PM		
	Station	Rest Area	Rest Area	Rest Area	Rest Area	Rest Area	Rest Area	Rest Area	Rest Area	Median	Median	Median	Median		
	Concrete Temperature	75	77	77	75	75	77	70	85	75	73	72	75		
	% Air Content [a]	8.8	8.0	7.5	8.3	6.5	8.8	6.5	8.5	***5.0***	8.0	8.8	8.0		
	Agency Correlation % Air Content														
	SAM Number**														
After Consolidation	Time														
	Concrete Temperature														
	% Air Content [b]														
	Air Loss Correction Factor [a-b]	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4		
	% Air Content or Adjusted % Air Content	7.4	6.6	6.1	6.9	5.1	7.4	5.1	7.1	***3.6***	6.6	7.4	6.6		
	Agency Correlation % Air Content														
	SAM Number**														
Additional Information or Comments															
Additional Information or Comments															

AIR CONTENT WORKSHEET/CHART



Project Number:						Engineer:		0		Contractor:			0		
Date															
Before Consolidation	Time														
	Station														
	Concrete Temperature														
	% Air Content [a]														
	Agency Correlation % Air Content														
	SAM Number**														
After Consolidation	Time														
	Concrete Temperature														
	% Air Content [b]														
	Air Loss Correction Factor [a-b]														
	% Air Content or Adjusted % Air Content														
	Agency Correlation % Air Content														
	SAM Number**														
Additional Information or Comments															
Additional Information or Comments															

Minnesota Department of Transportation 9/2018

Maturity - Field Data

Project No.: 8309-52 Tester: Patrick Levine Mix No.: 3A21

Location: St. James Contractor: PCI Probe No.: 1627+50

Curve #: 1 Engineer: Bob Williams TTF Required: 2400

Structural Unit Location: Mainline

Or Pavement Section to Open:

From STA: 1683+26 To STA: 1626+74

Apparatus Used: Maturity Meter

				Maturity Meter			
Date	**Time**	**Age (hours)**	**Air Temp (deg F)**	**TTF (deg C-hr)**			
6/13/19		0.00		0			
6/17/19	7:33 PM	114.00		2735			

Comments:

Minnesota Department of Transportation 9/2018

Maturity - Field Data

Project No.: 8309-52 Tester: Patrick Levine Mix No.: 3A21

Location: St. James Contractor: PCI Probe No.: 1566+00

Curve #: 1 Engineer: Bob Williams TTF Required: 2400

Structural Unit Location: Mainline

Or Pavement Section to Open:

From STA: 1626+74 To STA: 1565+52

Apparatus Used: Maturity Meter

				Maturity Meter			
Date	Time	Age (hours)	Air Temp (deg F)	TTF (deg C-hr)			
6/14/19		0.00		0			
6/18/19	13:02	90.00		**2166**			
6/19/19	8:31 AM	109.00		2627			

Comments:

Minnesota Department of Transportation

Maturity - Field Data

Project No.: 8309-52
Tester: Patrick Levine
Mix No.: 3A21

Location: St. James
Contractor: PCI
Probe No.: 1518+00

Curve #: 1
Engineer: Bob Williams
TTF Required: 2400

Structural Unit Location: Mainline
Or Pavement Section to Open:
From STA: 1565+52
To STA: 1517+30

Apparatus Used: Maturity Meter

				Maturity Meter			
Date	**Time**	**Age (hours)**	**Air Temp (deg F)**	**TTF (deg C-hr)**			
6/17/19		0.00		0			
6/19/19	8:41	41.00		**1107**			
6/20/19	7:15	64.00		**1681**			
6/21/19	5:30	86.00		**2135**			

Comments:

Minnesota Department of Transportation 9/2018

Maturity - Field Data

Project No.:	8309-52	Tester:	Patrick Levine	Mix No.:	3A21
Location:	St. James	Contractor:	PCI	Probe No.:	1343+00
Curve #:	1	Engineer:	Bob Williams	TTF Required:	2400

Structural Unit Location: Mainline

Or Pavement Section to Open:

From STA: 1291+35 To STA: 1344+08

Apparatus Used: Maturity Meter

				Maturity Meter			
Date	Time	Age (hours)	Air Temp (deg F)	TTF (deg C-hr)			
6/24/19		0.00		0			
6/26/19	17:06	47.00		**1066**			
6/27/19	9:03 AM	52.00		**1430**			
6/28/19	6:38 PM	83.00		**1863**			
6/28/19	8:56 PM	98.00		**2254**			
6/29/19	5:34 AM	107.00		2455			

Comments:

Maturity - Field Data

Project No.: 8309-52
Tester: Patrick Levine
Mix No.: 3A21
Location: St. James
Contractor: PCI
Probe No.: 1418+50
Curve #: 1
Engineer: Bob Williams
TTF Required: 2400

Structural Unit Location: Mainline
Or Pavement Section to Open:
From STA: 1344+08 To STA: 1419+91

Apparatus Used: Maturity Meter

				Maturity Meter			
Date	Time	Age (hours)	Air Temp (deg F)	TTF (deg C-hr)			
6/26/19		0.00		0			
6/28/19	8:43	50.00		**1166**			
6/29/19	5:26 AM	59.00		**1371**			
7/1/19	7:23 AM	108.00		2753			

Comments:

Minnesota Department of Transportation 9/2018

Maturity - Field Data

Project No.:	8309-52	Tester:	Patrick Levine	Mix No.:	3A21
Location:	St. James	Contractor:	PCI	Probe No.:	1492+90
Curve #:	1	Engineer:	Bob Williams	TTF Required:	2400

Structural Unit Location: Mainline

Or Pavement Section to Open:

From STA: 1419+91 To STA: 1493+58

Apparatus Used: Maturity Meter

				Maturity Meter			
Date	**Time**	**Age (hours)**	**Air Temp (deg F)**	**TTF (deg C-hr)**			
6/28/19		0.00		0			
7/1/19	7:32	36.00		**1816**			
7/2/19	7:44	84.00		**2374**			
7/3/19	7:65 am	109.00		3001			

Comments:

Minnesota Department of Transportation

9/2018

Maturity - Field Data

Project No.: 8309-52

Tester: Patrick Levine

Mix No.: 3A21

Location: St. James

Contractor: PCI

Probe No.: 1516+50

Curve #: 1

Engineer: Bob Williams

TTF Required: 2400

Structural Unit Location: Mainline

Or Pavement Section to Open:

From STA: 1493+58

To STA: 1517+30

Apparatus Used: Maturity Meter

				Maturity Meter			
Date	Time	Age (hours)	Air Temp (deg F)	TTF (deg C-hr)			
6/29/19		0.00		0			
7/2/19	7:44	68.00		**2063**			
7/3/19	8:04 AM	93.00		2724			

Comments:

Maturity - Field Data

Project No.: 8309-52
Tester: Patrick Levine
Mix No.: 3A21
Location: St. James
Contractor: PCI
Probe No.: 1516+50
Curve #: 1
Engineer: Bob Williams
TTF Required: 2400

Structural Unit Location: Ramp
Or Pavement Section to Open:
From STA: 1523+40
To STA: 1515+57

Apparatus Used: Maturity Meter

				Maturity Meter			
Date	Time	Age (hours)	Air Temp (deg F)	TTF (deg C-hr)			
7/3/19		0.00		0			
7/8/19	5:38	116.00		3311			

Comments:

Minnesota Department of Transportation 9/2018

Maturity - Field Data

Project No.: 8309-52 Tester: Patrick Levine Mix No.: 3A21

Location: St. James Contractor: PCI Probe No.: 1413+50

Curve #: 1 Engineer: Bob Williams TTF Required: 2400

Structural Unit Location: Turn Lanes

Or Pavement Section to Open:

From STA: 1515+57 To STA: 1487+83

Apparatus Used: Maturity Meter

				Maturity Meter			
Date	Time	Age (hours)	Air Temp (deg F)	TTF (deg C-hr)			
7/8/19		0.00		0			
7/10/19	14:38	46.00		**1280**			
7/11/19	6:04 AM	61.00		**1651**			

Comments:

Minnesota Department of Transportation 9/2018

Maturity - Field Data

Project No.: 8309-52
Tester: Patrick Levine
Mix No.: 3A21
Location: St. James
Contractor: PCI
Probe No.: 1412+50
Curve #: 1
Engineer: Bob Williams
TTF Required: 2400

Structural Unit Location: Turn Lanes
Or Pavement Section to Open:
From STA:
To STA:

Apparatus Used: Maturity Meter

				Maturity Meter			
Date	Time	Age (hours)	Air Temp (deg F)	TTF (deg C-hr)			
7/9/19		0.00		0			
7/15/19	7:37	132.00		3688			

Comments:

Minnesota Department of Transportation 9/2018

Maturity - Field Data

Project No.:	8309-52	Tester:	Patrick Levine	Mix No.:	3A21
Location:	St. James	Contractor:	PCI	Probe No.:	1825+50
Curve #:	1	Engineer:	Bob Williams	TTF Required:	2400

Structural Unit Location: Turn Lanes

Or Pavement Section to Open:

From STA: To STA:

Apparatus Used: Maturity Meter

				Maturity Meter			
Date	Time	Age (hours)	Air Temp (deg F)	TTF (deg C-hr)			
7/10/19		0.00		0			
7/15/19	7:18	108.00		3071			

Comments:

Maturity - Field Data

Project No.:	8309-52	Tester:	Patrick Levine	Mix No.:	
Location:	St. James	Contractor:	PCI	Probe No.:	
Curve #:	1	Engineer:	Bob Williams	TTF Required:	

Structural Unit Location:

Or Pavement Section to Open:

From STA: To STA:

Apparatus Used: Maturity Meter

				Maturity Meter			
Date	**Time**	**Age (hours)**	**Air Temp (deg F)**	**TTF (deg C-hr)**			
		0.00		0			

Comments:

TH 60 WB			
Sheet	**Total Pay Adjustment**	**ALR Dedcution**	**Total Pay Adjustment + ALR Dedcution**
Concrete	$11,351.95	$0.00	$11,351.95
Concrete 2	$17,172.55	$0.00	$17,172.55
Concrete 3	$20,447.75	$0.00	$20,447.75
Concrete 4	$744.31	$0.00	$744.31
Concrete 5	$4,254.20	$0.00	$4,254.20
Concrete 6	$15,997.75	$0.00	$15,997.75
Concrete 7	$13,701.55	$0.00	$13,701.55
Concrete 8	$10,573.20	$0.00	$10,573.20
Concrete 9	$10,573.20	$0.00	$10,573.20
Concrete 10	$11,129.45	$0.00	$11,129.45
Concrete 11	$11,151.70	$0.00	$11,151.70
Concrete 12	$6,761.56	$0.00	$6,761.56
Concrete 13	$1,602.00	$0.00	$1,602.00
Concrete 14	$9,358.35	$0.00	$9,358.35
Concrete 15	$19,508.80	-$300.00	$19,208.80
Concrete 16	$8,824.35	$0.00	$8,824.35
Concrete 17	$8,619.65	$0.00	$8,619.65
Concrete 18	$15,748.55	$0.00	$15,748.55
			$197,220.87

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190620-TH-60-D-1-1276+81-1223+84 190620-TH-60-D-2-1276+81-1223+84
Date Measured	20-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	Section 1	Section 2	Section 3
Beginning	1276+81	1276+81	
End	1224+01	1224+01	

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1276+81	1271+53	528	56.5	$378.25	S1
↓	1271+53	1266+25	528	75.1	-$449.45	↓
↓	1266+25	1260+97	528	74.7	-$431.65	↓
↓	1260+97	1255+69	528	58.8	$275.90	↓
↓	1255+69	1250+41	528	50.6	$640.80	↓
↓	1250+41	1245+13	528	52.3	$565.15	↓
↓	1245+13	1239+85	528	50.4	$649.70	↓
↓	1239+85	1234+57	528	49.2	$703.10	↓
↓	1234+57	1229+29	528	52.3	$565.15	↓
↓	1229+29	1224+01	528	55.5	$422.75	↓
S2	1276+81	1271+53	528	39.7	$890.00	S2
↓	1271+53	1266+25	528	53.3	$520.65	↓
↓	1266+25	1260+97	528	54.3	$476.15	↓
↓	1260+97	1255+69	528	43.2	$890.00	↓
↓	1255+69	1250+41	528	36.1	$890.00	↓
↓	1250+41	1245+13	528	37.2	$890.00	↓
↓	1245+13	1239+85	528	33.4	$890.00	↓
↓	1239+85	1234+57	528	34.5	$890.00	↓
↓	1234+57	1229+29	528	34.9	$890.00	↓
↓	1229+29	1224+01	528	46.9	$805.45	↓

Total Pay Adjustment	**$11,351.95**
Areas of Localized Roughness Deduction	**$0.00**
Total Pay Adjustment + Areas of Localized Roughness Deduction	**$11,351.95**

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190625-TH-60-D-1-1340+16-1276+81 190625-TH-60-D-2-1340+16-1276+81
Date Measured	25-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	Section 1	Section 2	Section 3
Beginning	1340+16	1340+16	
End	1276+80	1276+80	

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1340+16	1334+88	528	40.2	$890.00	S1
↓	1334+88	1329+60	528	48.9	$716.45	↓
↓	1329+60	1324+32	528	43.9	$890.00	↓
↓	1324+32	1319+04	528	48.0	$756.50	↓
↓	1319+04	1313+76	528	52.6	$551.80	↓
↓	1313+76	1308+48	528	50.4	$649.70	↓
↓	1308+48	1303+20	528	47.1	$796.55	↓
↓	1303+20	1297+92	528	53.4	$516.20	↓
↓	1297+92	1292+64	528	55.6	$418.30	↓
↓	1292+64	1287+36	528	56.3	$387.15	↓
↓	1287+36	1282+08	528	48.1	$752.05	↓
↓	1282+08	1276+80	528	60.5	$200.25	↓
S2	1340+16	1334+88	528	36.5	$890.00	S2
↓	1334+88	1329+60	528	44.7	$890.00	↓
↓	1329+60	1324+32	528	38.5	$890.00	↓
↓	1324+32	1319+04	528	40.0	$890.00	↓
↓	1319+04	1313+76	528	49.7	$680.85	↓
↓	1313+76	1308+48	528	47.5	$778.75	↓
↓	1308+48	1303+20	528	45.5	$867.75	↓
↓	1303+20	1297+92	528	47.4	$783.20	↓
↓	1297+92	1292+64	528	51.1	$618.55	↓
↓	1292+64	1287+36	528	50.5	$645.25	↓
↓	1287+36	1282+08	528	40.6	$890.00	↓
↓	1282+08	1276+80	528	46.5	$823.25	↓

Total Pay Adjustment	$17,172.55
Areas of Localized Roughness Deduction	$0.00
Total Pay Adjustment + Areas of Localized Roughness Deduction	$17,172.55

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190628-TH-60-D-1-1403+45-1340+16 190628-TH-60-D-2-1403+45-1340+16
Date Measured	28-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	**Section 1**	**Section 2**	**Section 3**
Beginning	1403+45	1403+45	
End	1340+09	1340+09	

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	**End Station**	**Segment Length (ft)**	**Final Smoothness (in/mi)**	**Segment Pay Adjustment**	
S1	1403+45	1398+17	528	47.6	$774.30	S1
↓	1398+17	1392+89	528	43.4	$890.00	↓
↓	1392+89	1387+61	528	44.3	$890.00	↓
↓	1387+61	1382+33	528	45.0	$890.00	↓
↓	1382+33	1377+05	528	42.7	$890.00	↓
↓	1377+05	1371+77	528	41.3	$890.00	↓
↓	1371+77	1366+49	528	46.1	$841.05	↓
↓	1366+49	1361+21	528	37.9	$890.00	↓
↓	1361+21	1355+93	528	30.8	$890.00	↓
↓	1355+93	1350+65	528	34.9	$890.00	↓
↓	1350+65	1345+37	528	37.5	$890.00	↓
↓	1345+37	1340+09	528	44.8	$890.00	↓
S2	1403+45	1398+17	528	51.6	$596.30	S2
↓	1398+17	1392+89	528	44.7	$890.00	↓
↓	1392+89	1387+61	528	49.9	$671.95	↓
↓	1387+61	1382+33	528	44.7	$890.00	↓
↓	1382+33	1377+05	528	42.6	$890.00	↓
↓	1377+05	1371+77	528	44.1	$890.00	↓
↓	1371+77	1366+49	528	50.3	$654.15	↓
↓	1366+49	1361+21	528	36.3	$890.00	↓
↓	1361+21	1355+93	528	31.1	$890.00	↓
↓	1355+93	1350+65	528	38.2	$890.00	↓
↓	1350+65	1345+37	528	39.8	$890.00	↓
↓	1345+37	1340+09	528	43.2	$890.00	↓

Total Pay Adjustment	**$20,447.75**
Areas of Localized Roughness Deduction	**$0.00**
Total Pay Adjustment + Areas of Localized Roughness Deduction	**$20,447.75**

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190910-TH-60-D-1-1435+00-1429+72 After CW 190910-TH-60-D-1-1408+60-1403+41 After CW 190910-TH-60-D-2-1408+60-1403+41 After CW
Date Measured	10-Sep-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	AFTER GRINDING

Stationing	Section 1	Section 2	Section 3
Beginning	1435+00	1408+60	1408+60
End	1429+72	1403+41	1403+41

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1435+00	1429+72	528	58.3	$298.15	S1
S2	1408+60	1403+41	519	55.2	$428.67	S2
S3	1408+60	1403+41	519	64.6	$17.50	S3

Total Pay Adjustment	$744.31
Areas of Localized Roughness Deduction	$0.00
Total Pay Adjustment + Areas of Localized Roughness Deduction	$744.31

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190810-TH-60-D-1-1429+72-1408+60 190810-TH-60-D-2-1435+00-1408+60
Date Measured	10-Aug-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	ORIGINAL FILE, CW TENTHS EXLUDED

Stationing	Section 1	Section 2	Section 3
Beginning	1429+72	1435+00	
End	1408+60	1408+60	

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1429+72	1424+44	528	47.1	$796.55	S1
↓	1424+44	1419+16	528	57.0	$356.00	↓
↓	1419+16	1413+88	528	58.2	$302.60	↓
↓	1413+88	1408+60	528	51.6	$596.30	↓
S2	1435+00	1429+72	528	69.3	-$191.35	S2
↓	1429+72	1424+44	528	43.9	$890.00	↓
↓	1424+44	1419+16	528	51.8	$587.40	↓
↓	1419+16	1413+88	528	56.8	$364.90	↓
↓	1413+88	1408+60	528	52.6	$551.80	↓

Total Pay Adjustment	$4,254.20
Areas of Localized Roughness Deduction	$0.00
Total Pay Adjustment + Areas of Localized Roughness Deduction	$4,254.20

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190629-TH-60-D-1-1487+78-1435+00 190629-TH-60-D-2-1487+78-1435+00
Date Measured	29-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	PPF FILE LABLED WRONG SHOULD BE 1487+78 NOT 1497+78

Stationing	Section 1	Section 2	Section 3
Beginning	1487+78	1487+78	
End	1434+98	1434+98	

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1487+78	1482+50	528	40.1	$890.00	S1
↓	1482+50	1477+22	528	42.8	$890.00	↓
↓	1477+22	1471+94	528	50.2	$658.60	↓
↓	1471+94	1466+66	528	51.1	$618.55	↓
↓	1466+66	1461+38	528	48.7	$725.35	↓
↓	1461+38	1456+10	528	46.2	$836.60	↓
↓	1456+10	1450+82	528	47.3	$787.65	↓
↓	1450+82	1445+54	528	43.8	$890.00	↓
↓	1445+54	1440+26	528	42.0	$890.00	↓
↓	1440+26	1434+98	528	51.0	$623.00	↓
S2	1487+78	1482+50	528	39.9	$890.00	S2
↓	1482+50	1477+22	528	39.5	$890.00	↓
↓	1477+22	1471+94	528	46.2	$836.60	↓
↓	1471+94	1466+66	528	40.2	$890.00	↓
↓	1466+66	1461+38	528	39.5	$890.00	↓
↓	1461+38	1456+10	528	40.3	$890.00	↓
↓	1456+10	1450+82	528	39.1	$890.00	↓
↓	1450+82	1445+54	528	41.5	$890.00	↓
↓	1445+54	1440+26	528	47.5	$778.75	↓
↓	1440+26	1434+98	528	57.3	$342.65	↓

Total Pay Adjustment	$15,997.75
Areas of Localized Roughness Deduction	$0.00
Total Pay Adjustment + Areas of Localized Roughness Deduction	$15,997.75

Data Entered By	Jamie Hulett	Data Checked By	
Signature		Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190619-TH-60-D-1-1572+48-1521+09 190719-TH-60-D-1-1530+24-1524+96 190619-TH-60-D-2-1572+48-1521+01
Date Measured	19-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	AFTER GRINDING EQUATION IN THE RUN

Stationing	**Section 1**	**Section 2**	**Section 3**
Beginning	1572+48	1530+24	1572+48
End	1530+24	1524+96	1524+96

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1572+48	1567+20	528	40.5	$890.00	S1
↓	1567+20	1561+92	528	51.2	$614.10	↓
↓	1561+92	1556+64	528	48.0	$756.50	↓
↓	1556+64	1551+36	528	42.9	$890.00	↓
↓	1551+36	1546+08	528	48.5	$734.25	↓
↓	1546+08	1540+80	528	42.5	$890.00	↓
↓	1540+80	1535+52	528	48.7	$725.35	↓
↓	1535+52	1530+24	528	49.7	$680.85	↓
S2	1530+24	1524+96	528	52.5	$556.25	S2
S3	1572+48	1567+20	528	41.9	$890.00	S3
↓	1567+20	1561+92	528	49.4	$694.20	↓
↓	1561+92	1556+64	528	46.7	$814.35	↓
↓	1556+64	1551+36	528	39.0	$890.00	↓
↓	1551+36	1546+08	528	42.9	$890.00	↓
↓	1546+08	1540+80	528	38.5	$890.00	↓
↓	1540+80	1535+52	528	49.1	$707.55	↓
↓	1535+52	1530+24	528	49.1	$707.55	↓
↓	1530+24	1524+96	528	54.2	$480.60	↓

Total Pay Adjustment	**$13,701.55**
Areas of Localized Roughness Deduction	**$0.00**
Total Pay Adjustment + Areas of Localized Roughness Deduction	**$13,701.55**

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190617-TH-60-D-1-1635+80-1572+48
Date Measured	17-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 2

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	Section 1	Section 2	Section 3
Beginning	1635+80		
End	1572+44		

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1635+80	1630+52	528	39.6	$890.00	S1
↓	1630+52	1625+24	528	44.2	$890.00	↓
↓	1625+24	1619+96	528	44.7	$890.00	↓
↓	1619+96	1614+68	528	42.2	$890.00	↓
↓	1614+68	1609+40	528	41.0	$890.00	↓
↓	1609+40	1604+12	528	39.0	$890.00	↓
↓	1604+12	1598+84	528	44.9	$890.00	↓
↓	1598+84	1593+56	528	44.4	$890.00	↓
↓	1593+56	1588+28	528	47.4	$783.20	↓
↓	1588+28	1583+00	528	40.7	$890.00	↓
↓	1583+00	1577+72	528	40.7	$890.00	↓
↓	1577+72	1572+44	528	40.4	$890.00	↓

Total Pay Adjustment	$10,573.20
Areas of Localized Roughness Deduction	$0.00
Total Pay Adjustment + Areas of Localized Roughness Deduction	$10,573.20

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190617-TH-60-D-1-1635+80-1625+24 190626-TH-60-D-1-1625+24-1619+96 190617-TH-60-D-1-1619+96-
Date Measured	17-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	Section 1	Section 2	Section 3
Beginning	1635+80	1625+24	1619+96
End	1625+24	1619+96	1572+44

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1635+80	1630+52	528	35.9	$890.00	S1
↓	1630+52	1625+24	528	46.4	$827.70	↓
S2	1625+24	1619+96	528	40.9	$890.00	S2
S3	1619+96	1614+68	528	51.6	$596.30	S3
↓	1614+68	1609+40	528	38.3	$890.00	↓
↓	1609+40	1604+12	528	39.0	$890.00	↓
↓	1604+12	1598+84	528	36.8	$890.00	↓
↓	1598+84	1593+56	528	41.9	$890.00	↓
↓	1593+56	1588+28	528	46.0	$845.50	↓
↓	1588+28	1583+00	528	39.0	$890.00	↓
↓	1583+00	1577+72	528	35.5	$890.00	↓
↓	1577+72	1572+44	528	39.9	$890.00	↓

Total Pay Adjustment	$10,279.50
Areas of Localized Roughness Deduction	$0.00
Total Pay Adjustment + Areas of Localized Roughness Deduction	$10,279.50

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

DOT

File Name(s)	190626-TH-60-D-1-1646+36-1635+80 190626-TH-60-D-2-1646+36-1635+80
Date Measured	26-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	Section 1	Section 2	Section 3
Beginning	1683+26	1683+26	
End	1646+30	1646+30	

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1683+26	1677+98	528	52.1	$574.05	S1
↓	1677+98	1672+70	528	47.3	$787.65	↓
↓	1672+70	1667+42	528	48.2	$747.60	↓
↓	1667+42	1662+14	528	44.9	$890.00	↓
↓	1662+14	1656+86	528	41.1	$890.00	↓
↓	1656+86	1651+58	528	32.0	$890.00	↓
↓	1651+58	1646+30	528	43.5	$890.00	↓
S2	1683+26	1677+98	528	50.6	$640.80	S2
↓	1677+98	1672+70	528	50.7	$636.35	↓
↓	1672+70	1667+42	528	51.0	$623.00	↓
↓	1667+42	1662+14	528	42.4	$890.00	↓
↓	1662+14	1656+86	528	41.6	$890.00	↓
↓	1656+86	1651+58	528	35.0	$890.00	↓
↓	1651+58	1646+30	528	42.1	$890.00	↓

Total Pay Adjustment	**$11,129.45**
Areas of Localized Roughness Deduction	**$0.00**
Total Pay Adjustment + Areas of Localized Roughness Deduction	**$11,129.45**

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190614-TH-60-D-1-1683+26-1646+36 190614-TH-60-D-2-1683+26-1646+36
Date Measured	14-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	Section 1	Section 2	Section 3
Beginning	1683+26	1683+26	
End	1646+30	1646+30	

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1683+26	1677+98	528	52.1	$574.05	S1
↓	1677+98	1672+70	528	47.3	$787.65	↓
↓	1672+70	1667+42	528	48.2	$747.60	↓
↓	1667+42	1662+14	528	44.9	$890.00	↓
↓	1662+14	1656+86	528	41.1	$890.00	↓
↓	1656+86	1651+58	528	32.0	$890.00	↓
↓	1651+58	1646+30	528	43.5	$890.00	↓
S2	1683+26	1677+98	528	50.1	$663.05	S2
↓	1677+98	1672+70	528	50.7	$636.35	↓
↓	1672+70	1667+42	528	51.0	$623.00	↓
↓	1667+42	1662+14	528	42.4	$890.00	↓
↓	1662+14	1656+86	528	41.6	$890.00	↓
↓	1656+86	1651+58	528	35.0	$890.00	↓
↓	1651+58	1646+30	528	42.1	$890.00	↓

Total Pay Adjustment	$11,151.70
Areas of Localized Roughness Deduction	$0.00
Total Pay Adjustment + Areas of Localized Roughness Deduction	$11,151.70

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190614-TH-60-D-1-1708+61-1686+18 190614-TH-60-D-2-1708+61-1686+18
Date Measured	14-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	Section 1	Section 2	Section 3
Beginning	1708+61	1708+61	
End	1686+15	1686+15	

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1708+61	1703+33	528	52.1	$574.05	S1
↓	1703+33	1698+05	528	47.3	$787.65	↓
↓	1698+05	1692+77	528	48.2	$747.60	↓
↓	1692+77	1687+49	528	44.9	$890.00	↓
↓	1687+49	1686+15	134	41.1	$225.87	↓
S2	1708+61	1703+33	528	34.8	$890.00	S2
↓	1703+33	1698+05	528	40.5	$890.00	↓
↓	1698+05	1692+77	528	41.1	$890.00	↓
↓	1692+77	1687+49	528	48.5	$734.25	↓
↓	1687+49	1686+15	134	53.3	$132.13	↓

Total Pay Adjustment	**$6,761.56**
Areas of Localized Roughness Deduction	**$0.00**
Total Pay Adjustment + Areas of Localized Roughness Deduction	**$6,761.56**

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190910-TH-60-D-1-1713+89-1708+61 After CW 190910-TH-60-D-2-1713+89-1708+61 After CW
Date Measured	10-Sep-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	AFTER GRINDING

Stationing	Section 1	Section 2	Section 3
Beginning	1713+89	1713+89	
End	1708+61	1708+61	

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1713+89	1708+61	528	45.5	$867.75	S1
S2	1713+89	1708+61	528	48.5	$734.25	S2

Total Pay Adjustment	$1,602.00
Areas of Localized Roughness Deduction	$0.00
Total Pay Adjustment + Areas of Localized Roughness Deduction	$1,602.00

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190614-TH-60-D-1-1745+20-1713+89 190614-TH-60-D-2-1745+20-1713+89
Date Measured	14-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	Section 1	Section 2	Section 3
Beginning	1745+20	1745+20	
End	1713+52	1713+52	

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1745+20	1739+92	528	43.1	$890.00	S1
↓	1739+92	1734+64	528	51.2	$614.10	↓
↓	1734+64	1729+36	528	49.0	$712.00	↓
↓	1729+36	1724+08	528	47.4	$783.20	↓
↓	1724+08	1718+80	528	42.6	$890.00	↓
↓	1718+80	1713+52	528	35.9	$890.00	↓
S2	1745+20	1739+92	528	49.5	$689.75	S2
↓	1739+92	1734+64	528	50.1	$663.05	↓
↓	1734+64	1729+36	528	52.5	$556.25	↓
↓	1729+36	1724+08	528	41.3	$890.00	↓
↓	1724+08	1718+80	528	38.5	$890.00	↓
↓	1718+80	1713+52	528	36.4	$890.00	↓

Total Pay Adjustment	**$9,358.35**
Areas of Localized Roughness Deduction	**$0.00**
Total Pay Adjustment + Areas of Localized Roughness Deduction	**$9,358.35**

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190612-TH-60-D-1-1803+20-1745+20 190612-TH-60-D-2-1803+20-1745+20
Date Measured	12-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	**Section 1**	**Section 2**	**Section 3**
Beginning	1803+20	1803+20	
End	1745+12	1745+12	

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	12
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1803+20	1797+92	528	39.7	$890.00	S1
↓	1797+92	1792+64	528	34.9	$890.00	↓
↓	1792+64	1787+36	528	32.4	$890.00	↓
↓	1787+36	1782+08	528	40.6	$890.00	↓
↓	1782+08	1776+80	528	40.1	$890.00	↓
↓	1776+80	1771+52	528	43.6	$890.00	↓
↓	1771+52	1766+24	528	37.5	$890.00	↓
↓	1766+24	1760+96	528	36.4	$890.00	↓
↓	1760+96	1755+68	528	40.7	$890.00	↓
↓	1755+68	1750+40	528	40.6	$890.00	↓
↓	1750+40	1745+12	528	37.6	$890.00	↓
S2	1803+20	1797+92	528	46.6	$818.80	S2
↓	1797+92	1792+64	528	35.7	$890.00	↓
↓	1792+64	1787+36	528	35.5	$890.00	↓
↓	1787+36	1782+08	528	42.3	$890.00	↓
↓	1782+08	1776+80	528	41.0	$890.00	↓
↓	1776+80	1771+52	528	41.6	$890.00	↓
↓	1771+52	1766+24	528	36.0	$890.00	↓
↓	1766+24	1760+96	528	42.9	$890.00	↓
↓	1760+96	1755+68	528	38.5	$890.00	↓
↓	1755+68	1750+40	528	41.2	$890.00	↓
↓	1750+40	1745+12	528	36.8	$890.00	↓

Total Pay Adjustment	**$19,508.80**
Areas of Localized Roughness Deduction	**-$300.00**
Total Pay Adjustment + Areas of Localized Roughness Deduction	**$19,208.80**

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190610TH-60-D-1-1855+86-1803+20
Date Measured	10-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	Section 1	Section 2	Section 3
Beginning	1855+86		
End	1803+06		

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	0

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1855+86	1850+58	528	41.8	$890.00	S1
↓	1850+58	1845+30	528	30.4	$890.00	↓
↓	1845+30	1840+02	528	31.0	$890.00	↓
↓	1840+02	1834+74	528	28.0	$890.00	↓
↓	1834+74	1829+46	528	38.0	$890.00	↓
↓	1829+46	1824+18	528	36.6	$890.00	↓
↓	1824+18	1818+90	528	46.7	$814.35	↓
↓	1818+90	1813+62	528	36.7	$890.00	↓
↓	1813+62	1808+34	528	32.9	$890.00	↓
↓	1808+34	1803+06	528	31.1	$890.00	↓

Total Pay Adjustment	$8,824.35
Areas of Localized Roughness Deduction	$0.00
Total Pay Adjustment + Areas of Localized Roughness Deduction	$8,824.35

Data Entered By	Jamie Hulett	Data Checked By	
Signature		Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190610-TH-60-D-2-1855+86-1834+74 190626-TH-60-D-2-1834+74-1829+46 190610-TH-60-D-2-1829+46-
Date Measured	10-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	Section 1	Section 2	Section 3
Beginning	1855+86	1834+74	1829+46
End	1834+74	1829+46	1803+06

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	0
ALR ≥ 225.0 (linear ft)	13

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1855+86	1850+58	528	46.9	$805.45	S1
↓	1850+58	1845+30	528	38.1	$890.00	↓
↓	1845+30	1840+02	528	36.2	$890.00	↓
↓	1840+02	1834+74	528	32.7	$890.00	↓
S2	1834+74	1829+46	528	49.4	$694.20	S2
S3	1829+46	1824+18	528	35.2	$890.00	S3
↓	1824+18	1818+90	528	42.9	$890.00	↓
↓	1818+90	1813+62	528	35.8	$890.00	↓
↓	1813+62	1808+34	528	34.8	$890.00	↓
↓	1808+34	1803+06	528	34.9	$890.00	↓

Total Pay Adjustment	$8,619.65
Areas of Localized Roughness Deduction	Corrective Work Required on ALR ≥ 225.0
Total Pay Adjustment + Areas of Localized Roughness Deduction	

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Data Checked By	
Signature	

1-Mar-2019

2019 Concrete Profile Summary

File Name(s)	190607-TH-60-D-1-1908+66-1855+86 190607-TH-60-D-2-1908+66-1855+86
Date Measured	7-Jun-2019
S.P./S.A.P.	
T.H./CSAH	
Lane Description	Mainline: lane 1

Smoothness Equation	PCC-A
Posted Vehicle Speed	> 45 mph
Certified Inertial Profiler	Yes
Certified Operator	Yes
Additional Information	

Stationing	Section 1	Section 2	Section 3
Beginning	1908+66	1908+66	
End	1855+86	1855+86	

Areas of Localized Roughness (ALR)	
175.0 ≤ ALR < 225.0 (linear ft)	19
ALR ≥ 225.0 (linear ft)	

	Beginning Station	End Station	Segment Length (ft)	Final Smoothness (in/mi)	Segment Pay Adjustment	
S1	1908+66	1903+38	528	68.2	-$142.40	S1
↓	1903+38	1898+10	528	47.4	$783.20	↓
↓	1898+10	1892+82	528	43.7	$890.00	↓
↓	1892+82	1887+54	528	31.3	$890.00	↓
↓	1887+54	1882+26	528	33.3	$890.00	↓
↓	1882+26	1876+98	528	32.1	$890.00	↓
↓	1876+98	1871+70	528	34.8	$890.00	↓
↓	1871+70	1866+42	528	28.8	$890.00	↓
↓	1866+42	1861+14	528	38.2	$890.00	↓
↓	1861+14	1855+86	528	42.1	$890.00	↓
S2	1908+66	1903+38	528	62.6	$106.80	S2
↓	1903+38	1898+10	528	45.7	$858.85	↓
↓	1898+10	1892+82	528	44.2	$890.00	↓
↓	1892+82	1887+54	528	35.7	$890.00	↓
↓	1887+54	1882+26	528	44.6	$890.00	↓
↓	1882+26	1876+98	528	35.1	$890.00	↓
↓	1876+98	1871+70	528	43.4	$890.00	↓
↓	1871+70	1866+42	528	40.0	$890.00	↓
↓	1866+42	1861+14	528	47.2	$792.10	↓
↓	1861+14	1855+86	528	44.7	$890.00	↓

Total Pay Adjustment	$15,748.55
Areas of Localized Roughness Deduction	
Total Pay Adjustment + Areas of Localized Roughness Deduction	

Data Entered By	Jamie Hulett
Signature	

Data Checked By	
Signature	

APPENDIX D
Phoenix Test (Unpublished Paper with Procedure)

Determining the Water to Cement Ratio of Fresh Concrete by Evaporation

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a Department of Civil and Environmental Engineering, Oklahoma State University, Stillwater, OK 74078, USA

Abstract

The water-cement ratio (w/cm) is one of the most influential parameters to determine the quality of concrete. A new test method has been developed that uses external heat to evaporate the water from the concrete before it has hardened. Data are presented for 258 mixtures with 23 aggregates, 9 cements, 5 supplementary cementitious materials, and 15 different admixtures. For the laboratory testing, the average measured w/cm is within 0.01 from the batched w/cm with a coefficient of variation (COV) of 3.2%. A subset of these mixes was evaluated with the AASHTO T 318 microwave test and the measured w/cm is 0.05 higher than the expected value and the COV is almost three times higher (8.9%). Field data is also presented from 27 mixtures and the measured w/cm shows good agreement with the batched values. The method, calculation, and practical applications of this new test method are presented.

Highlights

- Development of w/cm test with external heat for a 4x8 cylinder of fresh concrete.
- Average measured w/cm for laboratory mixtures was 0.01 from batched w/cm.

Keywords: water-cement ratio; w/cm; concrete fresh property testing; water-cement ratio test; w/cm test; Phoenix

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1. Introduction

Although modern concrete has been used for over a century, there is not a widely used test to evaluate the water to cement ratio (w/cm) within a fresh concrete mixture. The w/cm is arguably the most important parameter of concrete to determine the strength [1-3], consistency [4, 5], workability [6, 7], and durability [8, 9].

As water increases in a concrete mixture, the spacing of the cement grains will also increase. This increase in grain spacing can improve the workability for placing concrete but excessive water will decrease the performance of the concrete. If the water content is too high, hydration products will have greater difficulty filling the space between the cement grains [10]. This increase in porosity will also decrease the strength [11], stiffness [5], and increase the amount of shrinkage from drying [7]. Each increase of 0.01 w/cm can decrease the strength by 103 kPa [12]. Service life models predict that a 0.01 w/cm increase for typical concrete practices in Oklahoma would decrease the expected life of the structure by one year [13].

If 0.02 m^3 of water is added to a 6 m^3 mixture with 335 kg/m^3 of the binder, then this will increase the w/cm by 0.01. There are many ways for excess water to be added to concrete without being recorded. Some examples include leftover water or material from the previous mixture. Another possible error is incorrect moisture content of the aggregate in the mixture. Water can also be added inadvertently while cleaning a truck or to increase the workability at the job site.

Many attempts have been made to measure the w/cm in fresh concrete. The methods fall into the following categories: mechanical separation, absorption, electrical conductivity, and heat transfer. The mechanical separation methods utilized either a heavy liquid [14] or flocculation [15] of the concrete to separate the water from the mixture. One mechanical flocculation method could obtain the cement and water content from titrations [16]. These mechanical separation techniques require a calibration curve produced from similar materials and the equipment used is not practical for field testing. Gamma-ray backscatter and absorption [17] or ultrasonic wave transmission [18] have also been used. The gamma ray testing was not popular due to the careful training and handling required to run the equipment and the ultrasonic technique was determined to not be accurate for fresh concrete. Other methods used electrical conductivity [19, 20]. The technique uses the electrical resistivity between two probes in the fresh concrete to determine the w/cm. Many variables influence the reading of the probes including, aggregate size, temperature, admixtures, temperature, paste content, binder chemistry, and water content.

There has been some success from tests that use heating of the concrete to evaporate the water. A test that uses a microwave oven was developed [21] and ultimately became a standard [22]. A sample is weighed and placed in the microwave. After cooking for a fixed period, the sample is removed, crushed, weighed, and returned to the microwave. These steps are repeated until the sample does not change mass. The difference between the mass of the wet sample and the mass of the dry sample are used to calculate the total water. This information can be combined with the mass of cement in the mixture to determine the w/cm. The sample size in this test is only 1500 g or about one-third of a typical 4x8 cylinder. This small size makes the material inconsistent and the accuracy of the method has been suggested to be +/- 0.03 to 0.05 of the actual w/cm [23]. This variability has been criticized as too wide and therefore not useful.

For all of these reasons, these tests have not been adopted as an industry standard. Ultimately, a test is needed that is efficient, rapid, and accurate. The aim of this paper is to find a way to establish a test that meets these criteria. The presented method is known as the Phoenix and uses lab and field testing to examine 258 mixtures with 23 aggregates, 9 cements, 5 supplementary cementitious materials (SCM), and 15 different admixtures. The results are repeatable, able to be completed in the field, and show great potential.

2. Experimental Methods

2.1. Materials

A summary of laboratory mixtures investigated are shown in Table 1 and the field mixtures can be seen in

Table 2. Testing was completed for 231 laboratory mixtures and 27 field mixtures. Multiple w/cms from 0.36 to 0.48 are investigated for each aggregate source. These concrete mixtures used a type I cement that met requirements of ASTM C150 [24]. The oxide and Bogue calculations for this cement can be seen in Table 3.

Table 1. SSD Mixture Proportions.

w/cm	Cement *kg/m³*	Coarse *kg/m³*	Fine *kg/m³*	Water *kg/m³*	Coarse Aggregate Type	Fine Aggregate Type
0.36	390	1115	809	141	Granite 1	Natural Sand 1
0.39	390	1098	795	152	Granite 1	Natural Sand 1
0.42	390	1074	787	164	Granite 1	Natural Sand 1
0.45	390	1061	768	176	Granite 1	Natural Sand 1
0.48	390	1044	754	187	Granite 1	Natural Sand 1
0.42	390	1020	736	203	Granite 2	Natural Sand 1
0.45	390	1074	787	164	Granite 2	Natural Sand 1
0.48	390	1061	768	176	Granite 2	Natural Sand 1
0.39	390	1044	754	187	Granite 3	Natural Sand 1
0.45	390	1020	736	203	Granite 3	Natural Sand 1
0.39	362	1086	794	141	Granite 4	Natural Sand 1
0.45	362	1061	762	163	Granite 4	Natural Sand 1
0.42	362	1023	734	189	Limestone 1	Natural Sand 1
0.45	362	1083	826	141	Limestone 1	Natural Sand 1
0.48	362	1061	790	163	Limestone 1	Natural Sand 1
0.45	362	1017	767	189	Limestone 2	Natural Sand 2
0.36	362	1112	660	152	Limestone 3	Natural Sand 1
0.39	362	1098	647	163	Limestone 3	Natural Sand 1
0.42	362	1083	635	174	Limestone 3	Natural Sand 1
0.45	362	1062	619	189	Limestone 3	Natural Sand 1
0.48	362	1098	756	163	Limestone 3	Natural Sand 1
0.45	362	1068	830	163	Limestone 3	Manufactured Sand
0.45	362	1148	794	131	River Rock 1	Natural Sand 1
0.36	362	1133	781	141	River Rock 2	Natural Sand 1
0.45	362	1112	772	152	River Rock 2	Natural Sand 1

Table 2. Field testing materials batched.

Truck	Cement (kg/m³)	Fly Ash C (kg/m³)	Fly Ash F (kg/m³)	Slag (kg/m³)	Coarse (kg/m³)	Fine (kg/m³)	Water (kg/m³)	Coarse Aggregate Type	Fine Aggregate Type	Admixtures
1	316	78			889	897	166	Limestone 5	Natural Sand 2	AEA, WRA, Accelerator
2	338				1059	820	153	Limestone 5	Natural Sand 2	AEA, WRA
3	333				1061	815	156	Limestone 5	Natural Sand 2	AEA, WRA
4	333				1100	743	147	Limestone 6	Natural Sand 3	AEA, WRA
5	333				1113	739	145	Limestone 6	Natural Sand 3	AEA, WRA, Retarder
6	334				1102	749	145	Limestone 6	Natural Sand 3	AEA, WRA, Retarder
7	333				1095	745	140	Limestone 6	Natural Sand 3	AEA, WRA, Retarder
8	333				1095	745	140	Limestone 6	Natural Sand 3	AEA, WRA, Retarder
9	331				1086	742	142	Limestone 6	Natural Sand 3	AEA, WRA, Retarder
10	267	66			1114	788	131	Limestone 2	Natural Sand 2	AEA, WRA, Retarder
11	269	66			1159	784	131	Limestone 2	Natural Sand 2	AEA, WRA, Retarder
12	266	66			1140	784	131	Limestone 2	Natural Sand 2	AEA, WRA, Retarder
13	332				1109	787	147	Limestone 6	Natural Sand 3	AEA, WRA, Retarder
14	332				1106	74	145	Limestone 6	Natural Sand 3	AEA, WRA, Retarder
15	333				1100	743	146	Limestone 6	Natural Sand 3	AEA, WRA, Retarder
16	333				1113	739	142	Limestone 6	Natural Sand 3	AEA, WRA, Retarder
17	334				1102	749	140	Limestone 6	Natural Sand 3	AEA, WRA, Retarder
18	333				1102	749	143	Limestone 6	Natural Sand 3	AEA, WRA, Retarder
19	235		53	73	1056	737	130	Limestone 11	Natural Sand 4	AEA, HRWRA
20	230	59			1042	841	138	Limestone 8	Natural Sand 4	HRWRA
21	336				1038	769	161	Limestone 8	Natural Sand 4	AEA
22	235		55	73	1055	736	135	Limestone 11	Natural Sand 4	AEA, HRWRA
23	333				1054	785	147	Limestone 8	Natural Sand 4	AEA, HRWRA, accelerator
24	354	59			507	1203	208	Limestone 7	Natural Sand 4	-
25	226	60			991	878	141	Limestone 8	Natural Sand 4	AEA, HRWRA
26	283	72			1001	821	149	Limestone 9	Natural Sand 4	AEA, HRWRA
27	178			180	878	915	155	Limestone 10	Natural Sand 5	AEA, HRWRA

Table 3. Type I cement oxide analysis.

Oxide (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	TiO_2	P_2O_5	C_3S	C_2S	C_3A	C_4AF
Cement	21.1	4.7	2.6	62.1	2.4	3.2	0.2	0.3	-	-	57	18	8.2	7.8

Table 4. Tested aggregate summary.

Aggregate Type	Size	Specific Gravity	Absorption (%)	State
Granite	Coarse	2.75	0.46	OK
Quartzite-Granite	Coarse	2.75	0.51	GA
Granite	Coarse	2.59	1.06	MN
Quartzite-Granite	Coarse	2.66	0.66	MN
Dolomitic Limestone	Coarse	2.42	4.69	IA
Limestone	Coarse	2.67	0.70	OK
Limestone	Coarse	2.67	0.64	OK
Limestone	Coarse	2.85	0.76	OK
Limestone	Coarse	2.70	0.68	OK
Limestone	Coarse	2.76	0.72	OK
Limestone	Coarse	2.62	0.40	KS
Limestone	Coarse	2.63	1.70	KS
Limestone	Coarse	2.67	0.30	KS
Limestone	Coarse	2.67	1.80	KS
Limestone	Coarse	2.69	0.70	KS
Glacial Till	Coarse	2.67	1.52	MN
Glacial Till	Coarse	2.68	0.81	MN
Manufactured Sand	Fine	2.76	1.05	OK
Natural Sand	Fine	2.62	0.64	OK
Natural Sand	Fine	2.61	0.76	OK
Natural Sand	Fine	2.64	0.34	OK
Natural Sand	Fine	2.62	0.40	KS
Natural Sand	Fine	2.62	0.20	KS

Multiple coarse and fine aggregate sources were used with a specific gravity between 2.42 and 2.85 and absorption between 0.20 and 4.69%. Seventeen coarse aggregates that were mainly granite, limestone, and river rock were used. Six fine aggregates that were either natural or manufactured sand were also investigated. A summary of the aggregate investigated is in Table 4. All aggregate used met ASTM C33 [25] specification and are used in commercial concrete mixtures.

2.2. Concrete Mixture procedure and testing

Since the focus is to obtain an accurate w/cm, it was important to very accurately measure and account for the moisture in the aggregates. To do this, a standard laboratory method was used to prepare the samples. It has been described previously but is repeated here for the convenience of the reader [26].

"The aggregates for each mixture were collected from outside stockpiles and brought into a temperature-controlled room at 22°C for at least 24 hours before mixing. Aggregates were placed in a mixing drum, spun for a period of time, and a representative sample was taken to determine the moisture content to apply a moisture correction to the mixture.

At the time of mixing, all aggregates were loaded into the mixer along with approximately two-thirds of the mixing water. This combination was mixed for three minutes to allow the aggregate surface to saturate and ensure the aggregates were evenly distributed. Next, the cement, fly ash, and the remaining water was added and mixed for three minutes. The resulting mixture rested for three minutes while the sides of the mixing drum were scraped. After the rest period, the desired admixtures were added and the mixer was turned on and mixed for two minutes."

The fresh properties were measured and samples were created to complete the w/cm test. For the test, two samples were investigated simultaneously by the same operator for each mixture. Samples obtained for the microwave oven test were run in accordance with AASHTO T 318.

Some mixtures were hand mixed in small batches below 0.1 cubic feet. The aggregate used for the small mixtures was moisture corrected in the same way as the larger mixtures. To achieve accurate batch water, water was added to a dry bowl and weighed. All the materials were then added to the bowl with water and each mixed until thoroughly blended in the following order, admixture (if used), cement, fine aggregate, and coarse aggregate. This material was then sampled for the testing. Two samples were investigated simultaneously.

Field testing was completed for twenty-seven concrete mixtures from four concrete plants in Oklahoma and Kansas. The majority of the samples were taken on job sites that were constructing a bridge or pavement. The remaining samples were taken from ready-mix plants before the concrete was transported to the job-site. The field testing batched values can be seen in the appendix in Table 10.

2.3. Sample Size Selection

It was important to determine a satisfactory sample volume to use within the test. If the sample size investigated is too small, then the test will not give representative results. However, if the sample size used is too large then the increased volume in the test will increase the time required to complete the test.

To investigate this concrete mixture with 0.45 w/cm were sampled with a variety of volumes. The unit weight and the average measured w/cm was found. The method and calculation for the measured w/cm are presented in future sections of this paper. The results are presented in Table 5. According to Cement and Concrete Reference Laboratory [27], the single-operator standard deviation between measuring UW of concrete is 14.4 kg/m^3. This precision and bias are based on 7079 cm^3 volume. If this precision could be obtained with a smaller volume, then that would represent a satisfactory volume for the proposed test. Based on this testing 1648 cm^3 was used as it showed a satisfactory density and was able to accurately measure the w/cm of the concrete with the proposed test with a standard deviation that is similar for larger volumes. Again, it was important to pick a volume that was as small as possible to minimize the time in the test but also be representative of the concrete mixture. It appears that 1648 cm^3 meets this.

Table 5. Multiple size volumes tested for three, 0.45 w/cm mixtures.

Number Of Samples	Sample Volume (cm^3)	Average Density (kg/m^3)	Standard Deviation (kg/m^3)	Average Measured w/cm	Standard Deviation
9	694	2412.4	51.3	0.42	0.022
9	824	2410.8	22.4	0.44	0.021
9	1648	2428.4	4.8	0.45	0.010
9	1852	2428.4	8.0	0.45	0.010
9	5559	2418.8	11.2	0.44	0.011
9	7079	2423.6	8.0		

2.4. Test Device

The device used a heating element, an induction cooktop, pan, and a scale. The heating element temperature was ≈ 700 °C. The pan had a diameter of 23 cm and a depth of 8 cm. The 1500 Watt cooktop had a coil diameter of 20 cm. A scale with 0.01-gram accuracy and 10 kg capacity was used. The device setup can be seen in Figure 1. Conventional power was used in the laboratory and a generator was used in the field testing.

Figure 1. Overview of the testing device.

3. Test Method

The first step in the method is to gather concrete mixture information. The concrete mixture information required includes the mass of the batched materials, aggregate properties, binder specific gravities, and the total volume of the batch. For the aggregate properties, the specific gravity and absorption for each coarse and fine aggregate are needed.

The air volume in the concrete should be obtained by either using ASTM C231 [28] or based on the theoretical density calculation according to ASTM C138 [29]. The ASTM C138 method to obtain air is described in the calculations section.

Next, the mass and volume of the empty mold are recorded. This testing used a plastic 4x8 cylinder mold. Fresh concrete is sampled from the mixture in accordance with ASTM C172 [30]. All samples are prepared according to ASTM C31 [31]. The mold is filled, finished, and weighed with fresh concrete. The sample is then discharged into the pan and the mold is thoroughly emptied with a spatula. The mass of the empty mold is compared to the mass before starting the test. The mass should be within 10 g of the empty mold. This helps the operator determine that they have removed enough material from the form.

The material is placed in the pan so that it has a uniform thickness. The mass of the pan full of fresh concrete is recorded and placed into the test device. The cooktop is turned to the highest setting. The heating element is preheated for 10 min to reduce the time needed to complete the test. With these conditions, the test can be completed in 30 minutes. Figure 2 shows a mass loss for three samples over time.

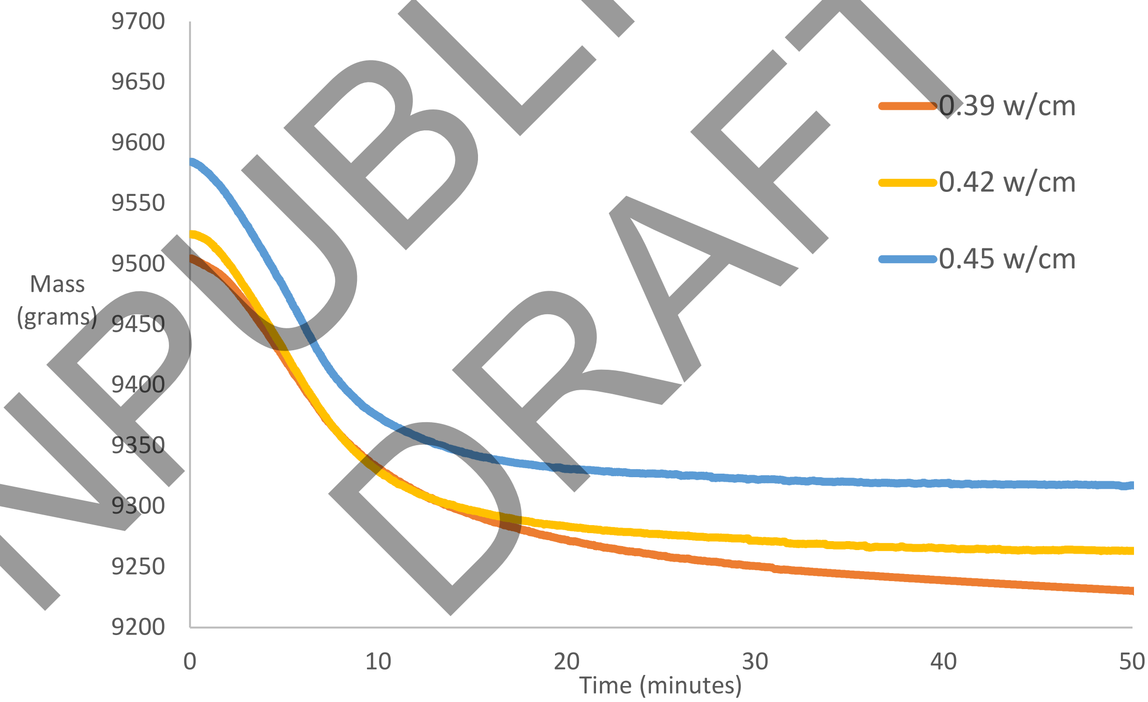

Figure 2. Mass loss of water over time.

The sample can be kept under the heating element unattended and weighed at any point after 30 minutes. To check if the concrete is finished losing water, the mass change should be < 2 g from two minutes of heat exposure. The final mass of the pan and concrete are recorded. This represents the total water evaporated, including the absorbed water in the aggregates. The concrete can then be removed and the pan can be cleaned.

A summary of the required steps for the test is in Table 6. The variable names assigned in Table 6 will be utilized for the calculation for the test method.

Table 6. Variable definitions for recorded values during the test method.

Description	***Variable Name***
Binder specific gravities	SG_{Binder}
Coarse aggregate absorptions	Abs_{Coarse}
Fine aggregate absorptions	Abs_{Fine}
Coarse aggregate specific gravities	SG_{Coarse}
Fine aggregate specific gravities	SG_{Fine}
Batched binder masses	M_{Binder}
Batched coarse aggregate masses	M_{Coarse}
Batched fine aggregate masses	M_{Fine}
Batch water mass	M_{Water}
Batched volume in mixer	V_{Batch}
Batched concrete air volume (See 4.1.1)	V_{Air}
Tare mass of cylinder	Cyl_{Tare}
Volume of cylinder	V_{Cyl}
Mass of cylinder filled with concrete	Cyl_{Full}
Mass of cylinder after emptied	Cyl_{Empty}
Mass of pan with fresh concrete	P_{fresh}
Mass of pan with dried concrete	P_{Dry}

3.1. Calculations

3.1.1. Air Volume

The air volume in the concrete can be found by using the measured density of the concrete. This density can be compared with the theoretical density from the batch information to obtain the air content. This is performed according to ASTM C138 by using the mold in the proposed test method.

The density of the concrete in the cylinder can be found as:

$$\text{Cyl Density} = (Cyl_{Full} - Cyl_{Tare}) / V_{Cyl} \quad \{1\}$$

The theoretical density of the batched concrete can be found as:

Theoretical Density = Total Batched Mass / Absolute Volume Batched (Air Free)

where

Total Batched Mass = $M_{Binder} + M_{Coarse} + M_{Fine} + M_{Water}$ {2}

and

Absolute Volume Batched (Air Free) = $((M_{Binder})/(SG_{Binder} * 1000)) + ((M_{Coarse})/(SG_{Coarse} * 1000)) + ((M_{Fine})/(SGFine * 1000)) + (M_{Water}/(1000)$ {3}

For theoretical density in lb/ft^3 mass is replaced by batched weight and each 1000 is replaced by 62.4 lb/ft^3.

The theoretical air content can be found by finding the % difference between the theoretical density and the cylinder density. This can be found mathematically as follows:

Air Content (%) = ((Theoretical Density– Cyl Density) / Theoretical Density) * 100 {4}

Or using equations, Air Content (%) = (({2} - {1}) / {2}) *100

The air content from ASTM C231 can also be used instead of this procedure.

3.1.2. Batched Absolute Volume Calculation

The absolute volume of concrete batched must be calculated for the fresh w/cm determination. This can be calculated with the batched masses and air volume from the batch information. This can be expressed mathematically as:

Absolute Volume Batched = $((M_{Binder}) / (SG_{Binder} * 1000)) + ((M_{Coarse}) / (SG_{Coarse} * 1000)) + ((M_{Fine}) / (SG_{Fine} * 1000)) + (M_{Water} / 1000) + (V_{Batch} * (V_{Air} / 100))$ {5}

3.1.3. Total Water Absorbed

As shown in Figure 2, all the water from the sample is removed from the concrete including the absorbed water in the aggregates. Concrete mixtures are adjusted and batched by assuming the aggregate are saturated surface dry. Although the aggregates are not usually in this condition when placed into a mixer, it is assumed that the aggregates reach a saturated condition before the concrete has set. Because the test evaporates all of the water from the concrete mixture, the aggregate absorption must be accounted for in the calculations. To account for this the absorbed water for each aggregate in the batch is calculated as follows:

$$\text{Coarse Aggregate Absorbed Water} = (Abs_{Coarse} / 100) * M_{Coarse} \quad \{6\}$$

and

$$\text{Fine Aggregate Absorbed Water} = (Abs_{Fine} / 100) * M_{Fine} \quad \{7\}$$

where

$$\text{Total Absorbed Water} = \text{Coarse Aggregate Absorbed Water} + \text{Fine Aggregate Absorbed Water} \quad \{8\}$$

If there are multiple coarse and fine aggregate sizes in the mixture each could be added to these values using the weight and absorption value for every additional aggregate to find the total absorbed water.

3.1.4. Batched Density

The batched density is calculated by taking the sum of the batched masses divided by the absolute volume of the batch. This can be shown mathematically as:

$$\text{Batched Density} = \text{Total Batched Mass} / \text{Absolute Volume Batched} \quad \{9\}$$

Or using equations, Batched Density = {2} / {5}

3.1.5. Cylinder and Pan Calculations

As mentioned before, the mass of material remaining in the mold should be < 10 g of the empty cylinder mass. The material that was placed in the pan is used to obtain the volume in the test. This can be shown mathematically as:

$$\text{Cylinder Volume Tested} = ((\text{Cyl}_{Full} - \text{Cyl}_{Empty}) / (\text{Cyl}_{Full} - \text{Cyl}_{Tare})) * V_{\text{Cyl}} \quad \{10\}$$

Next, the water lost in the test is calculated. This is found by the difference between the mass of the pan with fresh concrete from the mass of the pan with dry concrete. This can be shown mathematically as:

$$\text{Water Loss Mass} = P_{fresh} - P_{Dry} \quad \{11\}$$

3.1.6. Binder and Absorbed water in the Cylinder

The estimated water in the concrete cylinder represents the total water in the sample including the absorbed water in the aggregates. Next, the volume of the sample tested is divided by the absolute volume batched. This can be seen mathematically as:

Volume Ratio = Cylinder Volume Tested / Absolute Volume Batched {12}

Or using equations, as Volume Ratio = {11} / {5}

The volume ratio is a scale factor to reduce the material weights from a larger volume to the volume in the mold. Multiplying the volume ratio with a batch weight will represent the weight in the mold for that material. This will be used to determine the weight of the binder in the cylinder.

The weight of the binder in the cylinder can be found by multiplying the volume ratio with M_{Binder}. This can be seen mathematically as:

Cyl_{Binder} = Volume Ratio * M_{Binder} {13}

where Volume Ratio is equation {12}.

The total absorbed water for the batch has been calculated in equation {8}. This value needs to be adjusted to the water absorbed in the sample tested. The $Cyl_{WaterAbs}$ is the volume ratio multiplied by the total absorbed water. This can be seen mathematically as follows:

$Cyl_{WaterAbs}$ = Volume Ratio * Total Absorbed Water {14}

Or using equations, $Cyl_{WaterAbs}$ = {12} * {8}

3.1.7. W/cm Calculations

At the completion of the test the water loss from the sample represents the total water in the cylinder, this includes the absorbed water in the aggregate. For the w/cm calculation, the total water minus the aggregate absorbed water represents the adjusted water. The w/cm is determined by dividing the water loss mass minus the $Cyl_{WaterAbs}$ by the Cyl_Binder mass. This can be seen mathematically as follows:

$$\text{Measured w/cm} = (\text{Water Loss Mass} - Cyl_{WaterAbs}) / (Cyl_{Binder}) \quad \{15\}$$

Or Measured w/cm = ({11} – {14}) / {13}

The measured w/cm is the result of this fresh concrete w/cm test method. The measured w/cm can be compared with the batched w/cm. The batched w/cm is calculated by dividing the M_{Water} by M_{Binder}.

4. Results and Discussion

4.1. Laboratory Results

To determine the effectiveness of the proposed test, 231 lab mixtures with nine coarse aggregates, three fine aggregates at five different w/cm were tested. Figure 3 shows the average and one standard deviation for each measured w/cm versus the batched w/cm. In this graph, all of the data is combined at each w/cm. A line of equality is included on the graph to show an exact match of the batched and the measured w/cm. The two lines on either side represent a +/- 0.02 w/cm. This shows a reasonable range for the w/cm variation. The microwave oven test result is also shown in Figure 3.

The microwave testing was done on one of the concrete mixtures that corresponded with the introduced w/cm method.

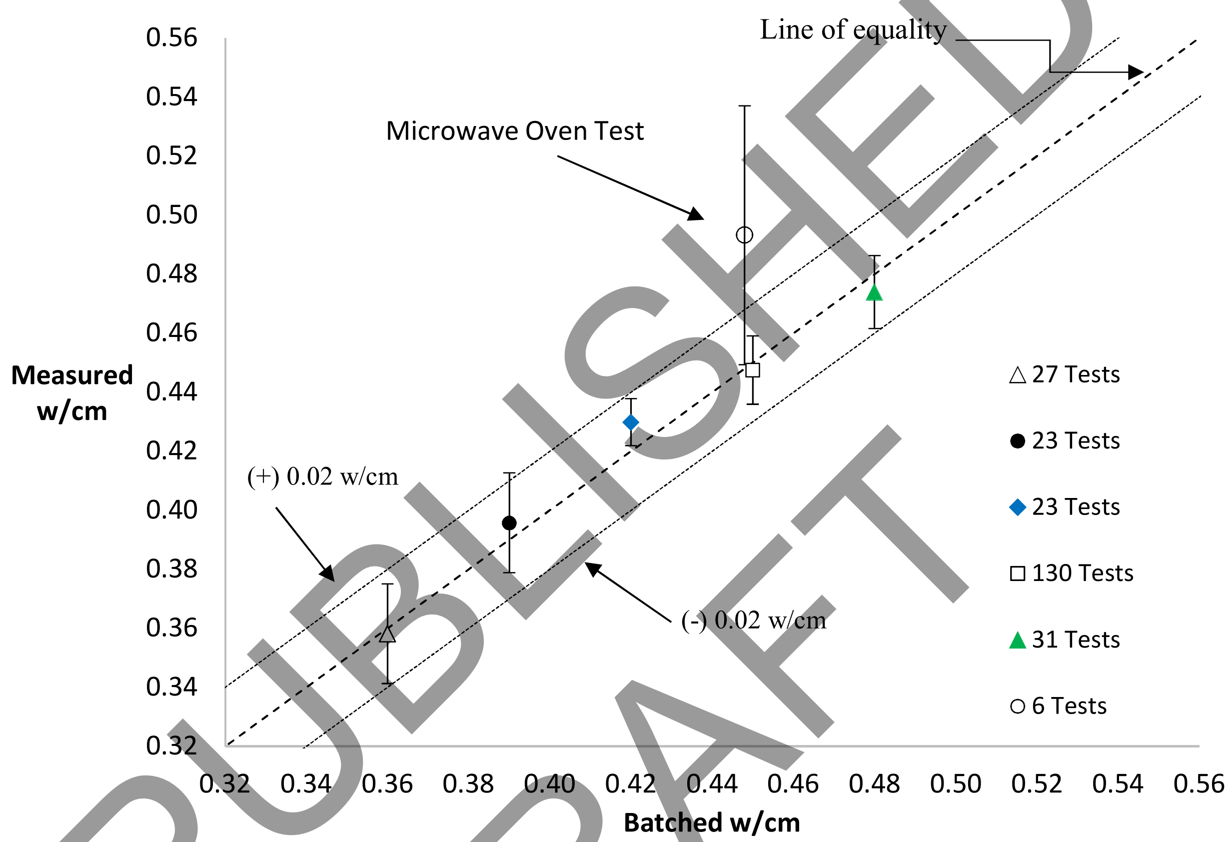

Figure 3. The average and one standard deviation of all batched and measured w/cm test results. An AASHTO T 318 microwave oven test at 0.45 w/cm has also been included for comparison. The microwave oven test data was from mixtures batched with 0.45 w/cm. The point has been slightly offset on the x-axis to better show the error compared with the 0.45 data.

The same data from Figure 3 is plotted again in Figure 4 but for the individual mixture combinations. The average and one standard deviation are shown for each data set. The data points have been offset on the X-axis to the results easier to read.

Table 7. Summary of fresh w/cm test, sorted by coarse aggregate type.

Tests	Batched w/cm	Average Measured w/cm	Difference Batched and Measured	Standard deviation	COV (%)	Coarse Aggregate Type	Fine Aggregate Type
4	0.36	0.38	-0.020	0.026	6.9	Granite 1	Natural Sand 1
13	0.36	0.36	0.000	0.013	3.5	Limestone 3	Natural Sand 1
3	0.36	0.35	0.010	0.010	2.9	Limestone 3	Natural Sand 2
4	0.36	0.34	0.020	0.012	3.6	River Rock 2	Natural Sand 1
11	0.39	0.40	-0.010	0.015	3.6	Granite 1	Natural Sand 1
4	0.39	0.38	0.010	0.024	6.4	Granite 3	Natural Sand 1
4	0.39	0.39	0.000	0.017	4.2	Granite 4	Natural Sand 1
4	0.39	0.41	-0.020	0.012	2.9	Limestone 3	Natural Sand 1
6	0.42	0.43	-0.010	0.008	2.0	Granite 1	Natural Sand 1
6	0.42	0.43	-0.010	0.008	1.9	Granite 2	Natural Sand 1
4	0.42	0.43	-0.010	0.004	0.9	Limestone 1	Natural Sand 1
7	0.42	0.43	-0.010	0.011	2.6	Limestone 3	Natural Sand 1
8	0.45	0.44	0.010	0.011	2.5	Granite 1	Natural Sand 1
2	0.45	0.43	0.020	0.012	2.7	Granite 1	Manufactured Sand
4	0.45	0.44	0.010	0.009	2.0	Granite 1	Natural Sand 2
7	0.45	0.44	0.010	0.011	2.4	Granite 2	Natural Sand 1
6	0.45	0.45	0.000	0.008	1.8	Granite 3	Natural Sand 1
4	0.45	0.46	-0.010	0.005	1.1	Granite 4	Natural Sand 1
6	0.45	0.46	-0.010	0.012	2.5	Limestone 1	Natural Sand 1
16	0.45	0.44	0.010	0.023	5.1	Limestone 2	Natural Sand 1
65	0.45	0.45	0.000	0.015	3.2	Limestone 3	Natural Sand 1
6	0.45	0.45	0.000	0.010	2.2	River Rock 1	Natural Sand 1
6	0.45	0.44	0.010	0.011	2.4	River Rock 2	Natural Sand 1
7	0.48	0.49	-0.010	0.011	2.3	Granite 1	Natural Sand 1
4	0.48	0.47	0.010	0.004	0.9	Granite 2	Natural Sand 1
10	0.48	0.47	0.010	0.015	3.1	Limestone 1	Natural Sand 1
10	0.48	0.47	0.010	0.020	4.2	Limestone 3	Natural Sand 1
9	**0.43**	**0.43**	**0.001**	**0.012**	**3.0**		

Bold indicates the average for all tests

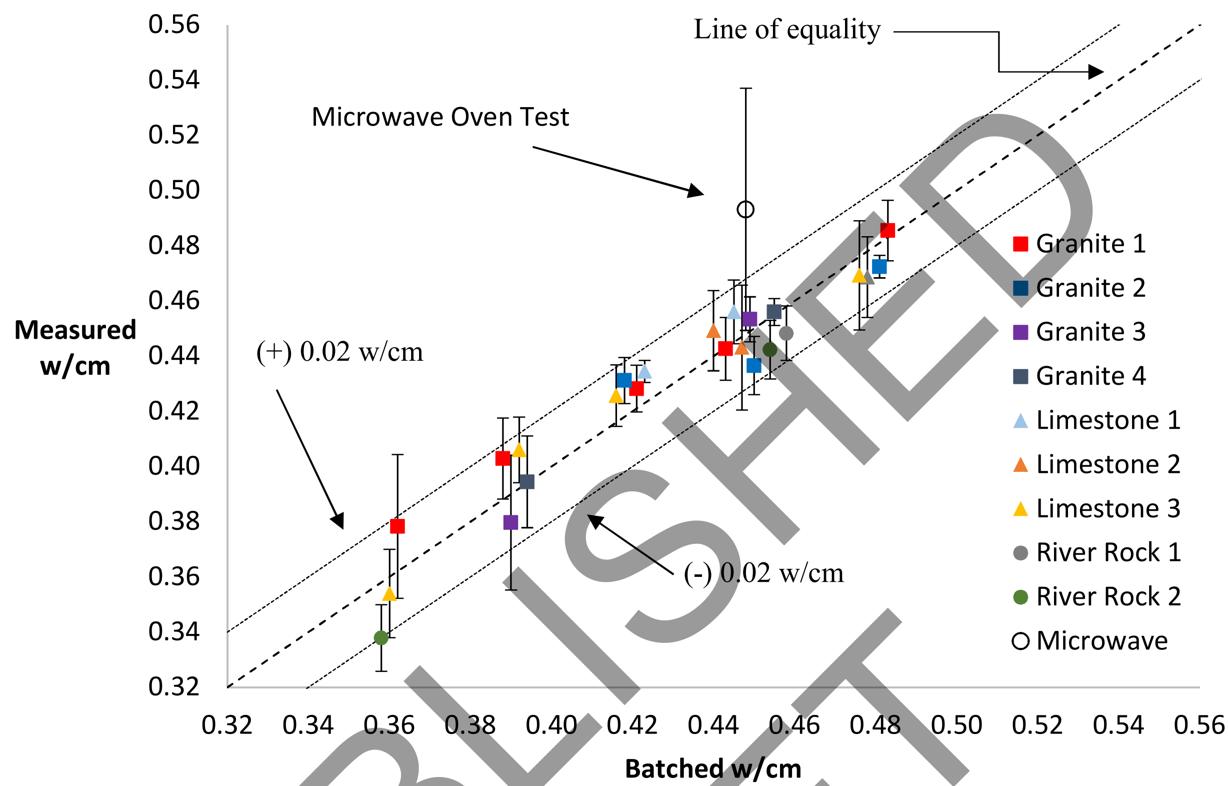

Figure 4. A comparison of the batched w/cm and measured w/cm for different mixtures. An average and one standard deviation are shown. The data at each tested w/cm have been staggered for easier viewing.

The average standard deviation for all measured w/cm for the 231 mixtures is 0.012 for w/cm between 0.36 and 0.48 for a variety of different materials. The average coefficient of variation (COV) for all the tests is 3.0%. This shows the test is precise. The results from Figure 3 show that the average results are within 0.01 from the batched w/cm and from table 6 the average difference between the batched and measured w/cm is 0.001. This shows that on average there is little difference between the batched and measured w/cm. The aggregate type and w/cm do not seem to influence the results for the materials and mixtures investigated. This is an improvement over the AASHTO T 318 test results as the difference in the measured and batched w/cm was 0.043, and the standard deviation was 0.044 w/cm with a COV of 8.9%. This variability is similar to the value reported by Hover, Bickley, and Hooton [23]. The standard deviation of the introduced w/cm test is roughly three times smaller than the standard deviation of the microwave oven test.

4.2. Field Results

Table 8 shows the results from 27 field concrete mixtures. Figure 5 compares the batched and measured w/cm for the field tests graphically.

Table 8. Field testing summary.

Truck Number	Batched w/cm	Average Measured w/cm	Difference Batched and Measured	Standard deviation*	COV (%)*
Truck 1	0.42	0.43	-0.01	0.005	1.23
Truck 2	0.45	0.45	0.00	0.009	1.99
Truck 3	0.47	0.46	0.01	0.004	0.97
Truck 4	0.44	0.44	0.00	0.013	2.99
Truck 5	0.44	0.44	0.00	0.004	1.01
Truck 6	0.43	0.47	-0.04	0.002	0.46
Truck 7	0.42	0.42	0.00	0.003	0.75
Truck 8	0.42	0.42	0.00	0.007	1.74
Truck 9	0.43	0.44	-0.01	0.003	0.61
Truck 10	0.39	0.39	0.00	0.007	1.75
Truck 11	0.39	0.39	0.00	0.002	0.55
Truck 12	0.39	0.39	0.00	0.004	1.04
Truck 13	0.44	0.46	-0.02	0.002	0.53
Truck 14	0.44	0.46	-0.02	0.016	3.38
Truck 15	0.44	0.48	-0.04	0.006	1.17
Truck 16	0.43	0.43	0.00	0.006	1.29
Truck 17	0.42	0.43	-0.01	0.008	1.78
Truck 18	0.43	0.44	-0.01	0.007	1.58
Truck 19	0.36	0.38	-0.02	0.003	0.87
Truck 20	0.48	0.49	-0.01	0.005	0.97
Truck 21	0.48	0.44	0.04	0.002	0.42
Truck 22	0.37	0.38	-0.01	0.006	1.43
Truck 23	0.44	0.42	0.02	0.005	1.18
Truck 24	0.50	0.54	-0.04	0.001	0.17
Truck 25	0.49	0.46	0.03	0.003	0.68
Truck 26	0.42	0.42	0.00	0.001	0.25
Truck 27	0.43	0.45	-0.02	0.003	0.77
	0.43	**0.44**	**0.00**	**0.010**	**1.17**

Bold values indicate average for all tests

*Two samples tested per truck

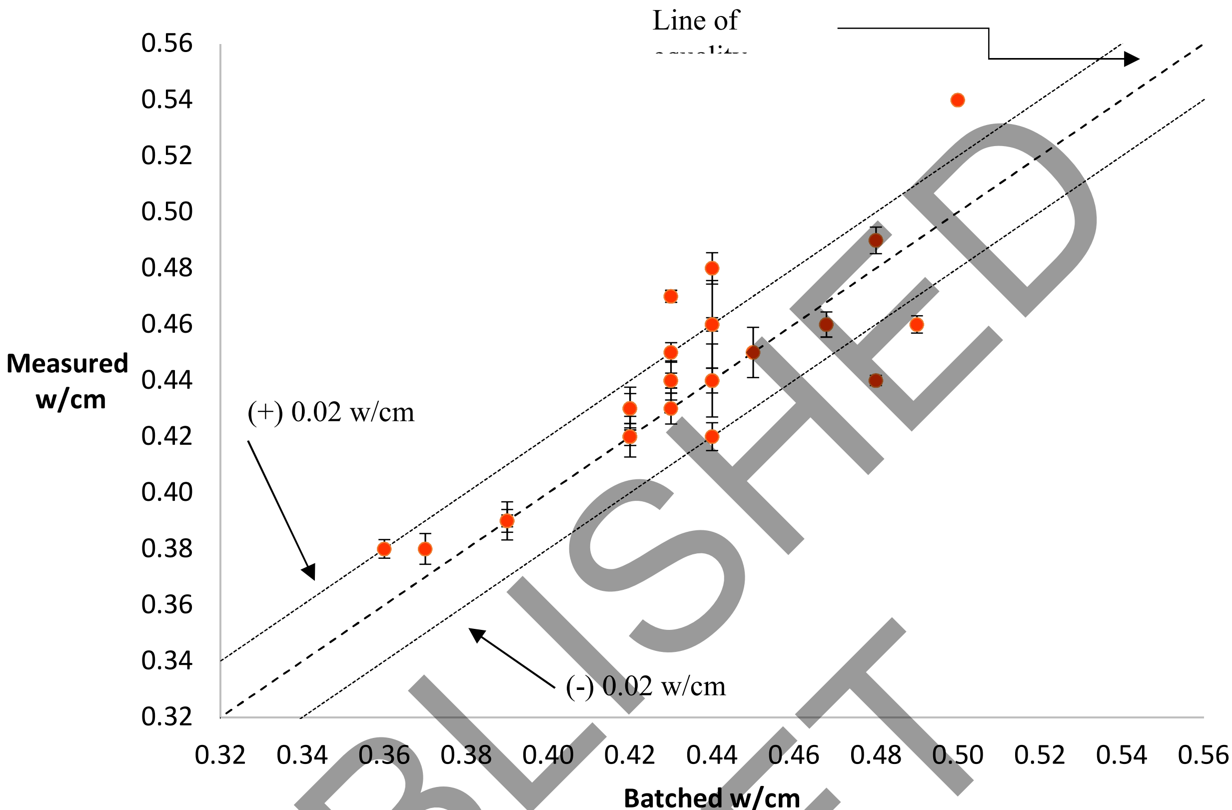

Figure 5. Field tests comparing the batched and measured w/cm. Two samples were tested and averaged per truck.

From Table 7 the average standard deviation was 0.010. This is very close to the 0.012 that was measured from the laboratory data. Also, the COV of the field data between the two measurements was 1.17%. This is a little lower than the 3.0% COV from the laboratory testing. It should be noted that the standard deviation and COV for the field measurements were based on two tests per truck. While this is a low number of samples for each measurement, it was not possible to measure more. Despite these low numbers for the field tests, the variance from both the lab and field are similar.

It was found that 15% of the field mixtures had a w/cm higher than 0.02 from batched w/cm. This was obtained from trucks at the batch plant and does not reflect the additional water that could be added before placement within the forms. Furthermore, these samples were not taken randomly. All concrete producers knew that the concrete was being sampled and this may have an impact on the quality of concrete that was provided for the testing. Despite these limitations, this test shows promise in being able to detect excess water in both laboratory and field concrete mixtures.

An example of the usefulness of the test can be shown by comparing two mixtures used for a bridge pier. The results from the testing and specifications are shown in Table 9 [32]. Because there is no test method to measure w/cm of fresh concrete, the specification limits the maximum slump of the concrete to 18 cm because of concerns for excess water. Both trucks were rejected because the slump was above the specified value; however, the testing shows that the measured w/cm for Truck 7 was within the allowable limits of the specification. This shows that there are many variables that impact the slump of concrete beside the w/cm. This also shows the value in more directly measuring the desired property instead of relying on indirect measurement methods for specifications.

Table 9. Truck 6 and 7 field testing results.

Truck Number	Batched w/cm	Average Measured w/cm	Measured Slump (cm)	Air Content (%)	Specified w/cm	Maximum Slump (cm)	Specified Air Content (%)
Truck 6	0.43	0.47	23	4.7	0.25-0.44	18	6±1.5
Truck 7	0.42	0.42	20	8.1	0.25-0.44	18	6±1.5

4.3. Practical Significance

The concrete industry does not have an established method to determine the w/cm of fresh concrete. This work presents a test method that has improved on previous methods and the results are accurate for a wide range of materials and mixtures. The inputs for the test can be easily determined with basic mixture design information and the unit weight of the fresh concrete. The results in the lab and field show promise.

This test method can benefit owners, contractors, and producers. Owners are interested in obtaining a durable concrete and the w/cm is helpful for determining this. Contractors want consistent products for construction and producers need tools to help them with the quality control of their materials. Being able to verify the fresh concrete w/cm in a timely manner would be of significant benefit to the industry. Currently, concrete with a high w/cm would not be identified until compressive strength testing or some other hardened property such as surface resistivity [33] or rapid chloride permeability [34] testing is completed. Unfortunately, this would take days or weeks to complete the testing. By identifying concrete mixtures that have excess water, one could better control the service life, properties, and constructability of a concrete mixture before the mixture is placed. This would benefit the entire concrete industry and improve the service life of our structures.

5. Conclusion

A test method is presented that measures the w/cm of the fresh concrete. Testing was performed for 231 laboratory mixtures and 27 field mixtures. The mixtures used 17 coarse aggregates and 6 fine aggregates with specific gravities between 2.42 and 2.85 and absorption between 0.20 and 4.69%. The method uses information about the mass of the ingredients, aggregate properties, and the unit weight of concrete. The test requires 1648 cm^3 or a 4x8 cylinder of concrete. The test can be completed within 30 minutes with this volume of material. The following conclusions can be drawn:

- For the laboratory mixtures with w/cm between 0.36 and 0.48, the average measured w/cm was within 0.01 from the batched w/cm and on average the difference was 0.001.
- For six mixtures with a batched 0.45 w/cm, the AASHTO T 318 microwave oven test was within 0.045 w/cm while the introduced test method was within 0.015 w/cm.
- The average standard deviation and COV for the laboratory and field mixtures were comparable (0.012 and 3.0% laboratory and 0.010 and 1.17% field).
- The standard deviation of the introduced w/cm was approximately three times lower than the AASHTO T-318 microwave oven test (3.0% compared to 8.9%).
- For the field testing, 15% of the mixtures were found to have a 0.02 w/cm or higher than the batched w/cm.

This shows that this proposed test method could provide a useful tool to measure the w/cm of fresh concrete in about 30 minutes with a reasonable size sample. The test also has the potential to directly measure the amount of water within concrete and not make an estimate of the value based on an indirect measurement from the slump test. The implementation of this test in the quality control of concrete has great potential to improve the quality and performance of concrete structures.

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7. Appendix

Table 10. Field testing batch tickets.

Truck	Batch Size (m^3)	Cement (kg)	Fly Ash C (kg)	Fly Ash F (kg)	Slag (kg)	Coarse (kg)	Fine (kg)	Water (kg)
1	10.5	2533	628			7140	7203	159
2	10.5	2712				8500	6586	147
3	10	2549				8110	6232	143
4	10	2545				8410	5679	135
5	10	2545				8509	5652	133
6	10	2554				8428	5724	133
7	10	2549				8373	5697	129
8	10	2549				8373	5697	129
9	10	2533				8301	5670	130
10	10	2041	508			8518	6024	120
11	10	2057	508			8863	5996	120
12	10	2037	508			8718	5996	120
13	10	2538				8482	6015	134
14	10	2538				8455	567	133
15	10	2545				8410	5679	134
16	10	2545				8509	5652	131
17	10	2554				8428	5724	128
18	10	2549				8423	5729	131
19	6	1080		245	333	4844	3379	72
20	9	1585	404			7167	5788	114
21	8	2055				6350	4704	118
22	8	1436		336	445	6450	4504	99
23	7.5	1912				6046	4500	101
24	7	1894	315			2712	6436	133
25	6.25	1082	288			4736	4196	81
26	3	649	166			2295	1882	41
27	8	1091			1100	5371	5597	113

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