

# **Variability of PEM Tests**

## ***FHWA Mobile Concrete Trailer (MCT) Experience***

Jagan Gudimettla, P.E.

*ATI Inc, Consultant to FHWA*

# Acknowledgements

- Nicolai Morari (MCT)
- Jon Anderson (MCT)
- Jerry Clemons (MCT)
  
- Craig Hughes (Cedar-Valley Corp)

# FHWA Data Collection Efforts

- Two Weeks
  - ✓ Fresh Concrete
  - ✓ Hardened Concrete
- Later Age Testing
  - ✓ 28 Day
  - ✓ 56 Day
- Wide Variety of Data
  - ✓ 30+ parameters collected



# PEM Tests

## Currently Performed by the MCT

### ➤ Strength

- ✓ Compressive Strength

### ➤ Cracking tendency

- ✓ Paste Content

### ➤ Freeze-Thaw durability

- ✓ SAM Meter

### ➤ Permeability

- ✓ Resistivity Testing/RCPT

### ➤ Aggregate stability

- ✓ No testing performed

### ➤ Workability

- ✓ Box Test
- ✓ V-Kelly \*

# Questions??

- How does total air content compare between the SAM and Type B Pressure Meter?
- How much does SAM Number vary in a given project?
- Does SAM Number and total air content have a direct relationship?
- How does the variability of the SAM compare with other tests?

# Sampling and Testing Variability

## ➤ Precision

- ✓ Repeatability
- ✓ Reproducibility

## ➤ Bias (Accuracy)

# Composite Variability

*Material*

*Process*

*Sampling*

*Testing*



Material

Process

Sampling

Testing

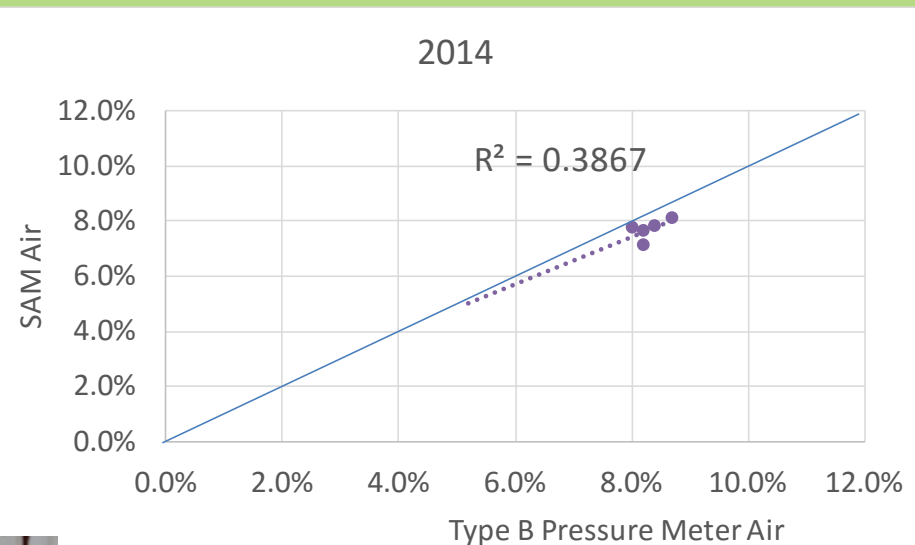
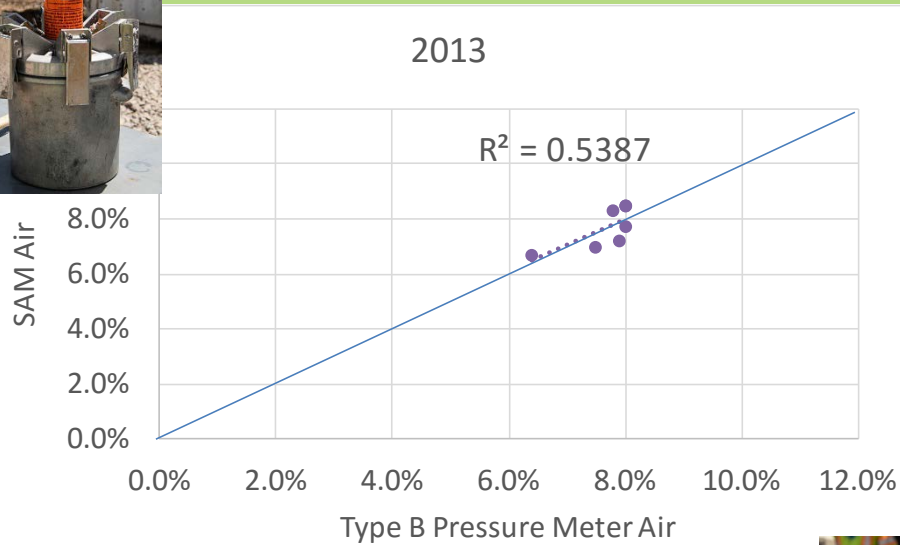
- Measures of Variability
  - ✓ Standard Deviation
  - ✓ Coefficient of Variation

# Test Matrix

- Data from 11 states
- Paving projects
- 6-8 data points from each state
- Tests on the same sample of concrete
  - ✓ Total Air – Type B Pressure Meter
  - ✓ Total Air – SAM Meter
  - ✓ SAM Number – SAM Meter
  - ✓ Spacing Factor – Air Void Analyzer
- Data from and Iowa Contractor (Cedar-Valley)
  - ✓ 37 Data points

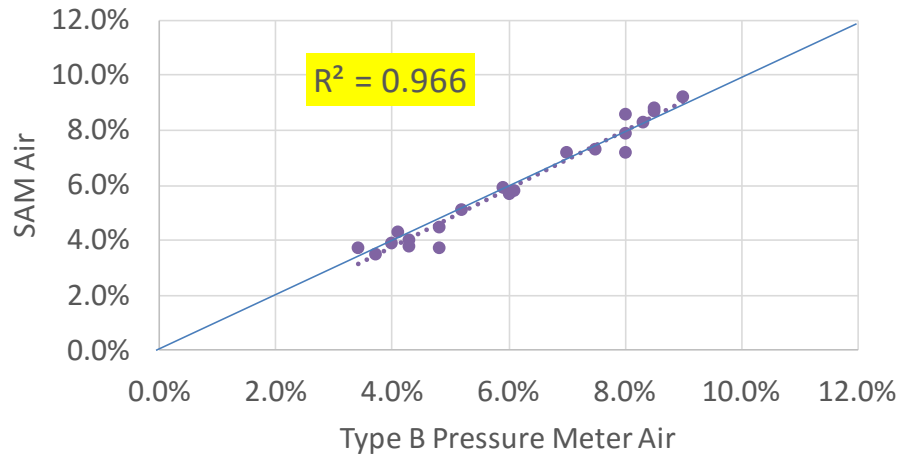


# SAM VS. Pressure Meter – Total Air

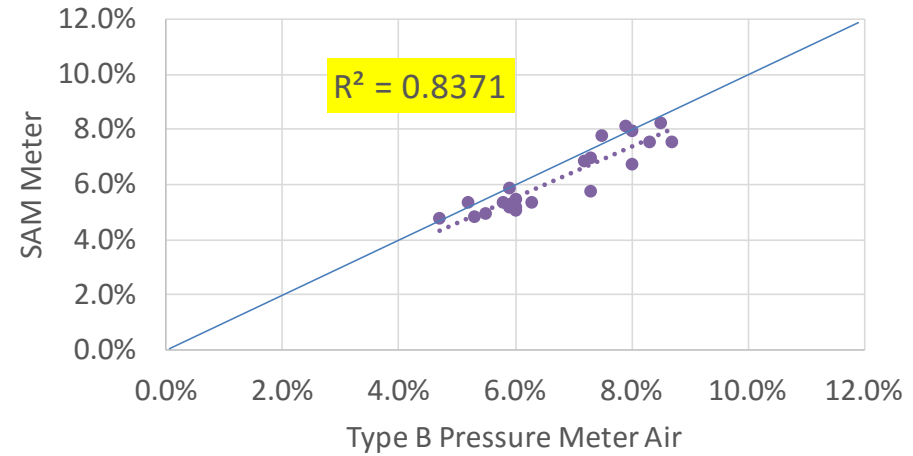


# SAM VS. Pressure Meter – Total Air

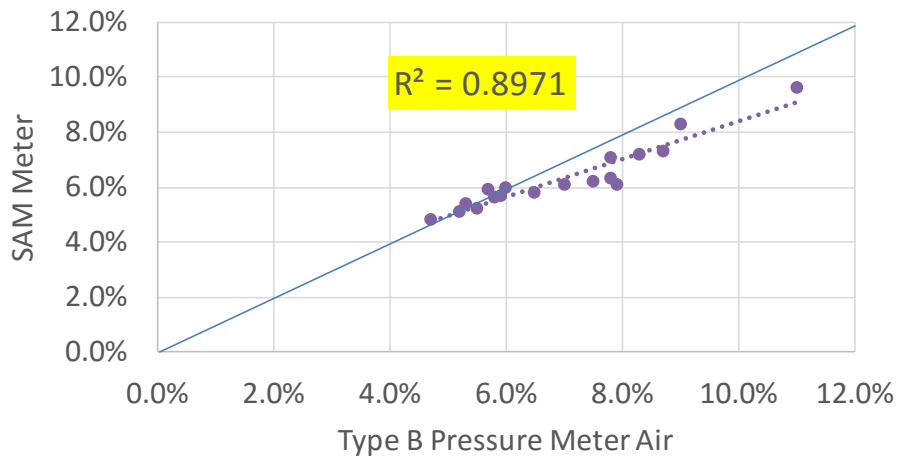
2015



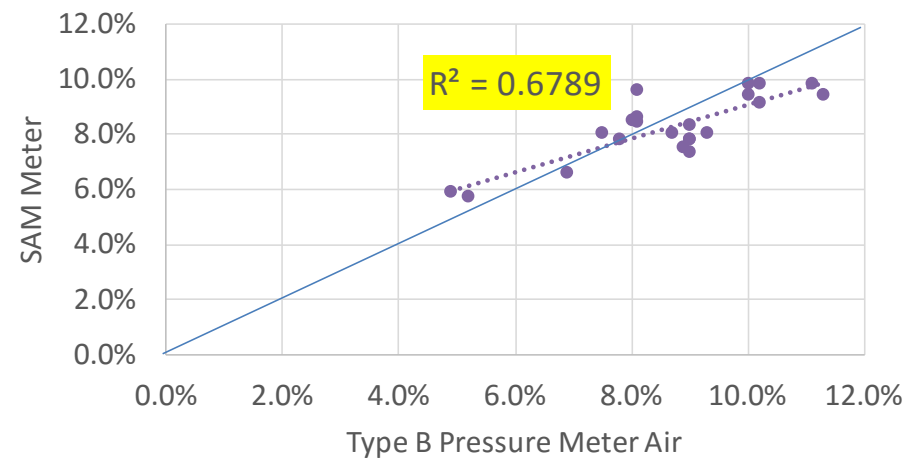
2016



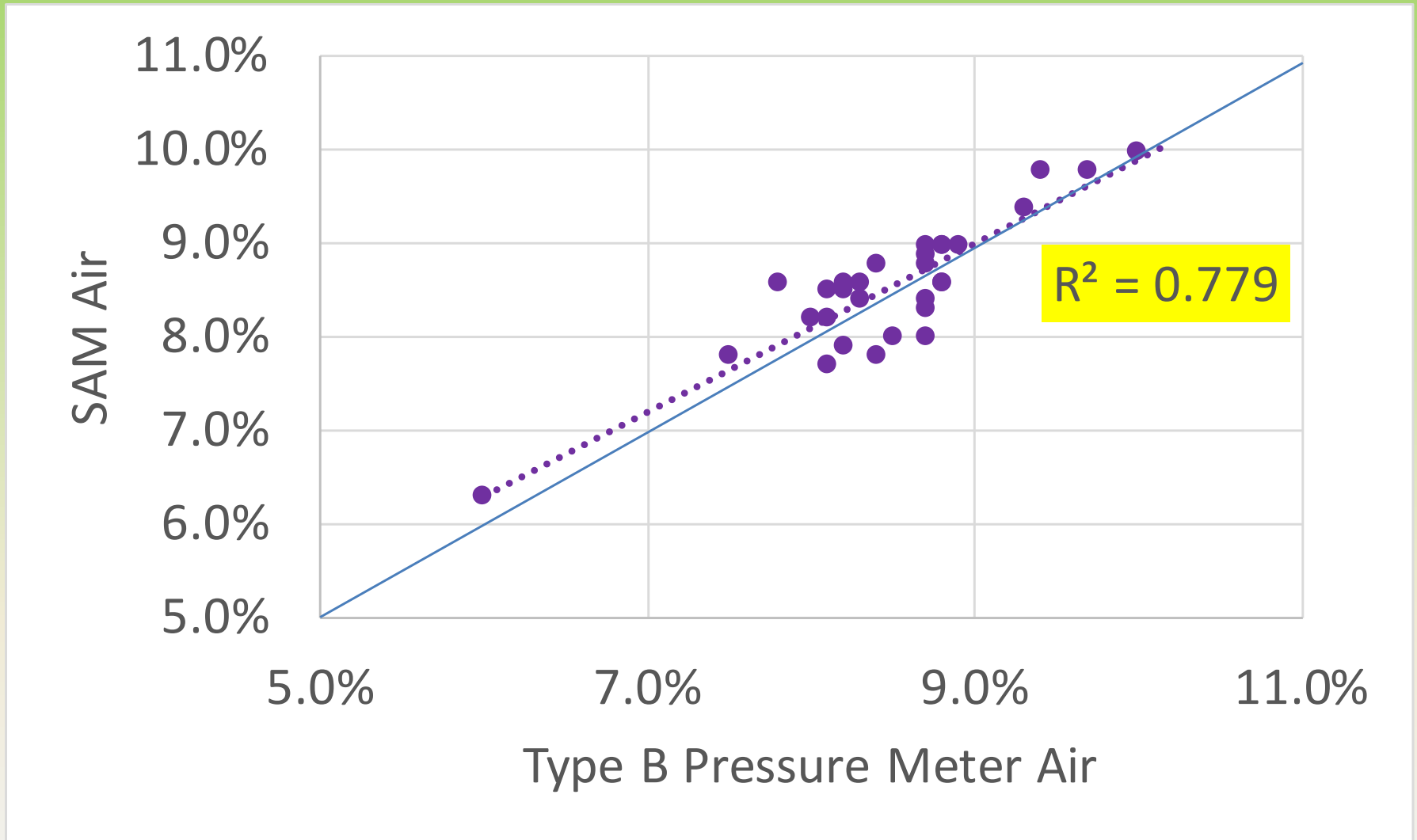
2017



2018



# Cedar-Valley Corp (Iowa Contractor)



# Air Void Analyzer (AVA)



# Average Results by Project

State	Number of Tests	Total Air	SAM Air	SAM Number	Spacing Factor - AVA
Michigan	7	7.7%	7.7%	0.10	0.006
Idaho	8	4.4%	4.1%	0.33	0.020
Ohio	6	8.1%	8.1%	0.19	0.009
New Mexico	7	6.5%	6.5%	0.26	0.009
Wisconsin	7	7.9%	7.5%	0.21	0.010
Washington State	8	6.5%	5.8%	0.28	0.009
Arkansas	8	8.5%	7.3%	0.18	0.009
Delaware	8	5.5%	5.5%	0.28	0.013
<b>Colorado</b>	<b>7</b>	<b>6.9%</b>	<b>7.3%</b>	<b>0.30</b>	<b>0.013</b>
Iowa	8	10.0%	9.4%	0.22	0.009
Minnesota	7	8.9%	7.9%	0.19	0.008
<b>Pooled Average</b>		<b>7.4%</b>	<b>7.0%</b>	<b>0.23</b>	<b>0.010</b>

# Average Results by Project

State	Number of Tests	Total Air	SAM Air	SAM Number	Spacing Factor - AVA
Michigan	7	7.7%	7.7%	0.10	0.006
<b>Idaho</b>	<b>8</b>	<b>4.4%</b>	<b>4.1%</b>	<b>0.33</b>	<b>0.020</b>
Ohio	6	8.1%	8.1%	0.19	0.009
New Mexico	7	6.5%	6.5%	0.26	0.009
Wisconsin	7	7.9%	7.5%	0.21	0.010
Washington State	8	6.5%	5.8%	0.28	0.009
Arkansas	8	8.5%	7.3%	0.18	0.009
Delaware	8	5.5%	5.5%	0.28	0.013
<b>Colorado</b>	<b>7</b>	<b>6.9%</b>	<b>7.3%</b>	<b>0.30</b>	<b>0.013</b>
Iowa	8	10.0%	9.4%	0.22	0.009
Minnesota	7	8.9%	7.9%	0.19	0.008
<b>Pooled Average</b>		<b>7.4%</b>	<b>7.0%</b>	<b>0.23</b>	<b>0.010</b>

# Standard Deviations by Project

State	Number of Tests	Total Air	SAM Air	SAM Number	Spacing Factor - AVA
Michigan	7	0.6%	0.7%	0.05	0.001
Idaho	8	0.8%	0.7%	0.13	0.007
Ohio	6	0.7%	0.8%	0.08	0.002
New Mexico	7	1.6%	1.7%	0.11	0.005
Wisconsin	7	0.5%	0.5%	0.04	0.006
Washington State	8	1.1%	1.2%	0.07	0.003
Arkansas	8	1.1%	1.2%	0.05	0.001
Delaware	8	0.4%	0.4%	0.12	0.002
Colorado	7	1.3%	1.2%	0.05	0.002
Iowa	8	1.0%	0.5%	0.03	0.002
Minnesota	7	0.4%	0.4%	0.05	0.002
<b>Pooled Standard Deviation</b>		<b>0.9%</b>	<b>0.9%</b>	<b>0.07</b>	<b>0.003</b>

# Coefficients of Variation by Project

State	Number of Tests	Total Air	SAM Air	SAM Number	Spacing Factor - AVA
Michigan	7	8%	10%	50%	10%
Idaho	8	19%	18%	40%	34%
Ohio	6	8%	10%	41%	27%
New Mexico	7	25%	26%	43%	49%
Wisconsin	7	6%	7%	19%	53%
Washington State	8	16%	21%	23%	29%
Arkansas	8	13%	16%	26%	16%
Delaware	8	8%	8%	43%	14%
Colorado	7	19%	16%	16%	19%
Iowa	8	10%	5%	14%	25%
Minnesota	7	4%	5%	28%	29%
<b>Pooled Coefficient of Variation</b>		<b>13%</b>	<b>13%</b>	<b>31%</b>	<b>28%</b>

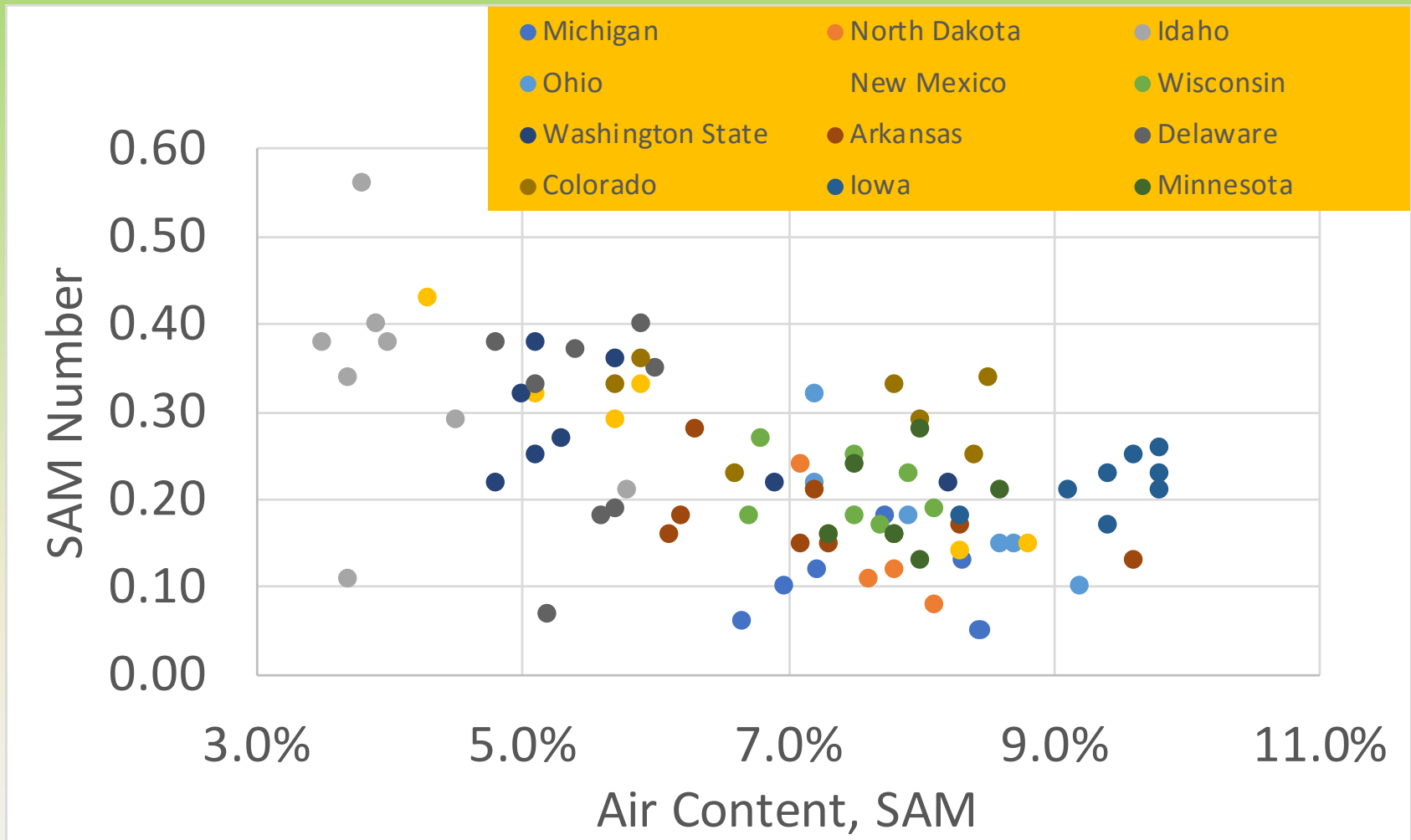


# Coefficients of Variation (COV) for Different Test Methods

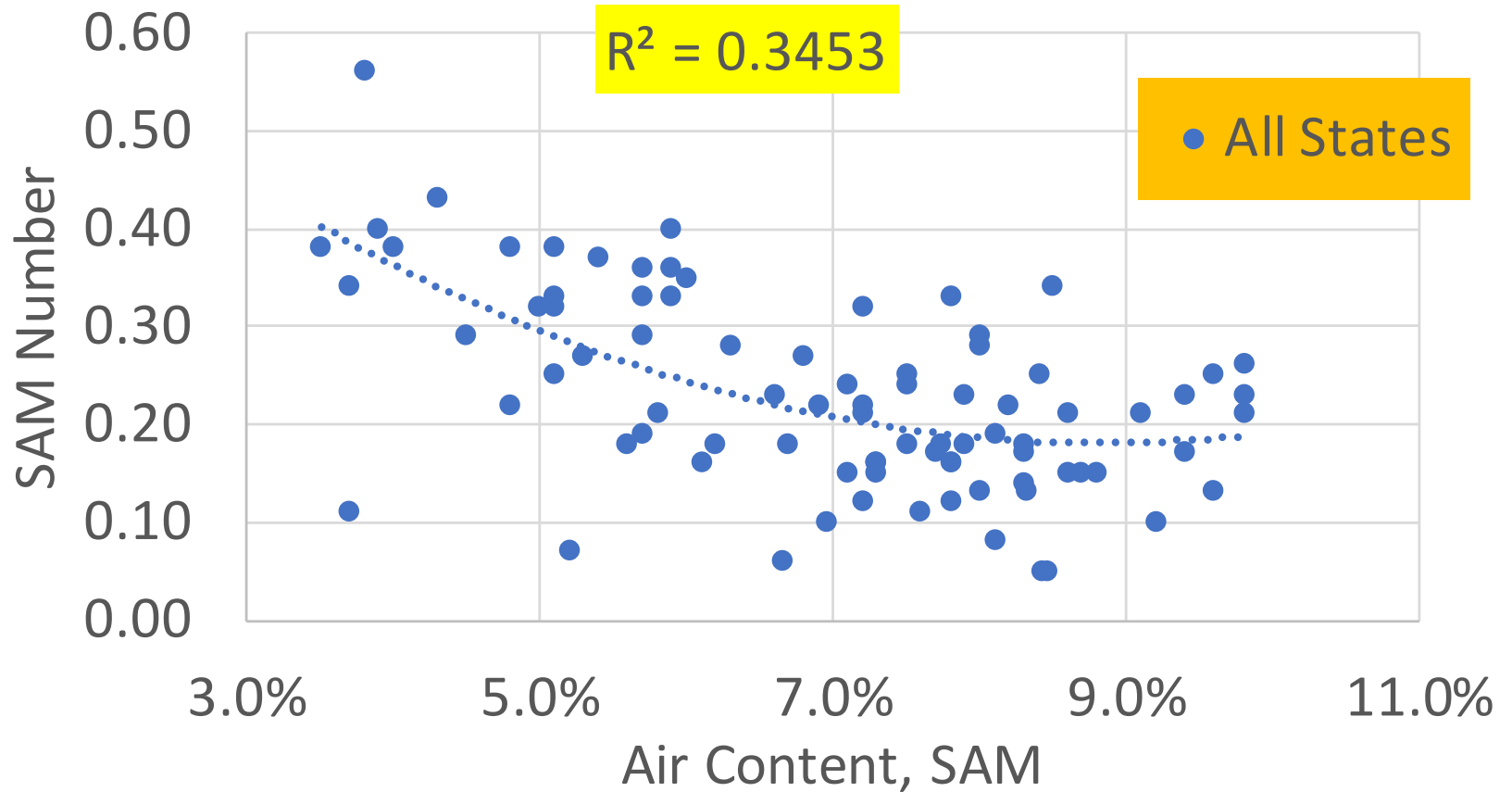
Test Method	Parameter	Composite COV during production	COV of the test method
SAM	SAM Number	31%	--
AVA	Spacing Factor	28%	--
ASTM C457	Spacing Factor	--	20%
ASTM C666*	Durability Factor	--	23%

\* From ASTM C666 with a durability factor of 75 and Method B

# SAM Number versus Air Content

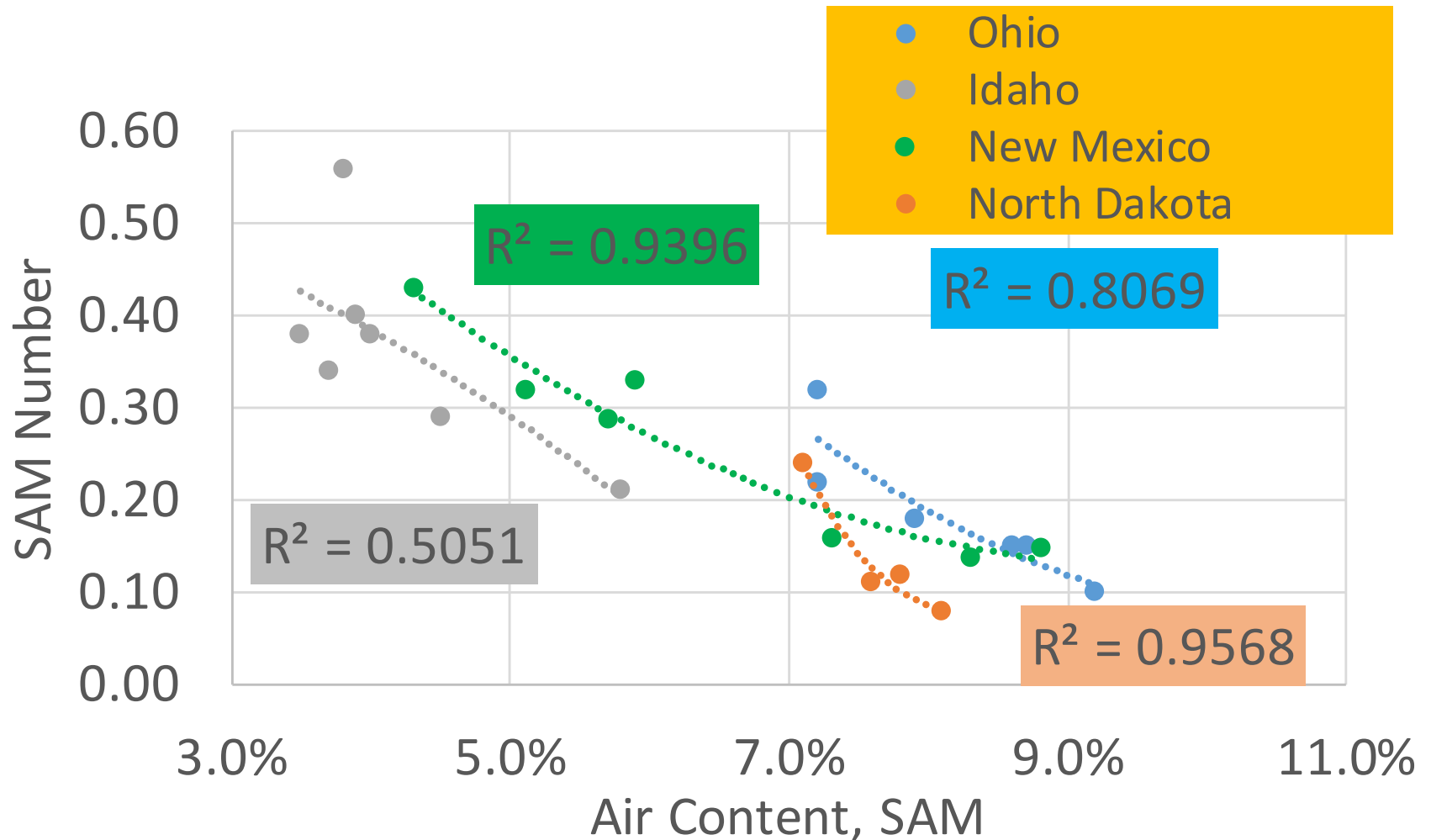


# SAM Number versus Air Content



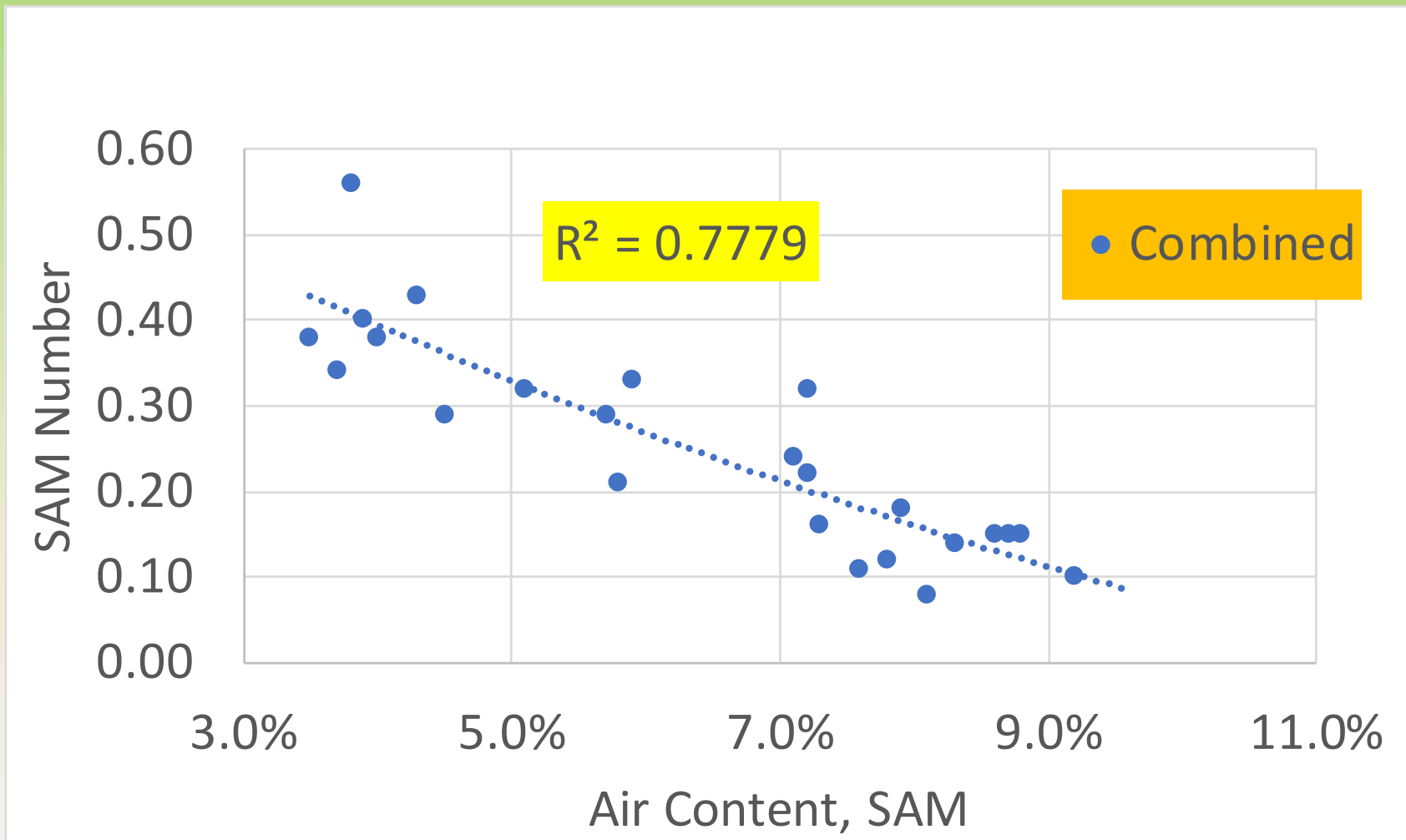
# SAM Number versus Air Content

## Mixtures with Good Correlation



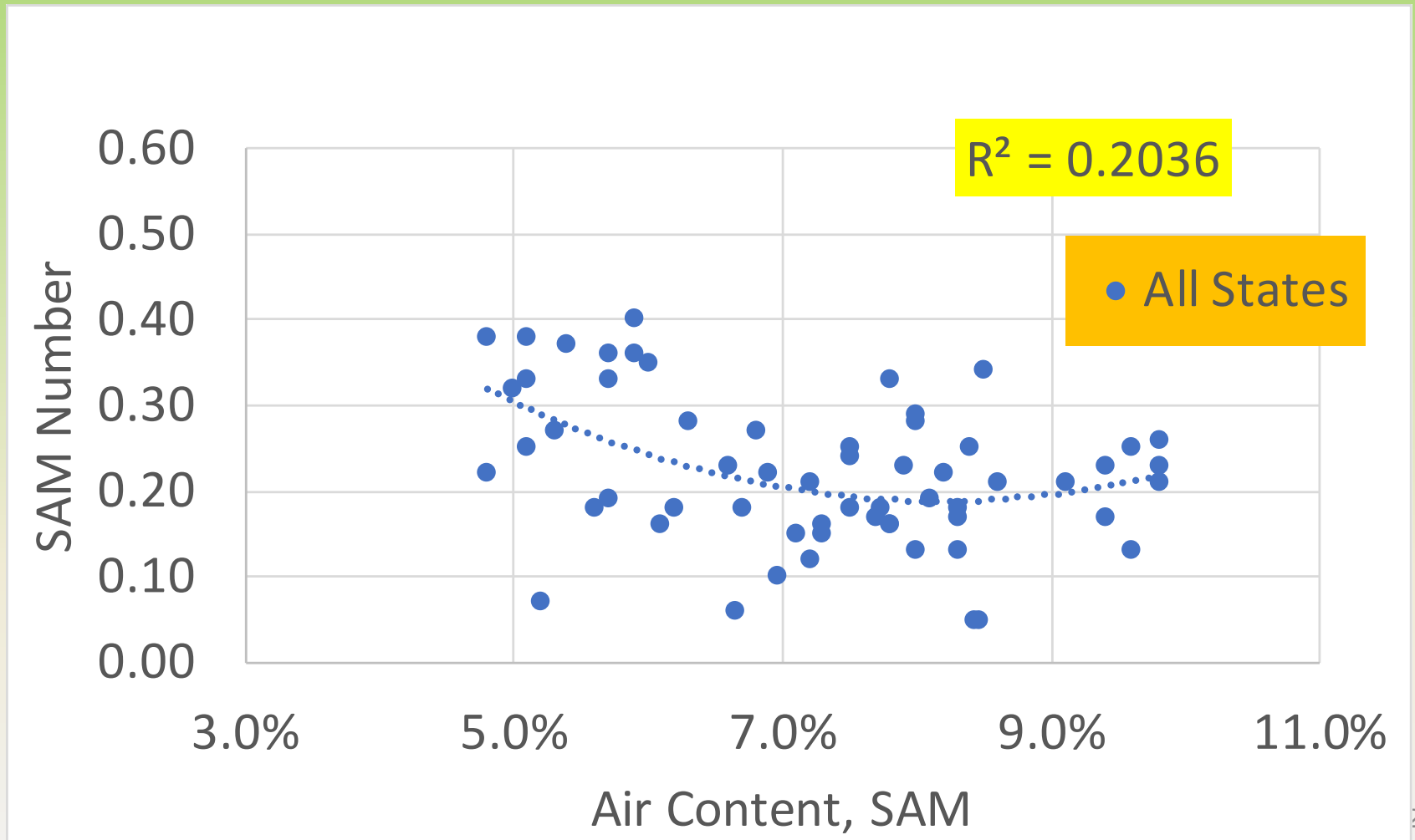
# SAM Number versus Air Content

## Mixtures with Good Correlation



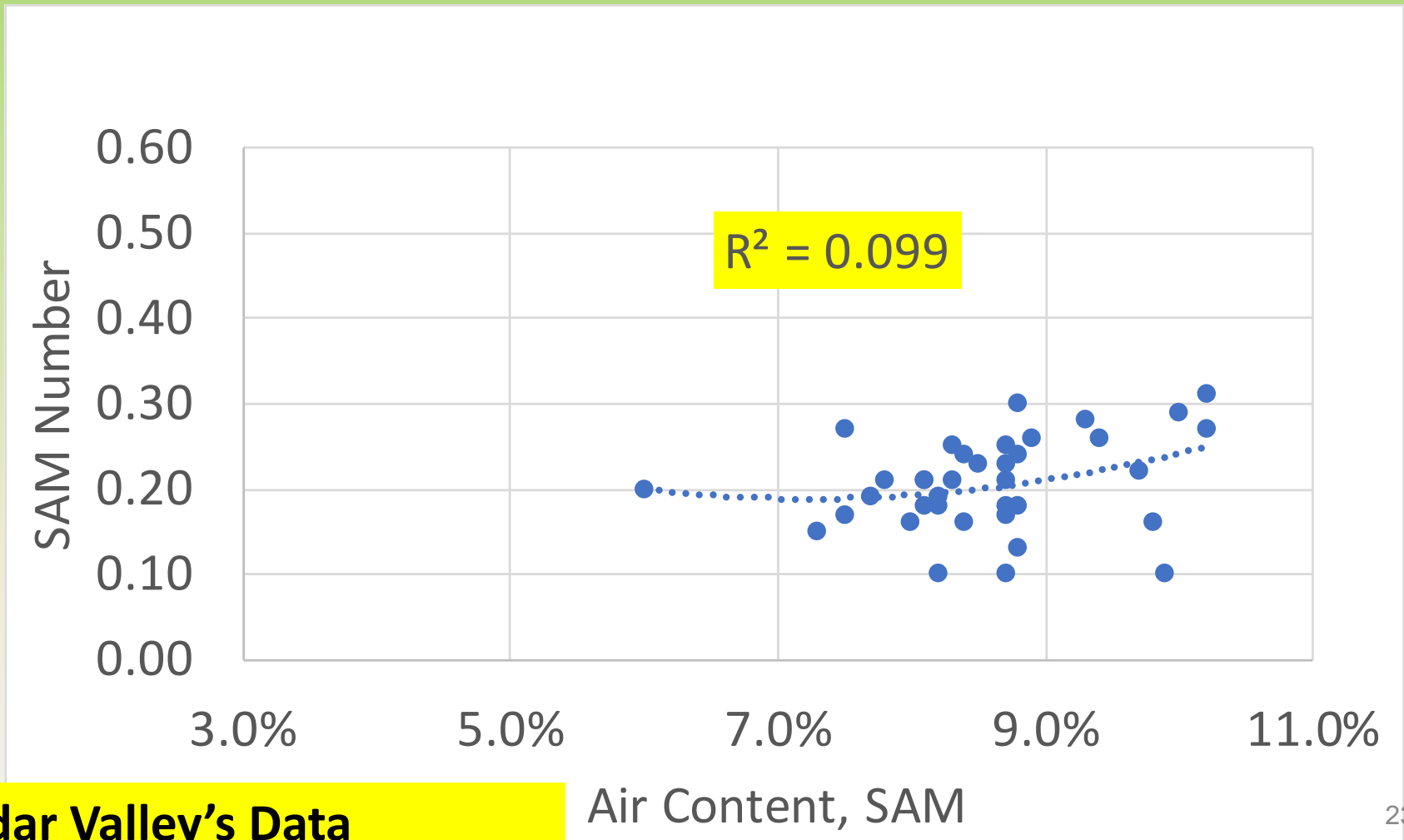
# SAM Number versus Air Content

Mixtures with Not so good Correlation

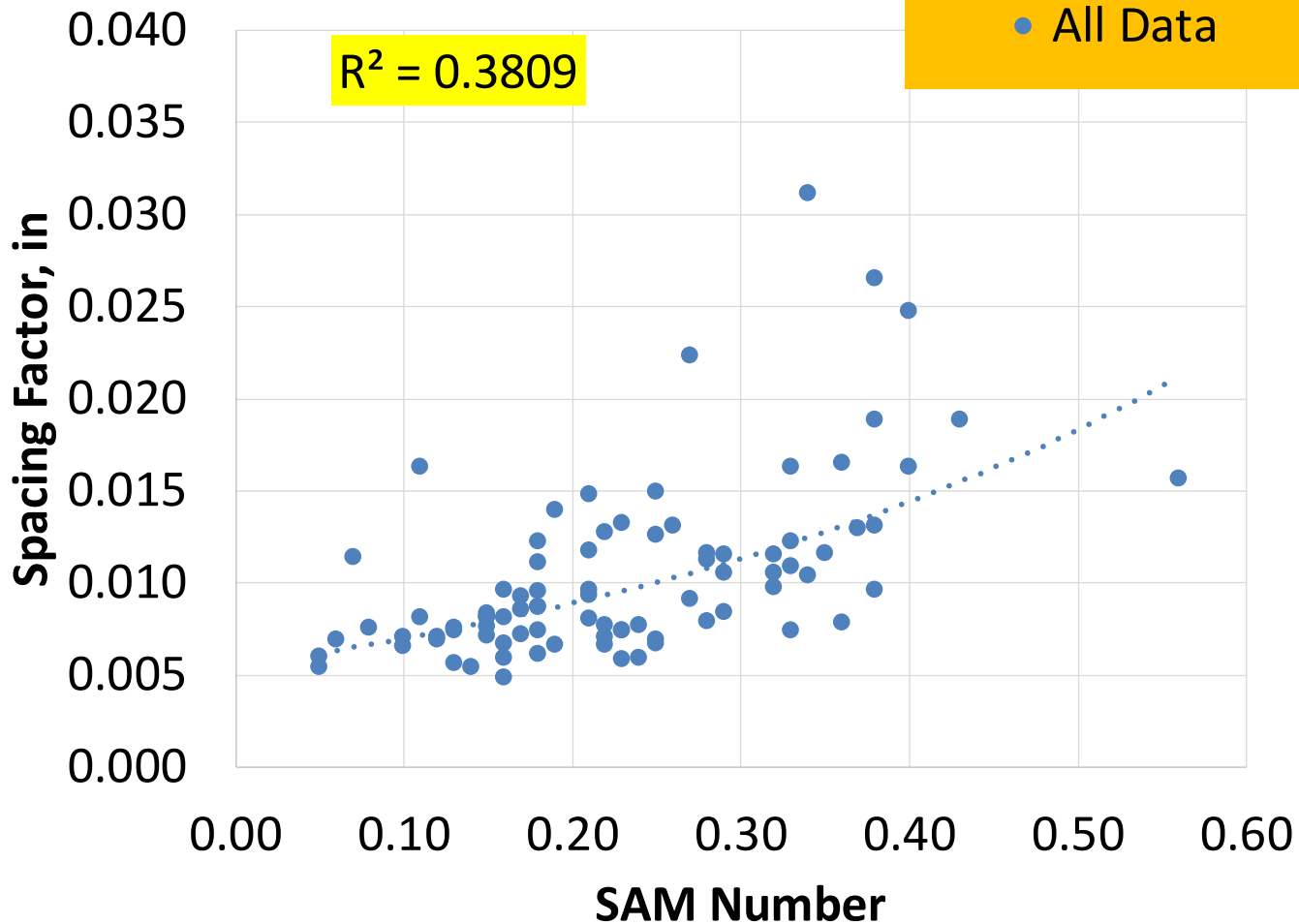


# SAM Number versus Air Content

Mixtures with Not so good Correlation



# SAM Number versus Spacing Factor

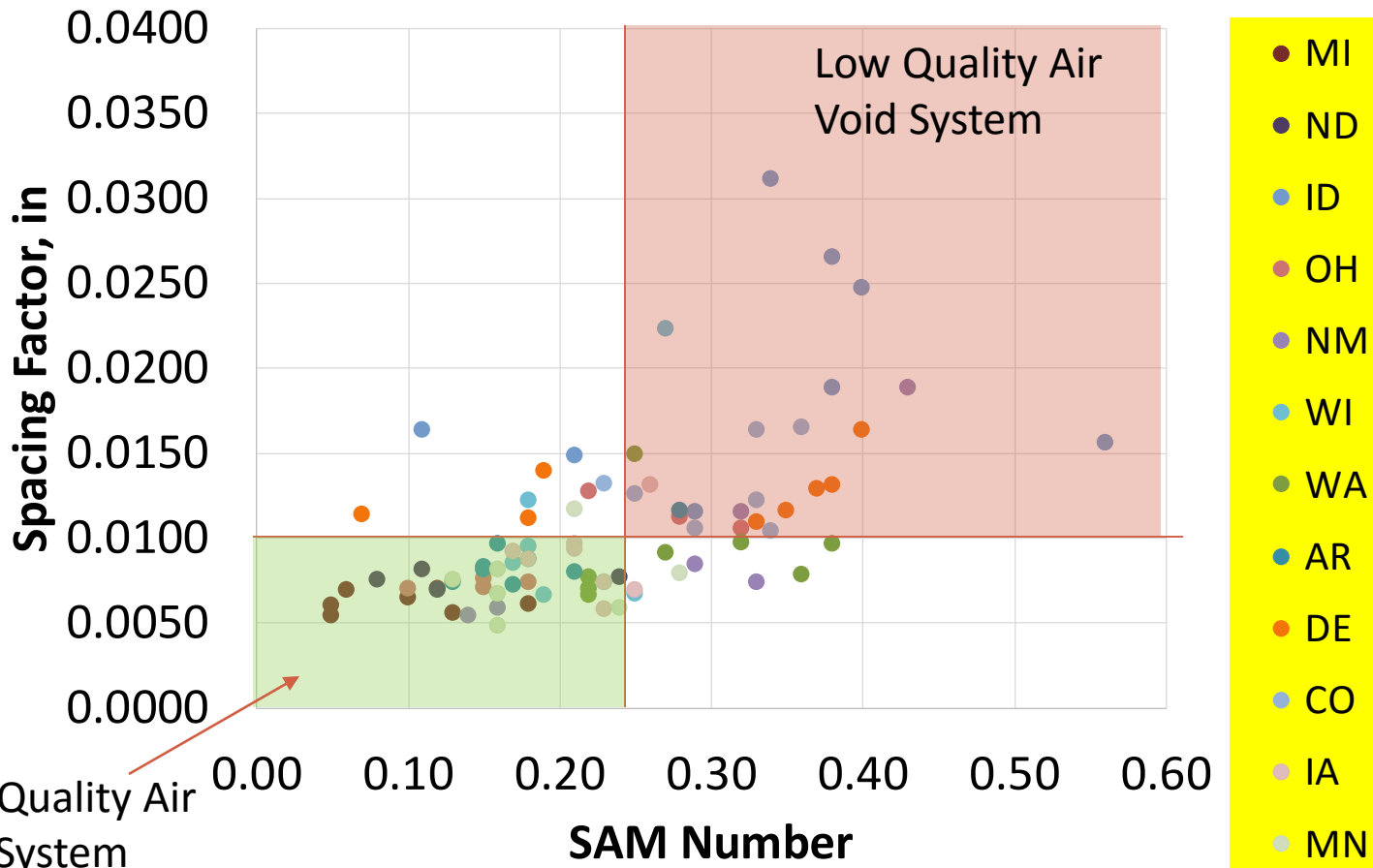




# SAM Number versus Spacing Factor



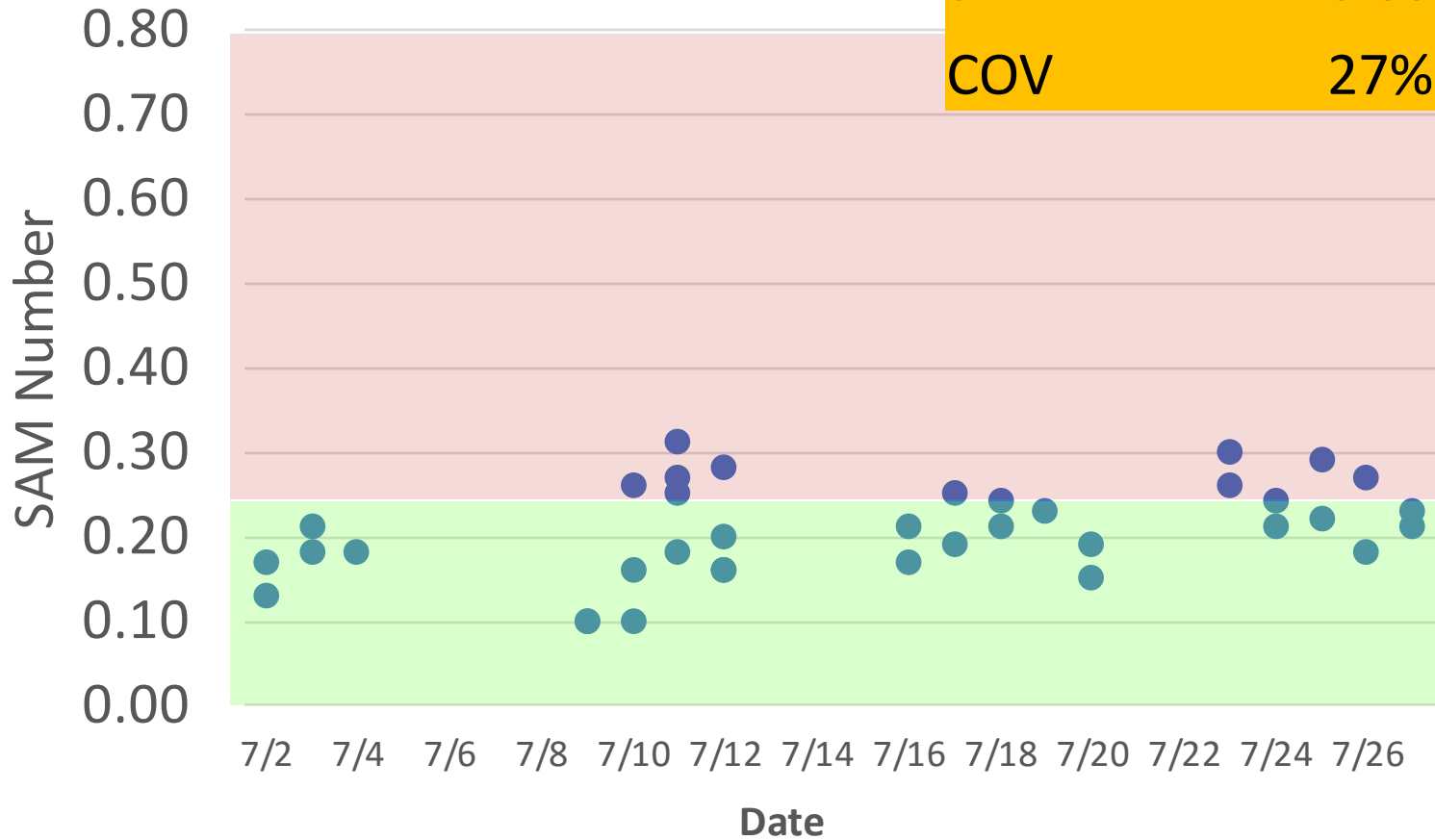
80% Agreement



# SAM Numbers – Extended Period

➤ Cedar Valley – Iowa

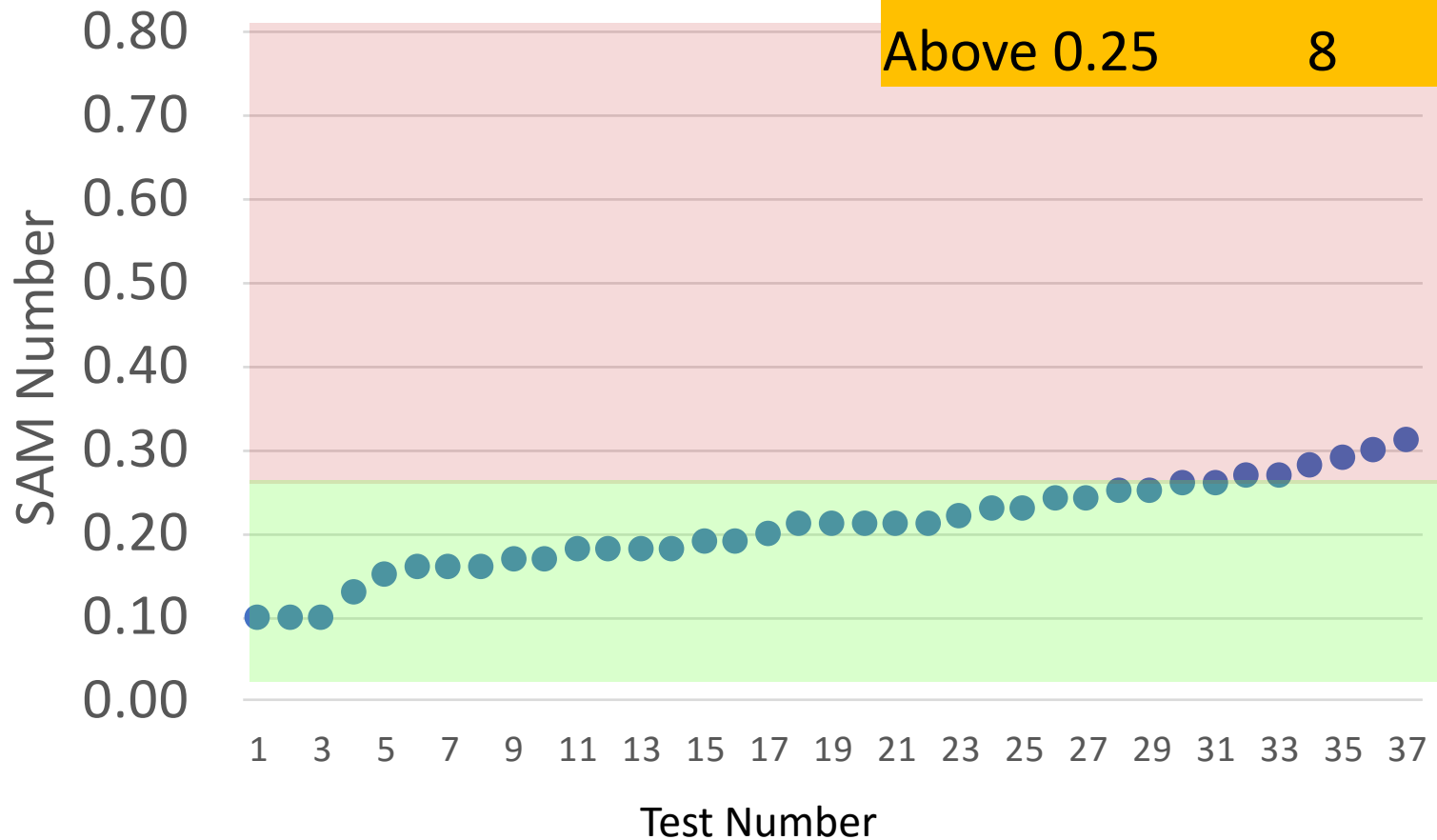
Average	0.21
SD	0.05
COV	27%



# SAM Numbers – Extended Period

## ➤ Cedar Valley – Iowa

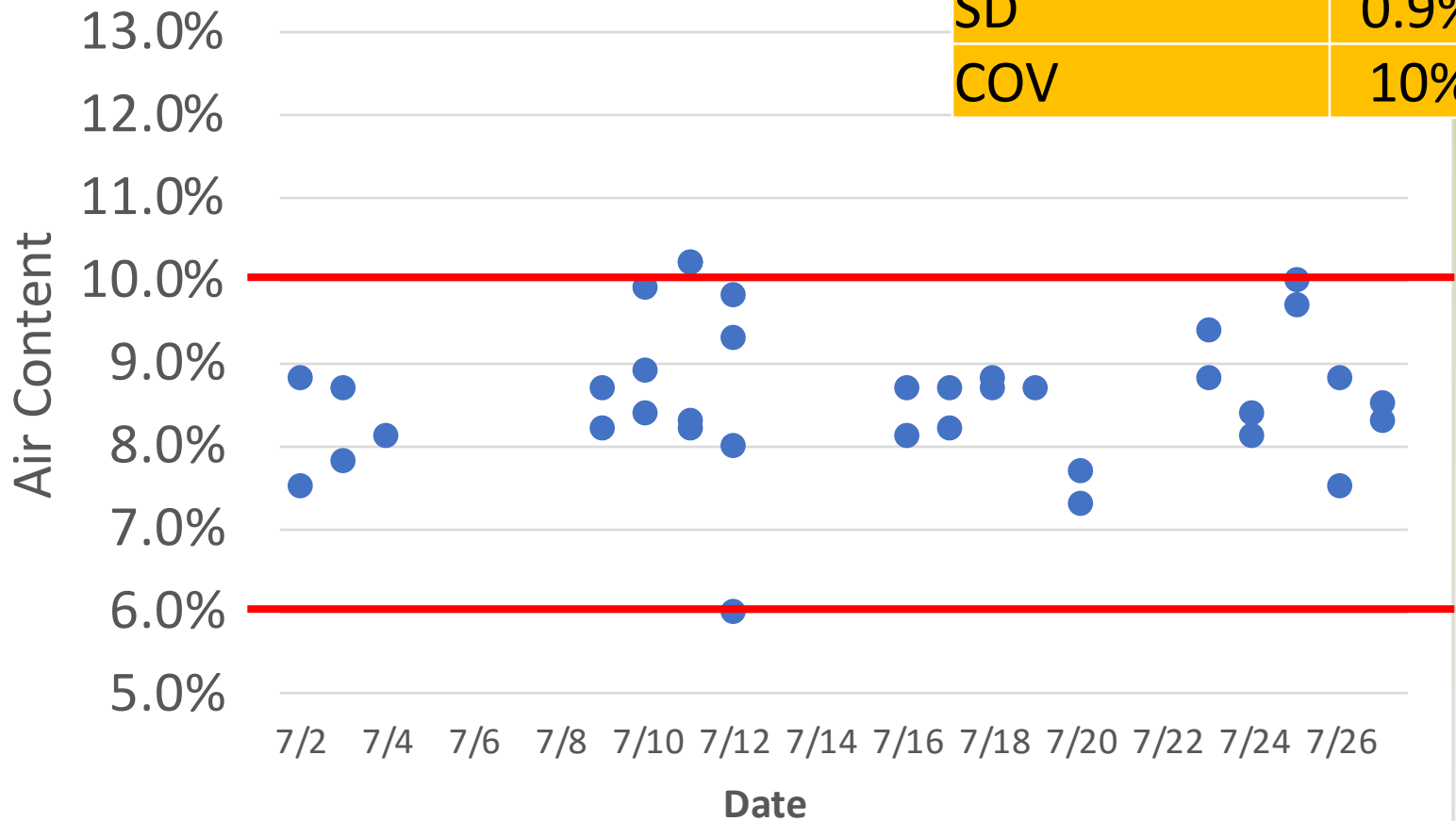
Total Tests	37
Above 0.30	1
Above 0.25	8



# SAM Air Content – Extended Period

## ➤ Cedar Valley – Iowa

Average	8.6%
SD	0.9%
COV	10%



# Conclusions

- Correlation of Total Air Content from Type B pressure meter and SAM meters was very good.
  - ✓ Similar standard deviations.
- The pooled Standard Deviation of the SAM number for a typical project is 0.07.
- The Coefficient of Variability (composite variability) of the SAM test from the 11 project was 31%, which compares well with existing test methods.

# Conclusions

- The relationship between total air content and the SAM number is mixture specific. This data illustrates why we need the SAM test.
  - ✓ For some mixture, as the air content increases, the SAM number decreases. In other cases, this relationship is not too obvious.
- The SAM Number of 0.25 correlates to a spacing factor (AVA) of 0.01” for the 11 paving projects.
  - ✓ 80% agreement in the field.

# Conclusions

- Care should be taken if using SAM test as a pass/fail test.
- SAM test would lend itself well in a PWL specification.

# Conclusions

- Care should be taken if using SAM test as a pass/fail test.
- SAM test would lend itself well in a PWL specification.



# Questions???

