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Concrete Pavement Quality Control Testing Requirements Needed for the Super Air Meter

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Abstract

Concrete freeze-thaw durability is prominently linked to the air void system within the concrete. Concrete pavements in Kansas undergo repetitive freeze-thaw cycles. Total air content measurements currently used on fresh concrete do not provide any indication of the air void size distribution. The Super Air Meter (SAM) addresses this issue by providing the air content and an additional number, the SAM number, which is claimed by the manufacturer to correlate to the concrete hardened air void spacing factor. In order to determine the variability and the frequency of testing needed for the SAM test, 16 sites across Kansas were investigated. The SAM test was performed at least once for every hour of paving. This study found that the SAM number has a 154 percent higher coefficient of variation per site than the total air content. It was also seen that there is a correlation between the air content and the SAM number. It is recommended that the Kansas Department of Transportation (KDOT) perform the SAM test at least four times per site per day.

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Chapter 1: Introduction

1.1 Research Background

Concrete pavements that are exposed to wet, cold climates with temperatures that cycle above and below the freezing point of water can deteriorate at rapid rates. Air entrainment in concrete can increase the durability of pavements in these harsh climates. Fresh concrete total air content is measured using pressurization as described by Boyle's law and standardized as ASTM C231 (2014). The air void system in hardened concrete is typically measured by examining air voids in polished concrete cross sections under a microscope as described by ASTM C457 (2012). While the pressure meter can quickly measure the total volume of air in fresh concrete, it has been shown that the total volume of air is not the most reliable indicator of the concrete freeze-thaw durability (Felice, 2012). The concrete air void spacing factor is a measure of the air bubble size and spacing, with a lower spacing factor indicative of an air void system more resistant to freezing and thawing (Albahttiti, 2015). Unfortunately, the concrete air content varies between concrete mixing, delivery, placement, and vibration (Albahttiti, Ghadban, Riding, & Lange, 2015). Hardened air void analysis can show how the air void system is affected by these variables, however, it can be time consuming and expensive. In order to address these issues with the conventional pressure meter fresh air content test and hardened air void analysis, the Super Air Meter (SAM) was developed by a research team at Oklahoma State University (Ley & Tabb, 2013). The Super Air Meter employs increasing sequential pressures to measure the SAM number, which is purported to be related to the concrete spacing factor, in addition to the total volume of air (Ley & Tabb, 2014). Recent studies have shown that the Super Air Meter results for the total air content remains within 10% of that of the regular air meter (Ley & Tabb, 2013).

1.2 Problem Statement

The Super Air Meter is a new technology developed recently at Oklahoma State University that measures concrete properties to give an index correlated to concrete hardened air void spacing factors. The device is based on the standard ASTM C231 Type B concrete air pressure meter (Ley & Tabb, 2014). The output of this test method is called the SAM number.

The SAM number is purported to be related to the concrete spacing factor in this test method. It is essential to assess the variability and to determine the frequency of testing needed to use the SAM number as a pay factor in addition to the total air content.

1.3 Research Objectives

The research objectives of this study were as follows:

- To quantify the typical variability seen on a project during a day.
- To determine the concrete sampling frequency required for measuring the SAM number and air content on Kansas concrete paving projects using statistical analysis.

1.4 Scope of Research

This research project was composed of two tasks. Task 1 focused on traveling to several construction projects across the state of Kansas to measure the SAM number on concrete sampled at different times during the paving day. Samples were taken as often as possible, with at least one SAM number reading measured every hour on site. Two 4 × 8-inch concrete cylinders were made for hardened air void analysis out of each sample of concrete that is found to have a SAM number above 0.3. The 4 × 8-inch concrete cylinders were delivered to the Kansas Department of Transportation (KDOT) so that KDOT can perform hardened air void analysis according to ASTM C457 on the cylinders. In Task 2, a statistical analysis was performed on the data collected to determine the sampling frequency required for SAM number measurements for a day's paving operations.

Chapter 2: Methodology

Concrete pavements were tested using the Super Air Meter at least once every hour during paving for every site visited, as shown in Figure 2.1. In order to understand the SAM number variability and repeatability, 16 paving sites were investigated. At these sites, concrete was collected from behind the paver, as shown in Figure 2.2, and moved in a bucket to the testing station where the Super Air Meter test was performed and two 4 × 8-inch cylinders were made. All tests were performed on a level wooden platform to reduce test variability. The Super Air Meter test is performed the same as the standard ASTM C231 (2014) test, except that instead of releasing the pressure and ending the test after the concrete air content is read, the valve between the top air chamber and bottom concrete chamber is closed. The procedure for measuring the pressure in the chamber after reaching equilibrium with the bottom chamber is repeated with the top air chamber pressure at 30 and 45 psi. After readings are taken at the 45 psi air chamber pressure step, the valves are opened to the atmosphere. The concrete is not removed, but water is reinjected into the bottom bowl to ensure that it is filled completely. The test is repeated at 14.5, 30, and 45 psi. The difference in the final pressure readings after the air at 45 psi in the top chamber is released to the bottom chamber between the two sequential pressurizations is called the SAM number.

The two cylinders accompanying each test were made according to ASTM C31 (2015). The samples were made in two layers, each rodded 25 times. These cylinders were sent to KDOT to perform the hardened air void analysis according to ASTM C457 (2012). In addition to the Super Air Meter test and the hardened air void cylinders, the concrete unit weight, temperature, and other site characteristics were measured and recorded. Table 2.1 shows the sites visited, number of tests performed, admixtures, and some site characteristics for this project. Testing started on May 24, 2016, and continued through July 21, 2016. The number of tests performed varied based on the length and the speed of the paving.

Figure 2.1: Super Air Meter Testing and Cylinder Making

Figure 2.2: Concrete Sample Taken from Behind the Paver

Table 2.1: Testing Locations, Number of Tests Performed, Admixtures, and Site Characteristics

Project No.	Location		ID	# Samples	Location Sampled	Truck Type	Finishing	AEA* Brand	AEA Amount (oz/yd^3)	Water Reducer Brand	Water Reducer Amount (oz/yd^3)
1	Sublette	US-56 & 83 South	1 - S	12	Intersection	Ready Mix	Paver	Euclid Eucon AEA-92S	0.75	Euclid Eucon WR 91	40
2	Sublette	US-56 & 83 West	2 - S	9	Intersection	Ready Mix	Paver	Euclid Eucon AEA-92S	0.75	Euclid Eucon WR 91	40
3	Junction City	I-70 & 77 South	3 - JC	8	Intersection	Ready Mix	Hand Finished	TERAPAVE	3	WR Grace ADVA 140M Type AF	27
4	McPherson	I-135 & 56 East	4 - M	15	Road Section	Ready Mix	Paver	MasterAir AE 90	5.5	MasterGlenium 7500	10.4
5	Junction City	I-70 & 77 North	5 - JC	7	Road Section	Ready Mix	Paver	TERAPAVE	7.5	WR Grace ADVA 140M Type AF	27
6	Junction City	I-70 & 77 North	6 - JC	9	Intersection	Ready Mix	Hand Finished	TERAPAVE	4.5	WR Grace ADVA 140M Type AF	27
7	Junction City	I-70 & 77 North	7 - JC	6	Road Section	Ready Mix	Paver	TERAPAVE	8	WR Grace ADVA 140M Type AF	27
8	Norton	US-36 W	8 - N	11	Road Section	Ready Mix	Hand Finished	Eucon AEA-92	8	Eucon MRX	35
9	Kansas City	I-70 E Near Exit 224	9 - KC	10	Interstate Section	Dump Truck	Paver	Eucon AEA-92	8.5	Eucon WR-91	19
10	Kansas City	I-70 E Near Exit 224	10 - KC	6	Interstate Section	Dump Truck	Paver	Eucon AEA-93	8.5	Eucon WR-92	14.1
11	Kansas City	I-70 E Near Exit 224	11 - KC	2	Interstate Section	Dump Truck	Paver	Eucon AEA-93	9.6	Eucon WR-92	19
12	Kansas City	I-70 E Near Exit 224	12 - KC	12	Interstate Section	Dump Truck	Paver	Eucon AEA-93	9.6	Eucon WR-92	19
13	Kansas City	I-35 N Near Exit 215	13 - KC	6	Interstate Section	Dump Truck	Paver	TERAPAVE	4.9	WRDA 82	20
14	McPherson	US-56 W	14 - M	5	Road Section	Ready Mix	Paver	Air 200	11	Glenium 7500	0
15	Lawrence	County Road 1750 N	15 - L	4	Road Section	Dump Truck	Paver	PolyChem SA	4.39	PolyChem 400	27.88
16	Lawrence	K-10	16 - L	12	Road Section	Dump Truck	Paver	PolyChem SA	5.83	PolyChem 400	28.1

* AEA = Air Entraining Agent

Chapter 3: Results and Discussion

A total of 143 SAM tests were run over 16 days of testing over a 9 week period. Out of these tests, 134 of the SAM measurements were considered valid results because they did not experience water leakage during the test or other failure. The data for the valid tests is shown in Appendix A. It was found that 68 of the samples (or 51%) had a SAM number greater than 0.2 and 31 of the samples (or 23%) had a SAM number greater than 0.3.

On July 9, 2016, a comparison was made of the results from two SAM meters on concrete sampled from the pavement at the same time. KDOT and Kansas State University (KSU) measured the air properties on the samples using different SAM apparatus. The comparison was repeated on three different concrete samples. Table 3.1 shows a comparison of the measurements made by KSU and KDOT. All measurements were in general agreement except for the third SAM number measurement. The cause of the discrepancy between the two SAM number measurements is unknown. It is possible that the small difference in air content measured could also be a sign that the concrete in the KDOT SAM had a poor air structure. It is also possible that the SAM number has inherent variability that should be examined in further detail. Air void analysis should be performed on companion concrete cylinders made from the batch sampled at 11:45 AM to determine the cause of the SAM number discrepancy.

Table 3.1: Comparison of KSU and KDOT SAM Number and Total Air Content

Time	KSU Measurements		KDOT Measurements	
	SAM Air Content (%)	SAM Number	SAM Air Content (%)	SAM Number
10:15 AM	8.5	0.16	8.4	0.18
11:00 AM	7.1	0.12	7.3	0.15
11:45 AM	7.0	0.08	6.4	0.46

The data presented in Figure 3.1 shows the correlation between the air content and the SAM number. The trends observed indicate that SAM number decreases as the air content increases. Even the standard deviation decreases as the air content increases in the data collected. As for the coefficient of variation (C_V), the SAM data indicates that the coefficient of variation from one test to the next one within the same site is 154% higher than that of the air content on average, as shown in Figure 3.2. The coefficient of variation (C_V) can be calculated using Equation 3.1, where s is the standard deviation and $\bar{x}$ is the average.

$$\textbf{Coefficient of Variation } (C_V) = \left(\frac{s}{\bar{x}}\right)(100\%) \qquad \textbf{Equation 3.1}$$

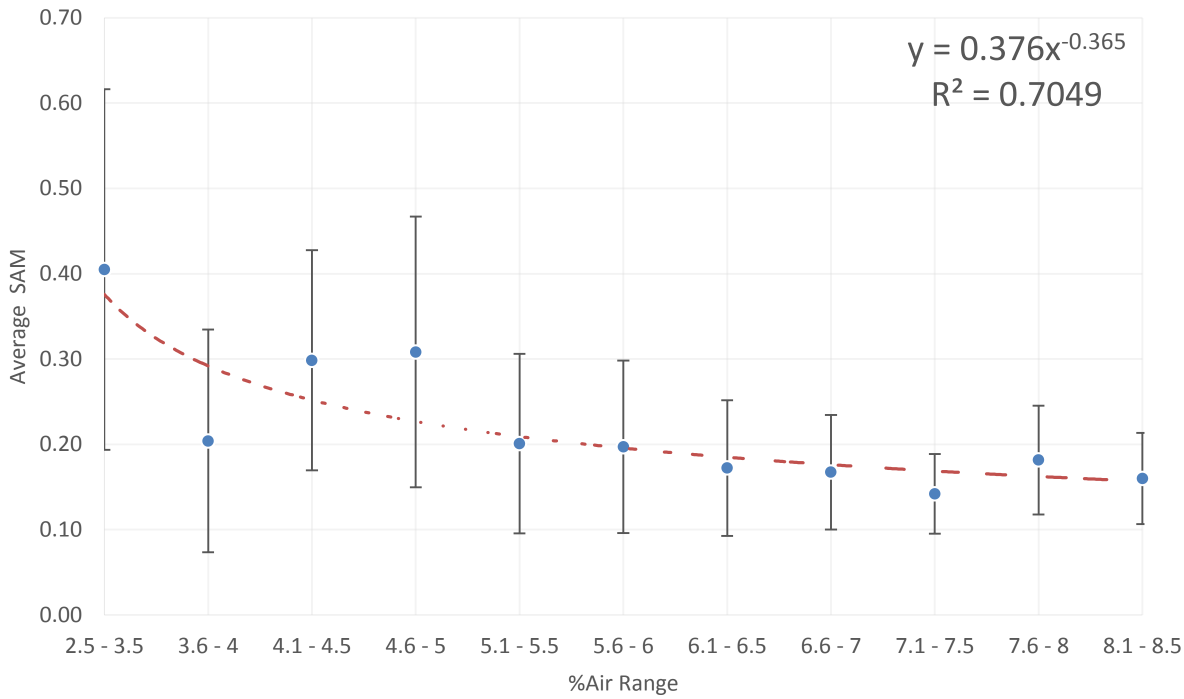

Figure 3.1: Average SAM Number at Various Air Content Ranges with Standard Deviation Bars

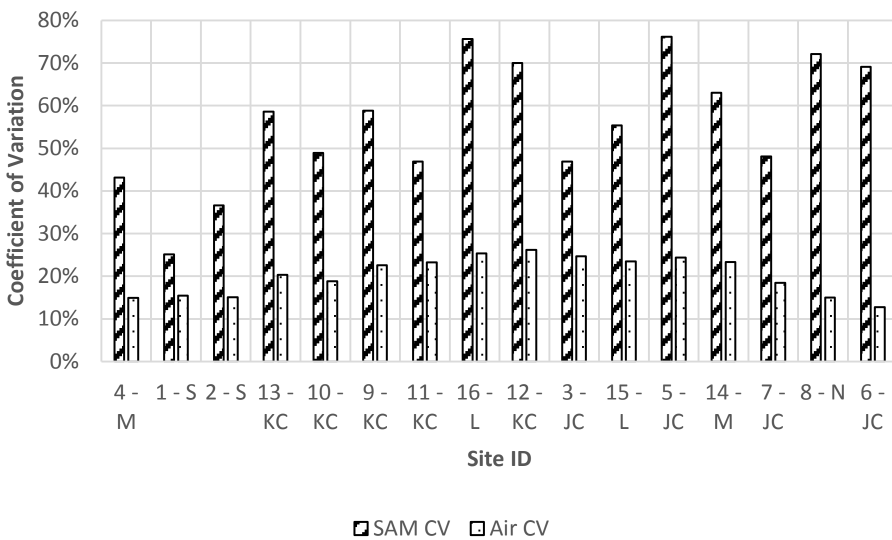

Figure 3.2: SAM Number versus Air Content Coefficients of Variation for the Various Sites

The data presented in Figure 3.1, Figure 3.2, and Table 3.2 indicate that the SAM number has a higher C_V than the air content, which could be the result of variation in the air void system and variation inherent in the method. The validity of this can be examined by comparing the SAM results with the hardened air content spacing factor and distribution. The SAM number average C_V for samples transported using ready-mixed trucks was 53%, whereas for concrete transported with dump trucks it was 59%. The air content C_V for concrete transported using ready-mixed trucks was likewise slightly lower at 18%, whereas the concrete transported with dump trucks had a C_V of 23%. This could be because the concrete transported with ready-mixed trucks had on average 0.5% higher air content.

Table 3.2: Statistics for the SAM Number versus the Air Content

Site ID	SAM Number			Air Content		
	Average	Standard Deviation	Coefficient of Variation (%)	Average (%)	Standard Deviation (%)	Coefficient of Variation (%)
1 - S	0.45	0.11	25	4.28	0.66	15
2 - S	0.32	0.12	37	4.5	0.68	15
3 - JC	0.25	0.12	47	6.04	1.49	25
4 - M	0.25	0.11	43	4.26	0.63	15
5 - JC	0.16	0.12	76	6.44	1.57	24
6 - JC	0.15	0.11	69	7.44	0.95	13
7 - JC	0.21	0.1	48	6.72	1.24	18
8 - N	0.14	0.1	72	7.07	1.06	15
9 - KC	0.21	0.12	59	5.13	1.16	23
10 - KC	0.25	0.12	49	5.07	0.95	19
11 - KC	0.28	0.13	47	5.5	1.28	23
12 - KC	0.19	0.13	70	5.71	1.49	26
13 - KC	0.19	0.11	59	4.58	0.93	20
14 - M	0.18	0.11	63	6.46	1.51	23
15 - L	0.22	0.12	55	6.28	1.47	23
16 - L	0.17	0.13	76	5.65	1.43	25
Overall	0.23	0.13	56	5.58	1.21	22

In order to determine the testing frequency required for the SAM number, a statistical analysis known as tolerance intervals can be employed (Guenther, 1977). In order to implement the tolerance intervals method, the data skewness needs to be adjusted by taking the natural logarithm of the SAM as can be seen in Figure 3.3. Once the data is adjusted, the tolerance width is calculated according to Equations 3.2 and 3.3. The tolerance width can be used to calculate the capability (C) of the process based on a 99% proportion for a two-sided tolerance interval with 95% confidence using Equation 3.4. The specification range for the SAM test as specified by the developer is 0.03 to 0.20 for adequate air system with 90% confidence and 0.21 to 0.70 for inadequate concrete (Marsh, 2015).

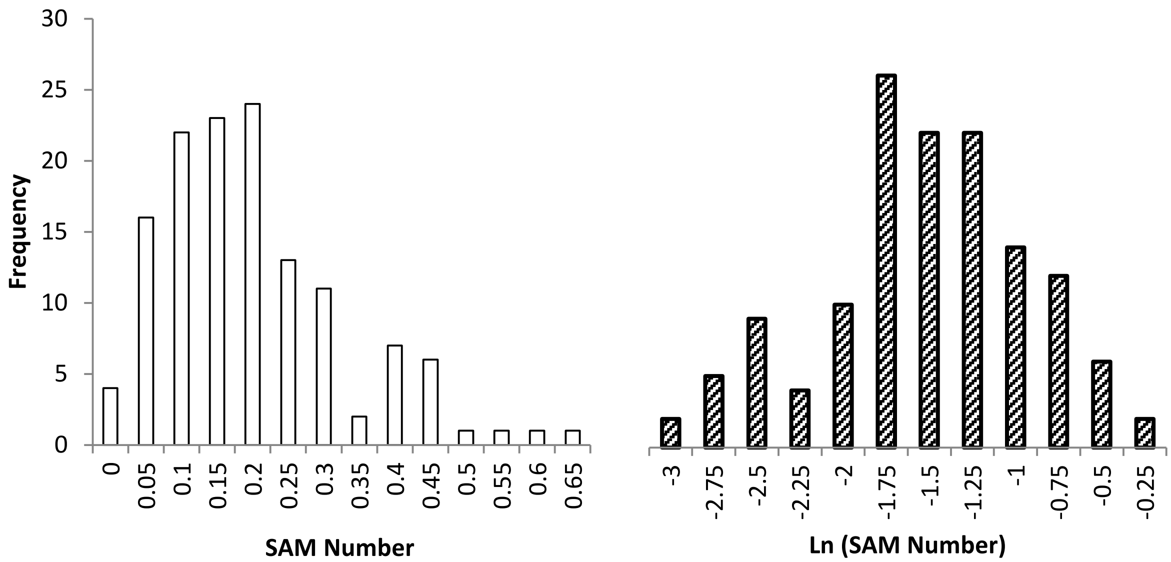

Figure 3.3: SAM Number versus the Natural Logarithm SAM Number Histogram

$$\boldsymbol{Tolerance\,Width = 2k_2 s}$$ **Equation 3.2**

$$\boldsymbol{k_2 = z_{(1-p)/2}\sqrt{\frac{(n-1)\left(1+\frac{1}{n}\right)}{\chi^2_{\gamma,n-1}}\left(1+\frac{(n-3)-\chi^2_{\gamma,n-1}}{2(n+1)^2}\right)}}$$ **Equation 3.3**

$$\boldsymbol{C = \frac{Specification\,Range}{Tolerance\,Width} = \frac{0.2-0.03}{2k_2 s}}$$ **Equation 3.4**

Where:

k_2 is a factor for the tolerance interval,

n is the sample size,

$\chi^2_{\gamma,n-1}$ is the critical value of the chi-square distribution, and

$z_{(1-p)/2}$ is the standard normal variate.

The values for $z_{(1-p)/2}$ and $\chi^2_{\gamma,n-1}$ can be found in statistics tables published in many texts books or using the Excel internal tables library (International Organization for Standardization, 2014).

Figure 3.4 shows the capability versus the testing frequency for the range given for the total air content and SAM number. As a result of the large standard deviations, the capability for any frequency remained low, below 35%. Regardless of the low capability, there was an increasing trend as the frequency of testing increased up to four tests per day per site, after which it remained constant at five tests. The total air content showed a much higher capability and continued to increase past four tests.

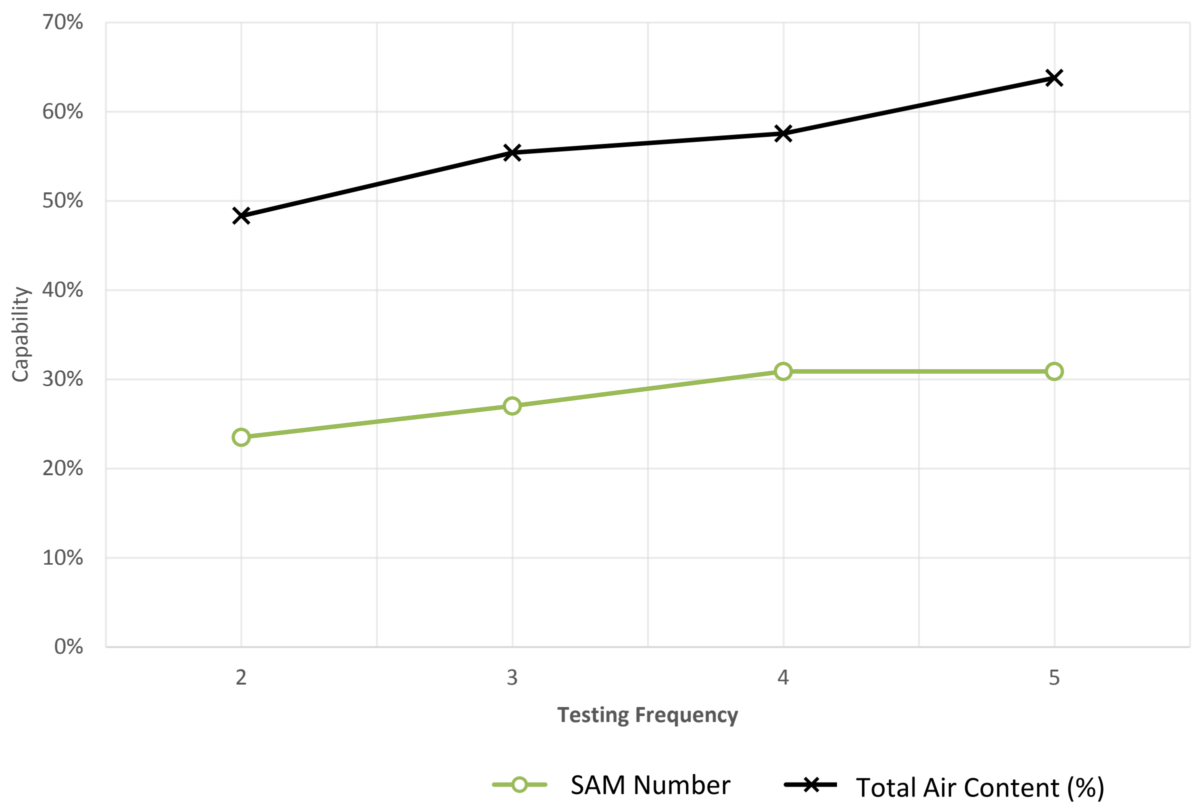

Figure 3.4: Testing Frequency versus the Capability

Chapter 4: Conclusions and Recommendations

4.1 Conclusions

In this study, the frequency and the variability of the SAM test were investigated. The experimental results obtained have led to the following conclusions:

1. There is correlation between the SAM number and the air content. The SAM number decreases as the air content increases.
2. The SAM number was shown to have a coefficient of variation 154% higher than the air content. This additional variability is likely because of variability in concrete air void systems and inherent variability in the test.
3. Statistical analysis of the data shows that the capability of the SAM number is relatively low, between 23% and 31%. Regardless of the low capability, there is a trend indicating that the capability improves up to four tests per day of testing, after which the capability remains constant at five tests per day per site. This means that the test method has very low capability and additional testing above four times per day of testing will not improve the capability.

4.2 Implementation Recommendations

The following recommendations are made based on the experiments conducted in this study:

1. SAM testing should be performed at least five times per site per day. Even though the statistics show that Super Air Meter readings could be run four times per day, it is not recommended to lower the number of tests conducted from the current level because of the need to also measure the total air content. This is because of the extremely low capability found with the SAM number test.
2. The SAM capability should be compared to the hardened air void analysis to determine if the increased variability is from the air void system variability or from inherent variability with the test method.

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Appendix A

Table A.1: Project #1 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
1	9:00 AM	1	10	1	-	149.3	76.6	3.2	0.62
1	9:20 AM	2	64	3	-	146.0	77.5	3.9	0.2
1	9:45 AM	3	128	5	-	145.0	79.8	4.6	0.48
1	10:05 AM	4	192	7	-	147.1	80.9	4.2	0.38
1	10:25 AM	5	288	10	0.75	146.5	80.1	4.1	0.43
1	10:40 AM	6	352	12	-	146.0	79.6	5.2	0.27
1	11:40 AM	7	608	20	-	147.1	82.6	4.1	0.48
1	12:05 PM	8	704	23	-	147.9	86.4	3.5	0.53
1	12:30 PM	9	832	27	-	146.6	84.7	4.7	0.66
1	1:20 PM	10	992	32	-	146.1	85.8	4.8	0.49
1	1:40 PM	11	1120	36	-	146.8	84.9	4.6	0.42
1	2:25 PM	12	1216	39	-	147.1	87.9	4.4	0.46

Table A.2: Project #2 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
2	11:35 AM	1	32	2	0.75	146.4	83.2	4.4	0.48
2	11:53 AM	2	96	4	-	145.9	82.2	4.2	0.32
2	12:10 PM	3	160	6	-	145.3	82	4.7	0.56
2	12:24 PM	4	224	8	1.75	144.8	80.3	4.5	0.2
2	12:45 PM	5	320	11	-	145.7	84	4.6	0.23
2	1:02 PM	6	384	13	-	146.0	81.2	4.5	0.37
2	1:26 PM	7	480	16	-	146.0	79.9	4.8	0.46
2	1:48 PM	8	576	19	-	146.2	81.6	4.5	0.11
2	2:35 PM	10	768	25	-	145.6	85	4.3	0.12

Table A.3: Project #3 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
3	9:38 AM	2	160	5	-	144.6	72.9	5.4	0.44
3	9:55 AM	3	200	6	-	145.0	73.1	5.3	0.23
3	10:18 AM	4	280	8	-	145.4	73.3	4.8	0.44
3	10:35 AM	5	320	9	-	142.8	73.9	6.2	0.3
3	11:20 AM	6	360	10	-	141.4	75.6	7.6	0.22
3	12:15 PM	8	480	13	-	142.2	78.8	6.7	0.15
3	12:35 PM	9	520	14	-	142.2	77.8	7	0.17
3	1:00 PM	10	600	16	-	144.4	79.4	5.3	0.04

Table A.4: Project #4 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
4	7:25 AM	1	40	2	-	148.2	76.7	3.9	0.32
4	8:00 AM	2	160	5	-	148.0	76.4	3.7	0.35
4	8:15 AM	3	320	9	-	147.0	78.6	4.6	0.35
4	8:40 AM	4	520	14	2.5	147.6	79.3	3.7	0.08
4	9:00 AM	5	600	16	2.25	146.2	75	4.8	0.25
4	9:23 AM	6	720	19	-	146.0	77.5	4.9	0.24
4	9:41 AM	7	840	22	-	146.6	77.3	4.8	0.17
4	10:12 AM	8	1000	26	-	147.0	78.1	4.9	0.28
4	10:34 AM	9	1200	31	-	148.0	78.1	4.3	0.45
4	11:15 AM	10	1480	38	1.25	148.8	80.5	3.45	0.15
4	12:10 PM	11	2000	51	-	147.6	81.3	4.4	0.21
4	12:31 PM	12	2160	55	-	147.6	82.4	4.3	0.31
4	12:55 PM	13	2200	56	-	149.6	83.5	2.8	0.32
4	1:18 PM	14	2320	59	-	148.0	82	4.3	0.19
4	1:45 PM	15	2520	64	-	147.0	81.8	5	0.06

Table A.5: Project #5 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
5	9:16 AM	1	40	2	-	146.2	77.3	5.1	0.08
5	9:36 AM	2	80	3	-	145.4	76.2	5.3	0.07
5	9:57 AM	3	160	5	2.5	140.4	77.7	6.9	0.11
5	10:34 AM	4	240	7	-	144.4	82.9	5.9	0.44
5	10:54 AM	5	320	9	-	142.2	82.4	7.3	0.14
5	11:27 AM	6	400	11	-	142.4	79.2	7	0.05
5	12:27 PM	8	560	15	-	142.4	87	7.6	0.2

Table A.6: Project #6 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
6	9:06 AM	1	0	1	3.5	142.6	80.8	6.9	0.25
6	9:26 AM	2	40	2	-	142.4	79	6.5	0.04
6	9:55 AM	3	80	3	-	139.0	81.4	7.7	0.08
6	10:16 AM	4	160	5	-	140.2	78.6	8.5	0.16
6	10:58 AM	6	240	7	-	141.4	81.1	7.1	0.12
6	11:16 AM	7	280	8	-	141.2	81	8.1	0.17
6	11:47 AM	8	320	9	-	142.8	81.2	7	0.08
6	12:28 PM	9	400	11	-	142.2	81.5	7.5	0.26
6	1:13 PM	10	480	13	-	142.2	83.6	7.7	0.21

Table A.7: Project #7 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
7	9:28 AM	1	0	1	-	144.0	83.7	6.4	0.21
7	9:47 AM	2	80	3	-	141.8	82.8	7.8	0.25
7	10:21 AM	3	120	4	2.75	143.0	82.8	6.8	0.24
7	11:03 AM	5	320	9	-	142.6	84.8	6.6	0.14
7	11:35 AM	6	440	12	-	145.2	85	6	0.19
7	12:00 PM	7	560	15	-	142.8	86.4	6.7	0.25

Table A.8: Project #8 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
8	7:15 AM	1	0	1	-	145.8	84.3	5	0.12
8	7:33 AM	2	40	2	-	139.4	85.2	8	0.13
8	7:57 AM	3	120	4	3.75	142.8	83.5	6.4	0.21
8	8:28 AM	4	200	6	-	141.4	81.1	7	0.15
8	8:50 AM	5	280	8	-	143.6	85.2	6.1	0.11
8	9:14 AM	6	320	9	-	141.2	85.2	7.1	0.13
8	10:27 AM	7	0	1	4	138.8	89.4	8.2	0.22
8	10:49 AM	8	80	3	-	141.4	90.1	7.2	0.17
8	11:17 AM	9	120	4	-	136.8	86.3	8.5	0.09
8	11:45 AM	10	240	7	-	140.8	87.6	6.8	0.07
8	12:10 PM	11	320	9	-	140.0	90.1	7.5	0.17

Table A.9: Project #9 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
9	9:34 AM	1	1376	64	-	146.2	89	5.4	0.18
9	10:00 AM	2	1920	73	-	148.0	89.5	4.4	0.32
9	10:21 AM	3	2208	82	-	146.6	90.1	5.5	0.17
9	10:45 AM	4	2400	88	-	145.4	87.5	6	0.2
9	11:11 AM	5	2656	96	0.5	146.0	90.1	5.4	0.26
9	11:43 AM	6	3008	107	-	147.8	91.3	4.5	0.34
9	12:15 PM	7	3424	120	-	147.2	92.4	4.9	0.26
9	12:38 PM	8	3680	128	-	147.0	91.2	5.1	0.12
9	1:09 PM	9	4128	142	-	146.4	91.5	5.2	0.18
9	1:42 PM	10	4544	155	-	146.8	90.9	4.9	0.09

Table A.10: Project #10 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
10	8:08 AM	2	1152	36	-	148.0	88.6	4.4	0.14
10	8:59 AM	3	1952	61	-	146.6	90.8	4.8	0.42
10	10:05 AM	4	2112	66	-	147.0	91.3	4.3	0.33
10	10:34 AM	5	2304	72	-	147.6	93	4.7	0.14
10	11:09 AM	6	3008	94	-	143.4	91.7	6.7	0.23
10	12:22 PM	7	3040	95	-	145.4	89.6	5.5	0.25

Table A.11: Project #11 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
11	7:36 AM	1	512	17	-	145.6	87.2	5.9	0.16
11	8:07 AM	2	896	29	-	146.8	87.3	5.1	0.4

Table A.12: Project #12 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
12	7:13 AM	1	512	17	-	146.2	81.7	5	0.27
12	7:36 AM	2	640	21	-	179.2	82	5.7	0.31
12	8:05 AM	3	1280	41	-	146.0	83	5.9	0.08
12	8:44 AM	4	1760	56	-	146.0	86.1	5.4	0.17
12	9:23 AM	5	2272	72	-	144.4	85.7	7	0.21
12	10:13 AM	6	2304	80	-	147.0	86	4.8	0.16
12	10:46 AM	7	2880	93	-	145.6	85.8	6.5	0.22
12	11:24 AM	8	3200	103	-	146.6	89.4	5.8	0.28
12	11:51 AM	9	3584	115	-	146.4	87.8	6	0.26
12	12:50 PM	10	4352	139	-	151.0	88.3	5.3	0.05
12	1:20 PM	11	4832	154	-	147.2	89.4	5.6	0.15
12	1:47 PM	12	5120	163	-	146.6	90.8	5.5	0.07

Table A.13: Project #13 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
13	11:33 AM	1	1472	47	-	147.0	93.9	4.1	0.09
13	12:08 PM	2	1664	53	-	146.8	90.6	4.4	0.24
13	1:21 PM	3	2240	71	-	148.2	96.9	4	0.07
13	2:04 PM	4	2496	79	-	146.4	94.6	4.9	0.3
13	2:42 PM	5	2752	87	-	145.2	93	5.1	0.21
13	3:15 PM	6	2976	94	-	144.6	97.5	5	0.24

Table A.14: Project #14 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
14	9:09 AM	1	600	16	1.25	142.8	86.5	6.4	0.2
14	9:48 AM	2	880	23	-	143.8	86.7	6.1	0.15
14	10:15 AM	3	1080	28	-	143.6	87.3	6.2	0.13
14	10:44 AM	4	1240	32	-	143.0	93.3	6.6	0.2
14	11:14 AM	5	1400	36	-	141.8	88	7	0.21

Table A.15: Project #15 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
15	9:15 AM	1	1260	-	1.75	145.0	87.7	6.3	0.14
15	9:45 AM	2	1500	-	-	147.2	88.9	5.3	0.27
15	10:55 AM	3	2040	-	-	142.8	90.7	7.2	0.15
15	11:29 AM	4	2280	-	-	145.6	89.6	6.3	0.3

Table A.16: Project #16 Results

Project #	Time	Test #	Yd^2 placed before	Truck #	Slump (in.)	Unit Weight (lbs/ft^3)	Concrete Temp. (°F)	SAM Air Content (%)	SAM Number
16	6:46 AM	1	1028	-	1.75	146.2	82.8	5.8	0.06
16	7:08 AM	2	1234	-	-	144.6	84.4	6.2	0.06
16	7:26 AM	3	1645	-	-	144.4	82.7	5.8	0.17
16	7:40 AM	4	1850	-	-	142.2	83.5	5.7	0.14
16	8:03 AM	5	2056	-	-	146.2	86.5	5.4	0.27
16	8:27 AM	6	2467	-	-	145.4	86.4	5.2	0.22
16	8:45 AM	7	2673	-	-	141.0	83.9	6.1	0.17
16	9:35 AM	8	3290	-	-	146.6	86	5.3	0.33
16	9:59 AM	9	3701	-	-	145.0	86.3	5.8	0.22
16	10:22 AM	10	4112	-	-	144.6	86.5	5.6	0.1
16	10:45 AM	11	4318	-	-	145.0	88.4	5.5	0.17
16	11:09 AM	12	4523	-	-	145.6	86	5.4	0.17


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