QMC - PEM Test Data Comparison

Iowa Concrete Paving Conference
February 7th, 2020
Des Moines, IA

Todd Hanson, PE Concrete Materials Engineer

Introduction

- Brief History of QMC
- Lessons Learned
- PEM Shadow Project
- QMC vs PEM
- Future

Pavement Placement Issues

- Mid ‘80s to mid ‘90s seemed to get a couple projects a year with workability issues
- Some related to mix & some related to incompatibility
- Since QMC rarely

US 169 Webster Co. 1990

Direct Relationship To Placement Problems & Long Term Durability

US 169 Webster Co. 2007

Development of QMC Specification

- 1997 First (QMC) project awarded
- Technical Partnering Meetings
- Incentive – Compressive Strength
- A- Mix

PARTNERING CHARTER
FRED CARLSON CO., ALLIED CONSTRUCTION CO., LEHIGH CEMENT CO., INDUSTRIAL SERVICES GROUP , W.R. GRACE, IOWA DOT CENTRAL LAB & , DISTRICT TWO MATERIALS LAB, CONSTRUCTION OFFICE & THE NEW HAMPTON RESIDENT CONSTRUCTION OFFICE.

April 6, 2000

We the Fred Carlson Co., Allied Construction Co., Lehigh Cement Co., Industrial Services Group, W.R. Grace, the Iowa DOT Central Lab. and Construction Office, the District 2 Materials Lab., and New Hampton RCE Office are committed to producing high quality and economical portland cement concrete pavements on a timely basis by providing a consistent and performance based pavement material, with sufficient mixing and quality placement.

Mix Design & Communication

- The Fred Carlson Co. will furnish the Iowa DOT with documentation of various mix designs and tests that have been designed to provide the desired performance results from alternative considered materials and admixture. They will also indicate under what conditions each mix will be employed.
- The Iowa DOT will review the mix designs identified for project use by the Fred Carlson Co. and provide constructive comments on the application of each mix.
- The Fred Carlson Co., material suppliers, and Iowa DOT will continue to communicate prior to and during the construction as material supplies change, to share information on the implied changes in mix design that are required to meet the contract performance criteria.
- The communication lines and report format, for reporting test results, mix adjustments, changes will be outlined by both parties at the preconstruction conference

Aggregate Production & Communication

- The Fred Carlson Co. will indicate in writing the Quality Control plan that provides his staff, material suppliers, and the Iowa DOT with a plan for assessing the quality of the aggregates, cement, admixtures, and the mix provided to the roadway and placed.
- The communication lines between contractor staff and Iowa DOT personnel, for identification of test results, the need for change at the plant or at the grade will be outlined at the preconstruction meeting by both parties.
- The aggregate, cement and admixture suppliers will develop the communication lines with the Fred Carlson Co. to assure the quality and quantity of the materials will be provided in a timely manner and establish guidelines on how to effect changes if mix changes become needed on the project.

Concrete Paver Construction & Iowa DOT Communications

- The Fred Carlson Co. in the Quality Control plan will identify the communication lines that respond to problems encountered at the paver with the mix and how adjustments will be made at the paver and plant.

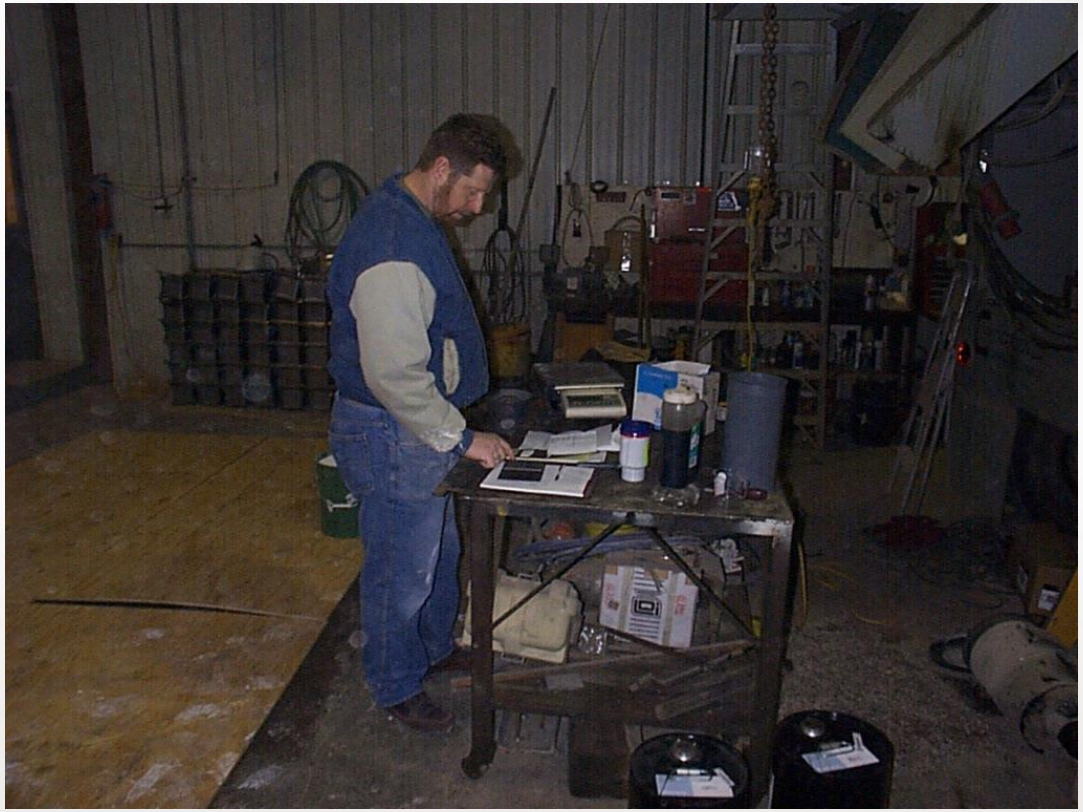
QMC History - Strength

- 1998 to 1999 projects -12 projects
  - 28 day third point flexural
    - >600 psi (avg - 1 stdev)

Strength	Pay Factor
BELOW 450	REMOVE
450 - 474	70
475 - 499	75
500 - 524	80
525 - 549	85
550 - 559	90
560 - 569	92
570 - 579	94
580 - 589	96
590 - 599	98
600 - 624	100
625 - 649	101
650 - 674	102
675 & ABOVE	103

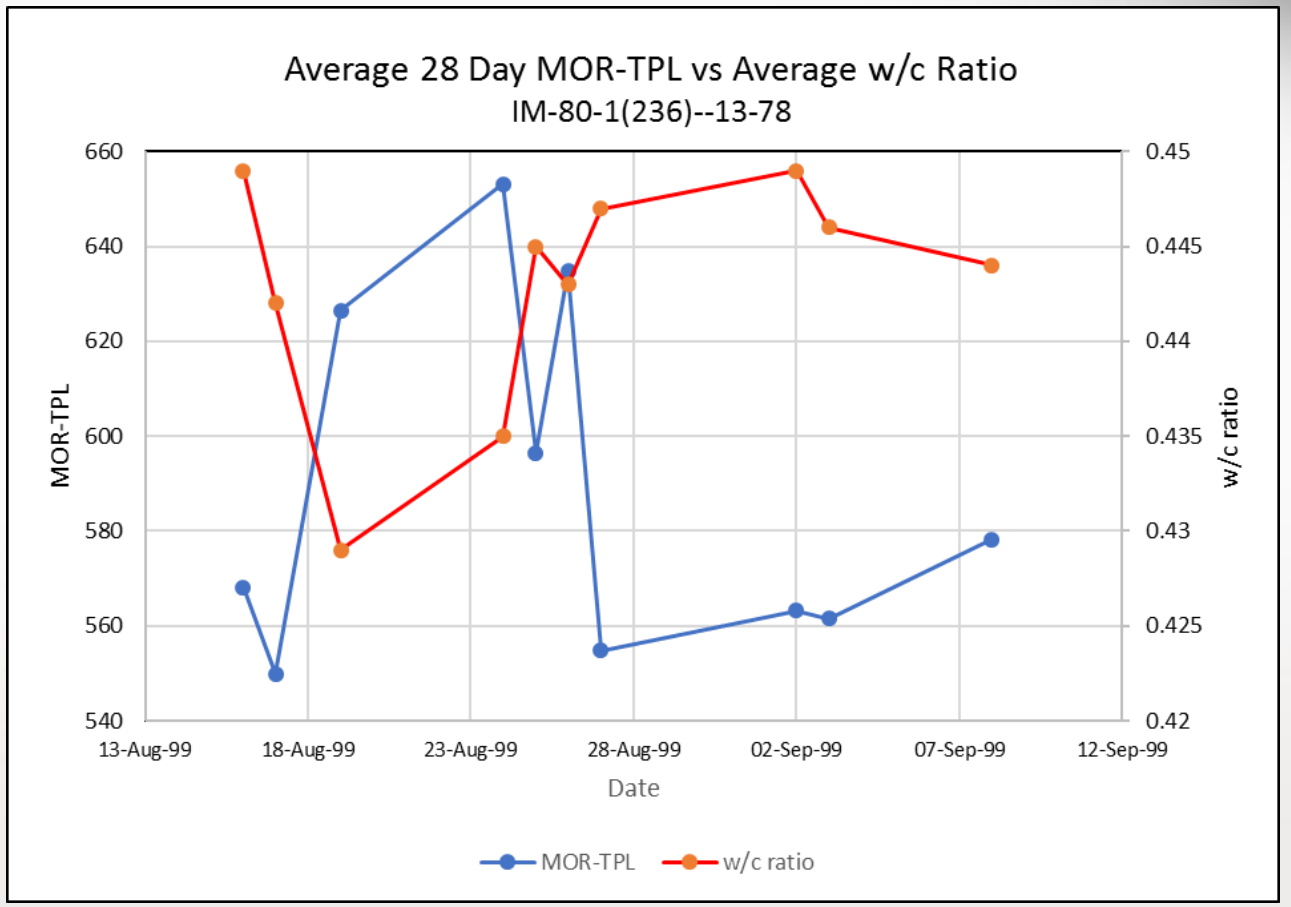
QMC History - Strength

- Multiple Mix Designs
- Fred Carlson Lab
  - 11 mixes for Mason City bypass



QMC History - Strength

- Minimal mix improvement
- Couple projects with significant disincentive$
- Issues with long haul distance with soft aggregate
- Changes to QMC Needed



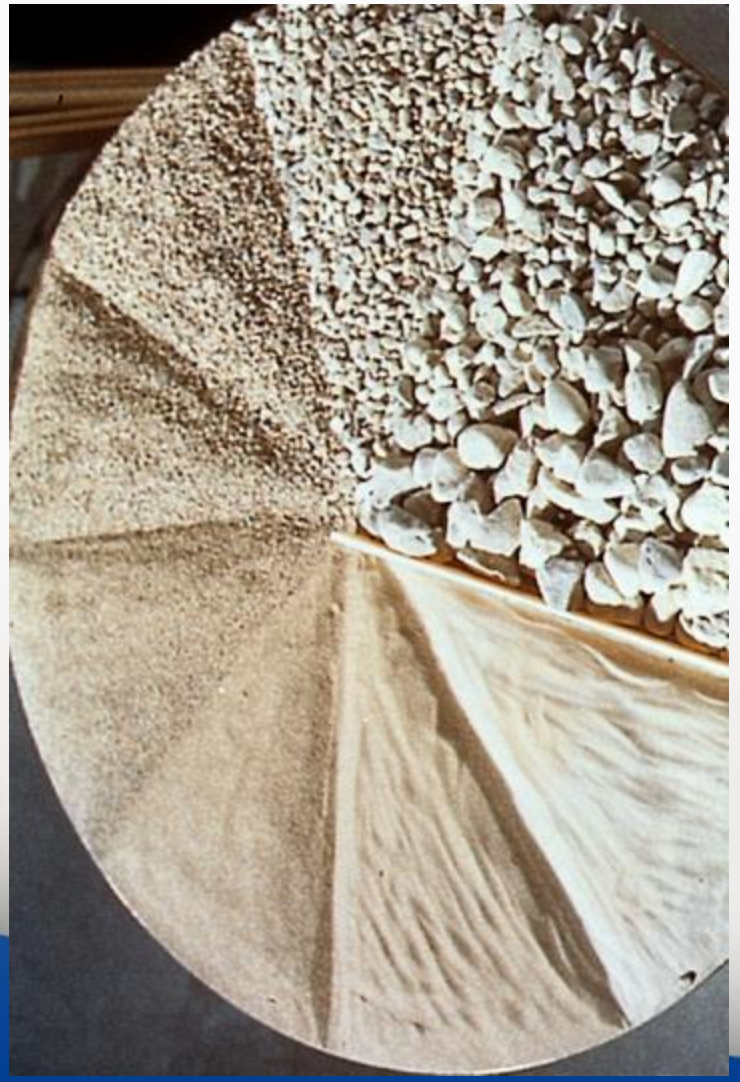
QMC History - Strength

- Do we make better concrete because we test beams?
- Or, do we make better beams?
- Not a strong correlation of strength to durability

Optimized Gradation in Slipform Rail Experience

- 1999 near Rudd
- Reduced Cement 709 to 603 lbs/cy
- 1st Use of Shilstone Gradation
- Left car running, in case it went south
- But, Placement improved dramatically

Optimized Mix Design for Pavements



Based on Coarseness - Workability Factor Chart

- Improved Placement Characteristics
- Response to vibrator
- Reduced Shrinkage
- Allows for Quality Control

THE SHILSTONE COMPANIES, INC.

Materials Technology for Design and Construction

CONCRETE MIX ANALYSIS
INTERPRETING THE COARSENESS FACTOR CHART

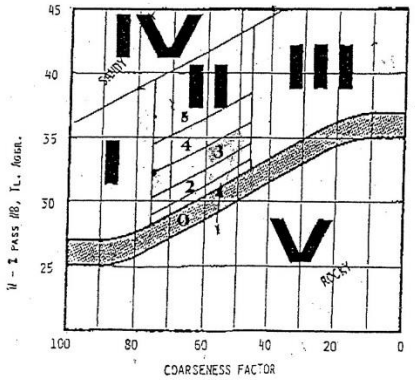
The Coarseness Factor Chart was developed by James Shilstone in 1974 following research for the U. S. Army Corps of Engineers for construction in Saudi Arabia. The findings were reported in CONCRETE INTERNATIONAL, June 1990 in a paper titled "Concrete Mixture Optimization" (p.33). Since introduction, the chart has been extensively used as a means to evaluate the characteristics of concrete mixtures.

The purpose is to address the combined aggregate grading. When aggregates are mixed in concrete, it is the combined grading that affects performance on the job. Strength is seldom the problem. The problems are related to placement, finishing, and durability. While the concrete industry normally classifies aggregates as coarse or fine, the research reflected the need for three size groupings - coarse, intermediate, and fine.

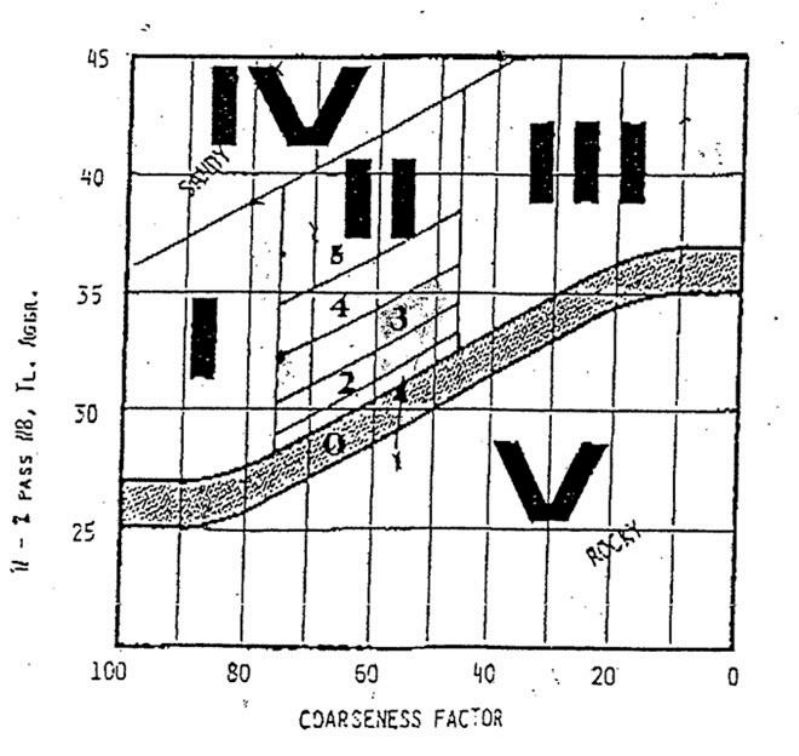
The Coarseness Factor ("x" axis) on the chart is the percent of all material retained on the No. 8 sieve that is also retained on the 3/8" sieve. The "y" axis is the percent of aggregate passing the No. 8 sieve adjusted for cementitious materials content. The "x" plotted on the chart reflects the affect of cement content on the effective amount of fine sand. When a "+" is plotted, no adjustment was necessary. The diagonal bar reflects the approximate optimum combined aggregate grading when using rounded gravel or cubically crushed stone and natural sand.

Much has been learned regarding use of this Chart. Following is a summary of interpretations derived from many years of experience evaluating thousands of mixtures:

ZONE I: Coarse, gap-graded tends to segregate; ZONE II: Well graded 1-1/2" and 1";
ZONE III: 3/4" and finer; ZONE IV: Sticky - "The Courthouse"; ZONE V: Rocky
"0" - Optimum but excellent control required; "1" - Excellent but caution;
"2" - Excellent paving & slip form; "3" - High quality slab; "4" - Good general;
"5" - Varies to materials and construction needs. Same general trends for Zone III



GLEN LAKES TOWER, SUITE 105, 9400 N. CENTRAL EXPRESSWAY, DALLAS, TEXAS 75231-5033
(214) 361-9801
FAX: (214) 361-7925



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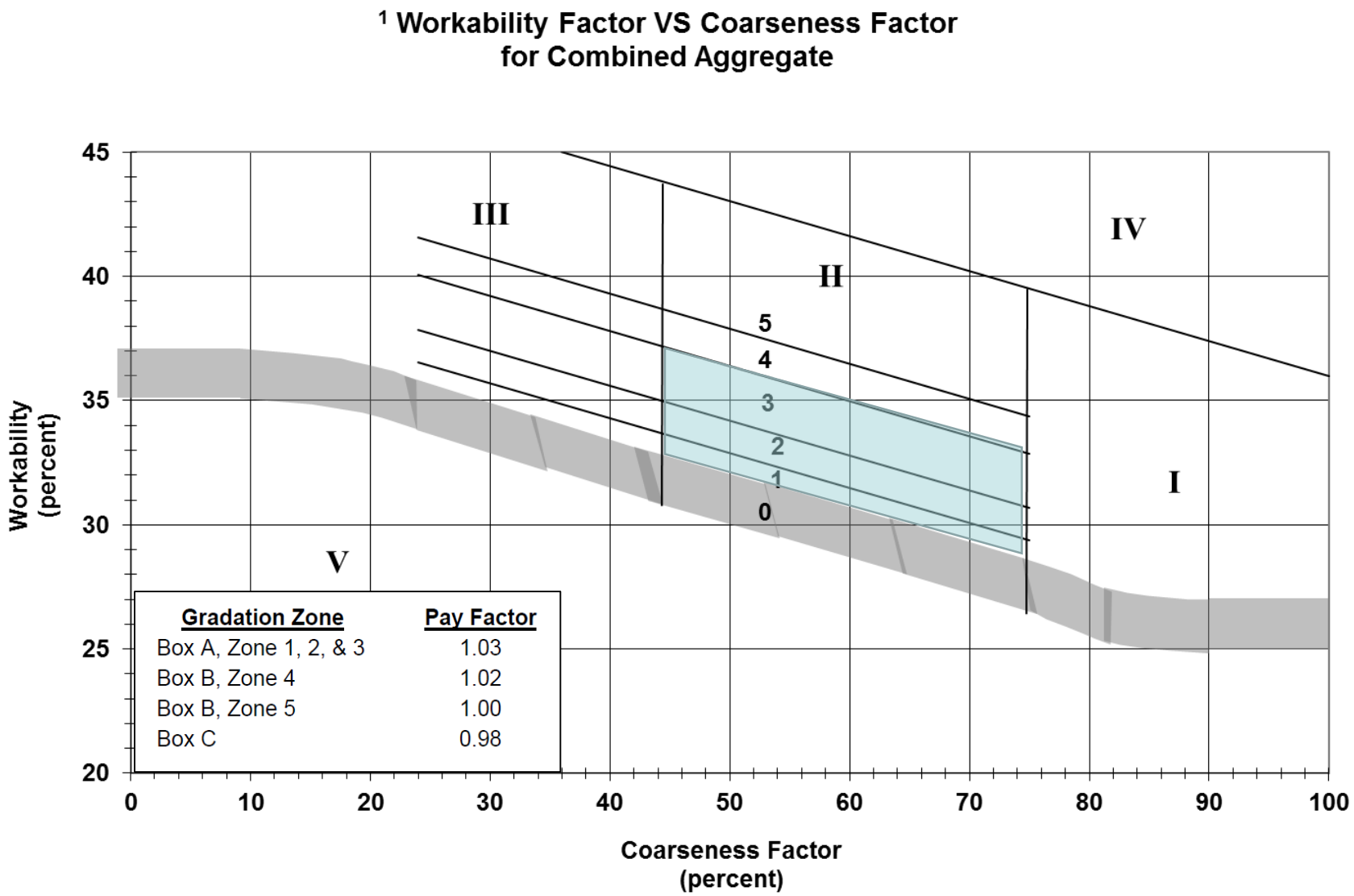
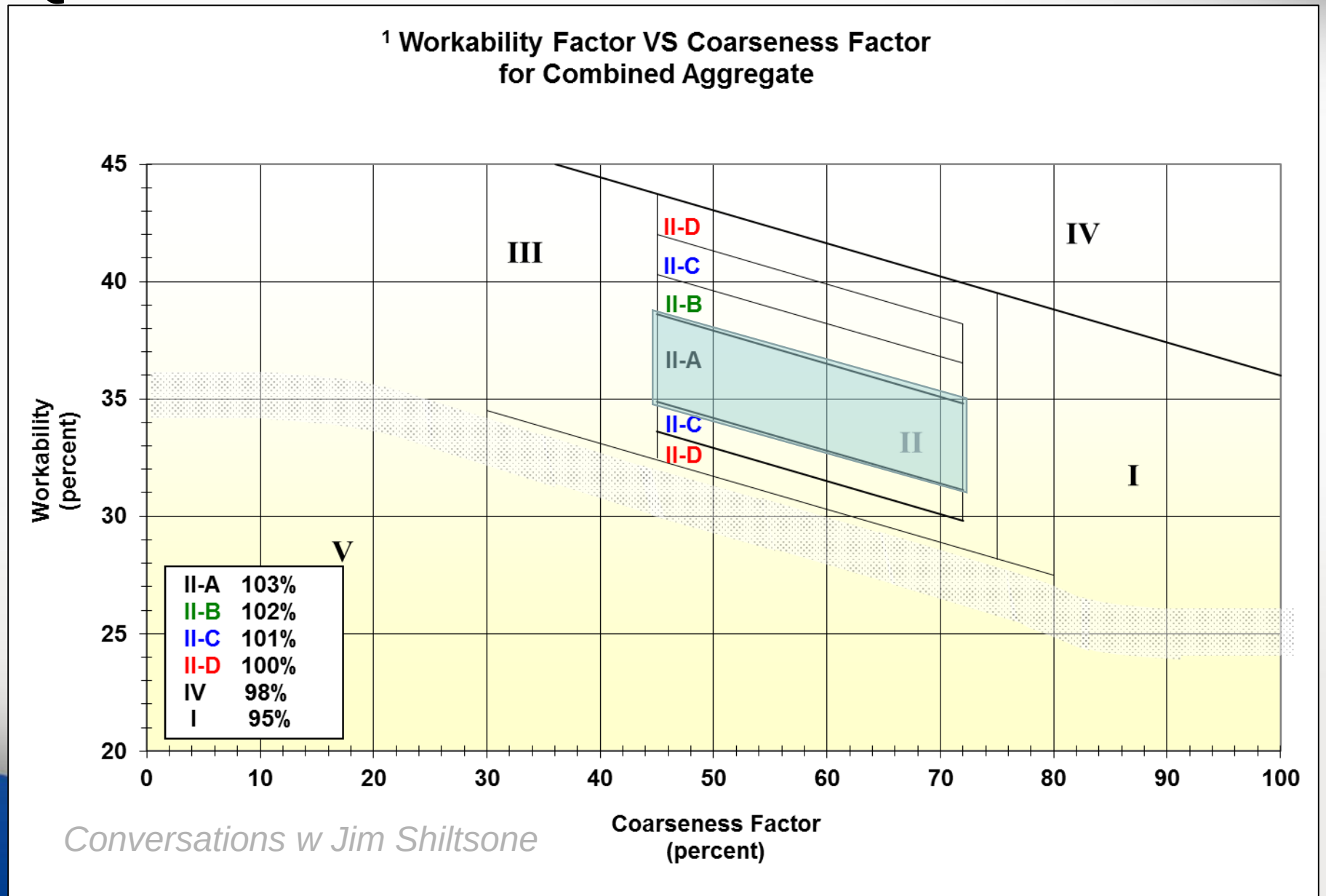
QMC Gradation Incentive 2000-2004

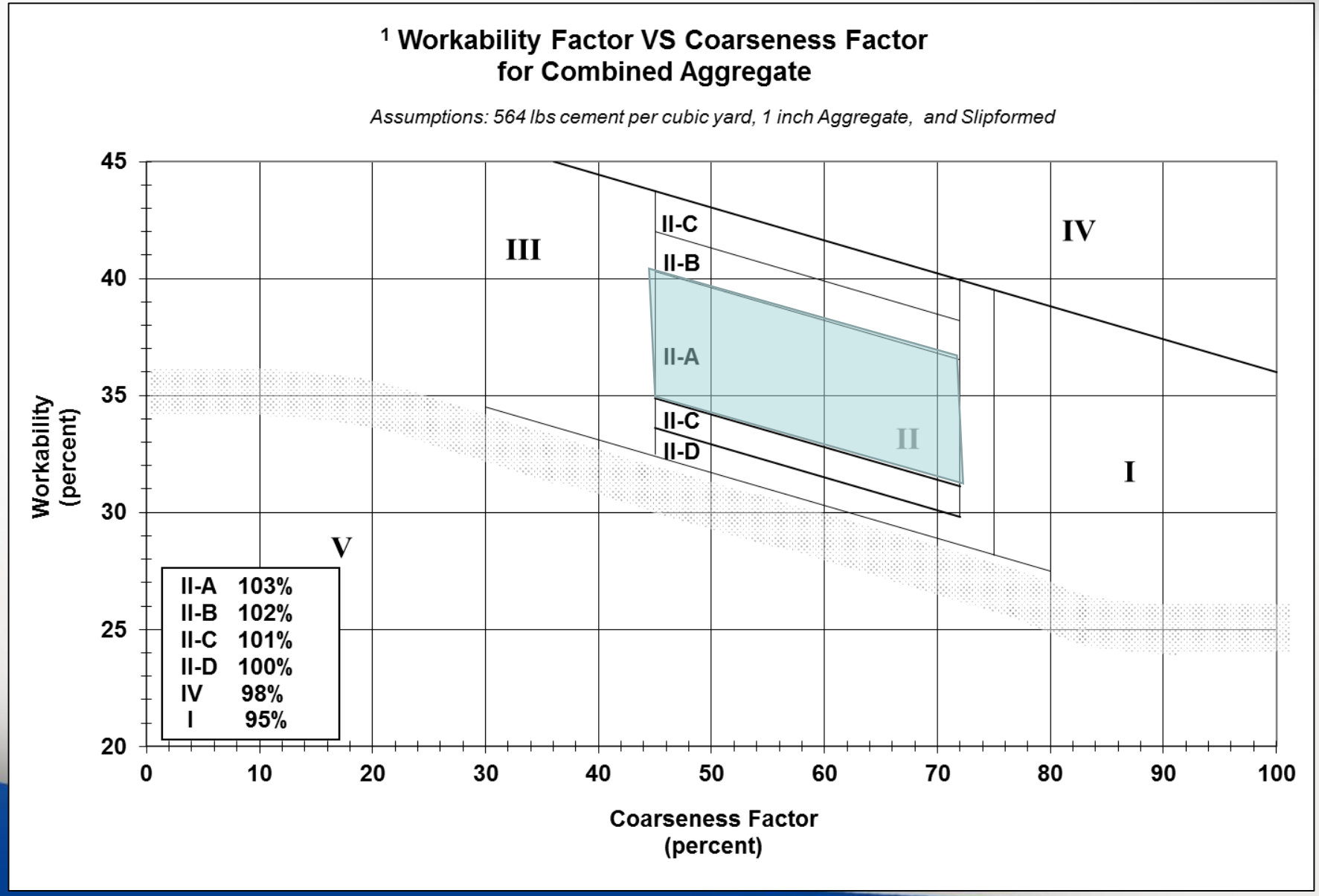


QMC Gradation Incentive 2004-2007

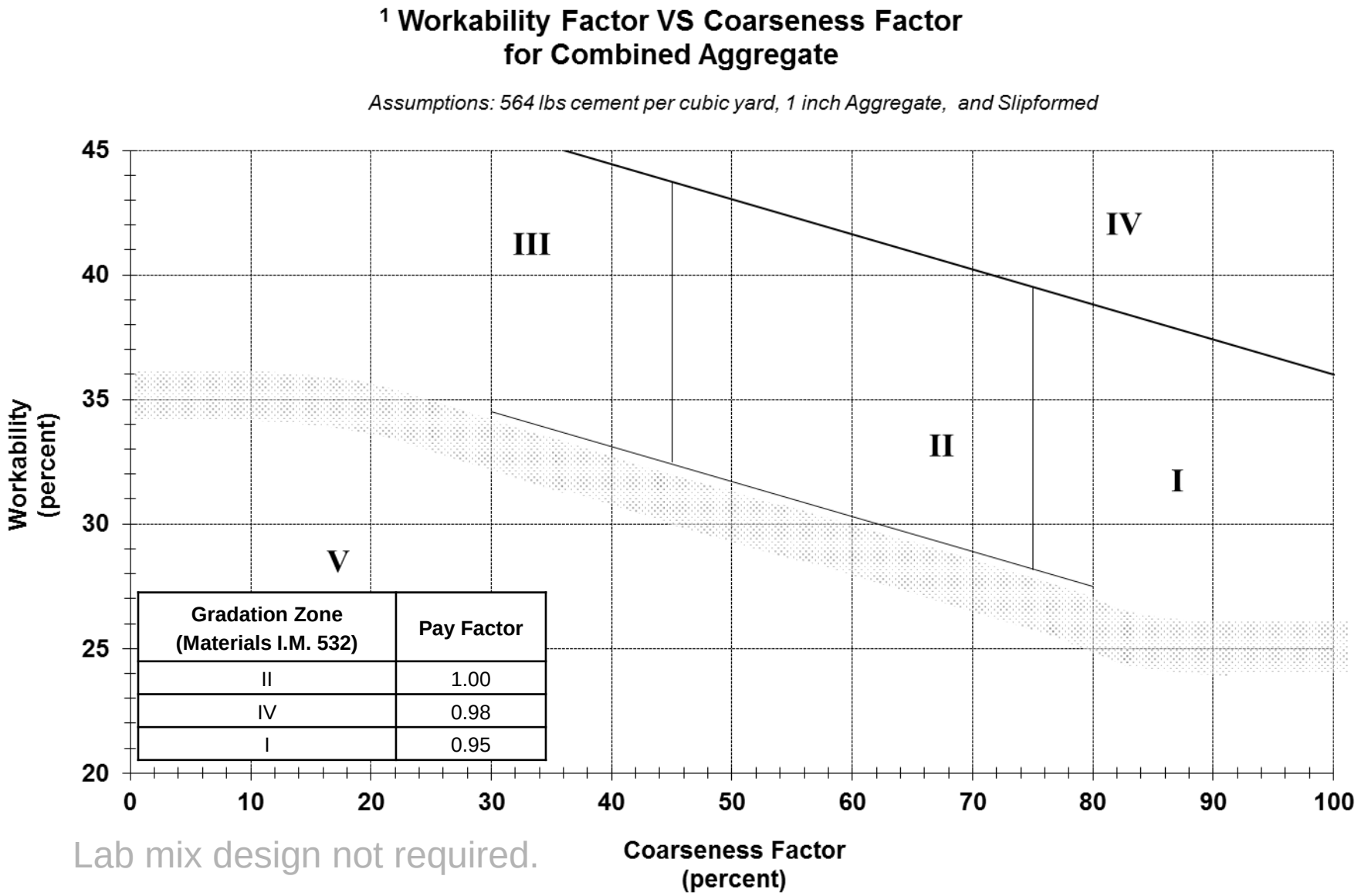


Conversations w Jim Shiltsone

QMC Gradation Incentive 2007-2015



QMC Gradation 2016 to 2019



Gradation Zone (Materials I.M. 532)	Pay Factor
II	1.00
IV	0.98
I	0.95

Lab mix design not required.

QMC Effect of Aggregate Shape

Intermediate Aggregates

QMC – Aggregate Shape

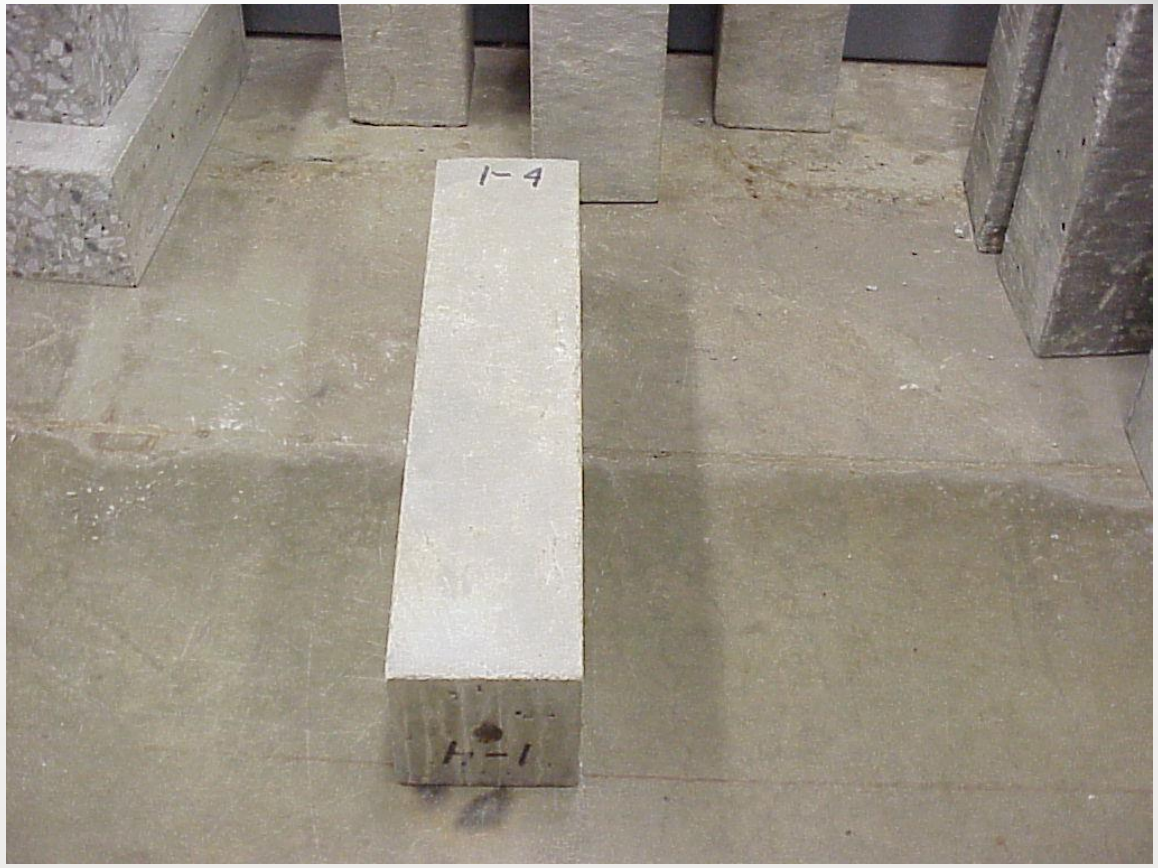
- US 75 Woodbury Co. 2000
- Quartzite CA & IA
  - 45.5% CA/ 19.5% IA/ 35% FA
- Coarse on Shilstone Chart
- Results
  - finishing difficulties
  - edge tear
  - slow production rates

QMC – Aggregate Shape

- US 75 Woodbury 2001
- Quartzite CA & IA
  - 53.5% CA/ 9.5% IA/ 37% FA
- Better Intermediate aggregate shape
- Results
  - better finishability
  - no edge tear
  - normal production rates

Intermediate Aggregate Research

- MLR-2000-03
  - Class 2, 3, 3I pea gravel
  - F/T test salt soaked
  - Minimal difference
- Allow pea gravel up to 15% lower durability class
- Improved Workability



QMC - Aggregate Shape

- IA 60 Sioux County 2005
- Quartzite CA & Pea Gravel IA
  - 42.5% CA/ 14.5% IA/ 43% FA
- Results
  - Excellent finishability
  - Excellent smoothness

QMC - Aggregate Shape

- Quartzite CA Stockpile

- Pea Gravel IA Stockpile

QMC – Aggregate Shape

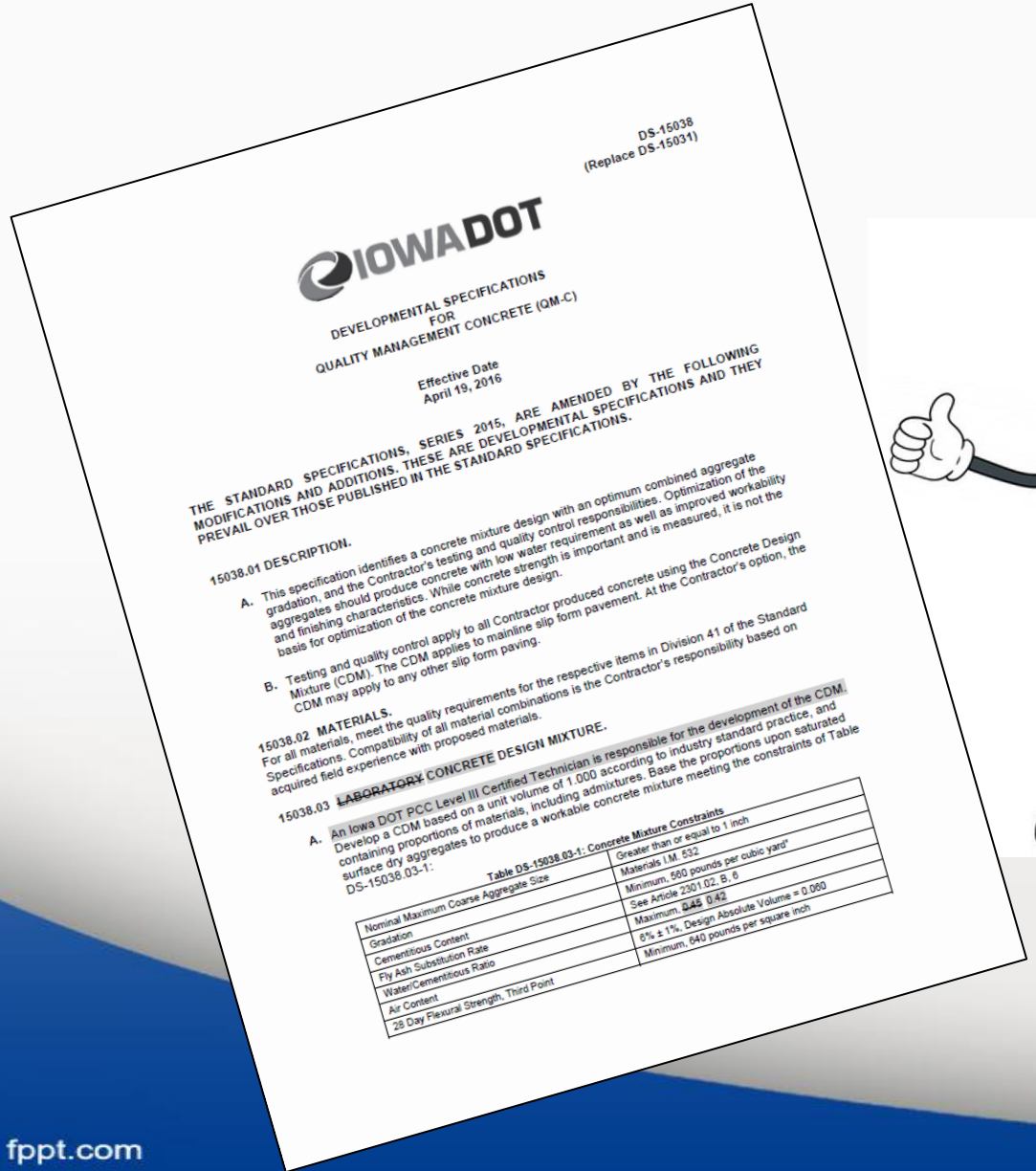
- US 20 Woodbury County 2016
- Gravel CA & Pea Gravel IA
  - 48% CA/ 10% IA/ 42% FA
- Key results
  - Excellent finishability
  - normal production rates
  - <u>Edge tended to dip at baskets</u>

Too workable or Too much paste ??

QMC Lessons Learned Summary

- Partnership with contractors expedited changes
- Placement impacts durability
- Excessive handling with soft aggregates affect strength
- Well graded aggregates improve placement
- Aggregate shape and texture affect placement
- Slag and fly ash reduce permeability

How does QMC mix compare with PEM?



DS-15038
(Replace DS-15031)

IOWADOT

DEVELOPMENTAL SPECIFICATIONS
FOR
QUALITY MANAGEMENT CONCRETE (QM-C)

Effective Date
April 19, 2016

THE STANDARD SPECIFICATIONS, SERIES 2015, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE DEVELOPMENTAL SPECIFICATIONS AND THEY PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

15038.01 DESCRIPTION.

A. This specification identifies a concrete mixture design with an optimum combined aggregate gradation, and the Contractor's testing and quality control responsibilities. Optimization of the aggregates should produce concrete with low water requirement as well as improved workability and finishing characteristics. While concrete strength is important and is measured, it is not the basis for optimization of the concrete mixture design.

B. Testing and quality control apply to all Contractor produced concrete using the Concrete Design Mixture (CDM). The CDM applies to mainline slip form pavement. At the Contractor's option, the CDM may apply to any other slip form paving.

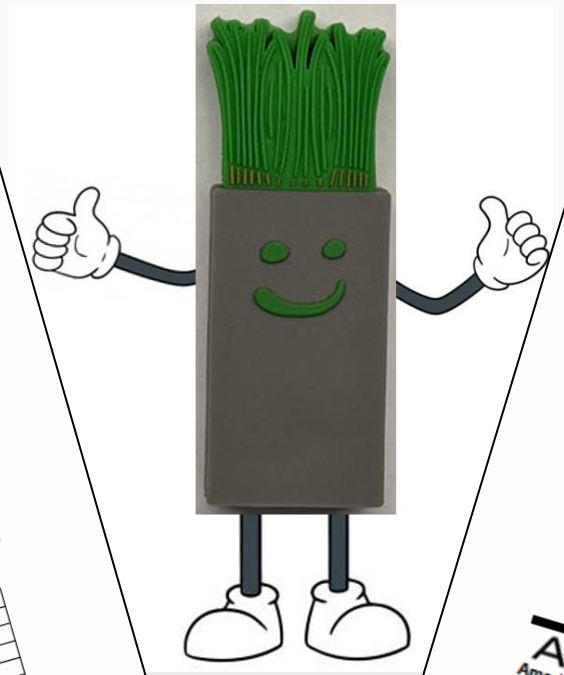
15038.02 MATERIALS.
For all materials, meet the quality requirements for the respective items in Division 41 of the Standard Specifications. Compatibility of all material combinations is the Contractor's responsibility based on acquired field experience with proposed materials.

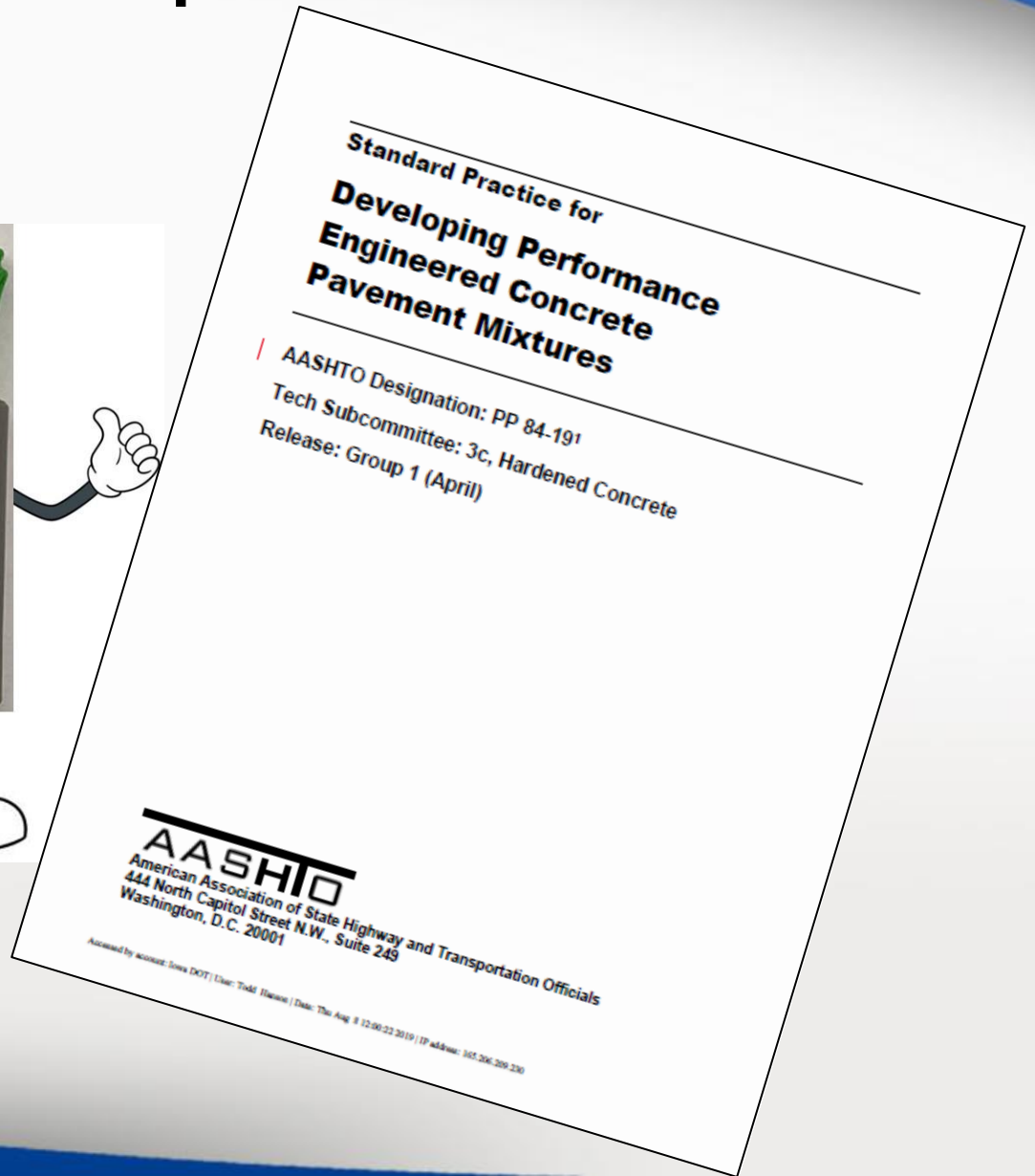
15038.03 ~~LABORATORY~~ CONCRETE DESIGN MIXTURE.

A. An Iowa DOT PCC Level III Certified Technician is responsible for the development of the CDM. Develop a CDM based on a unit volume of 1.000 according to industry standard practice, and containing proportions of materials, including admixtures. Base the proportions upon saturated surface dry aggregates to produce a workable concrete mixture meeting the constraints of Table DS-15038.03-1:

Table DS-15038.03-1: Concrete Mixture Constraints

Nominal Maximum Coarse Aggregate Size	Greater than or equal to 1 inch
Gradation	Materials I.M. 532
Cementitious Content	Minimum, 560 pounds per cubic yard*
Fly Ash Substitution Rate	See Article 2301.02, B, 6
Water/Cementitious Ratio	Maximum, ~~0.45~~ 0.42
Air Content	6% ± 1%, Design Absolute Volume = 0.060
28 Day Flexural Strength, Third Point	Minimum, 640 pounds per square inch





Standard Practice for
Developing Performance Engineered Concrete Pavement Mixtures

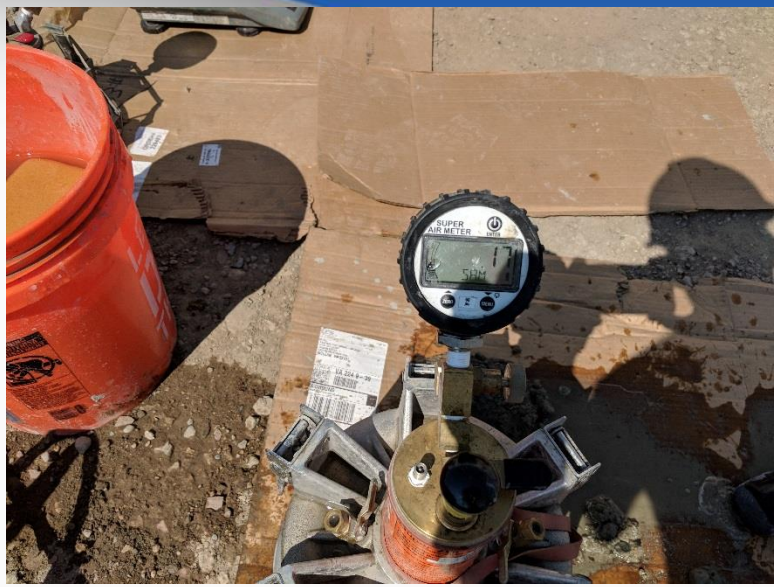
AASHTO Designation: PP 84-19[1]
Tech Subcommittee: 3c, Hardened Concrete
Release: Group 1 (April)

AASHTO
American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Accessed by account: Iowa DOT | User: Todd Hanson | Date: Thu Aug 8 12:00:22 2019 | IP address: 165.206.209.230

PEM – Critical Parameters

- Cold weather resistance (cold locations)
  - SAM Air Meter, LTDSC- Salt Resistance
- Transport properties/permeability (everywhere)
  - Resistivity/Formation Factor
- Aggregate stability (everywhere)
  - ASR/D-Cracking
- Workability (everywhere)
  - Box Test/V-Kelly
- Strength (everywhere)
  - Flexural or Compressive
- Shrinkage (dry locations)
  - Ring Test



PEM Pooled Fund Research Project

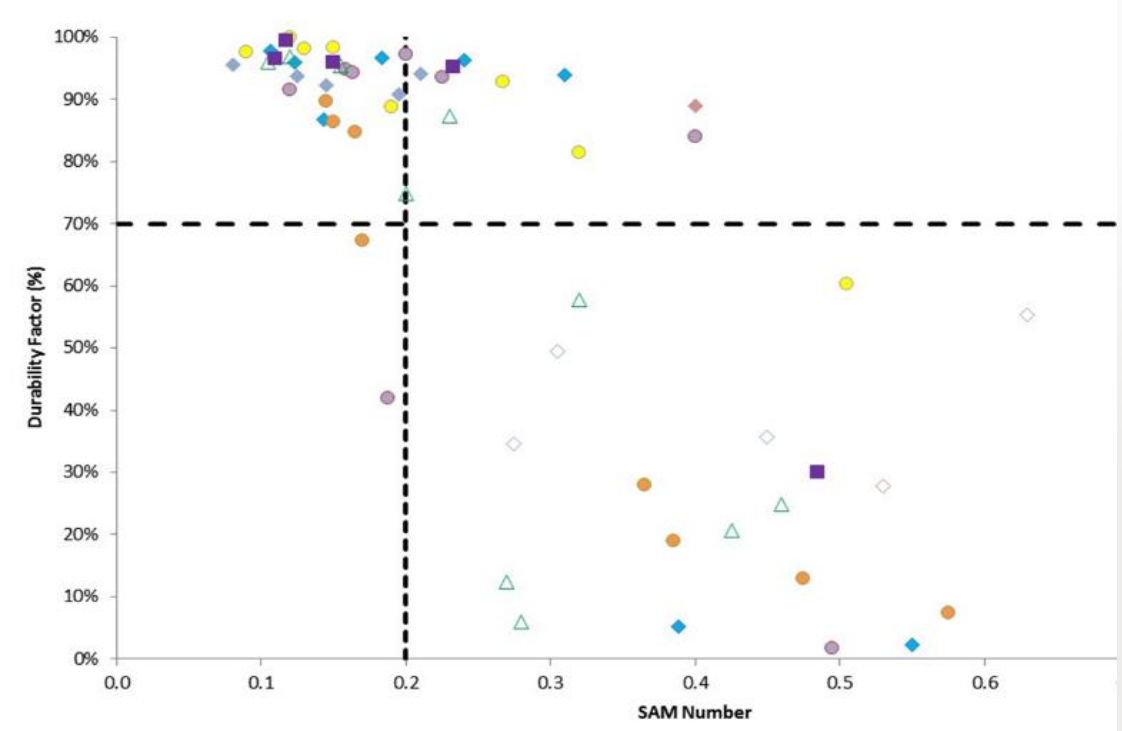
- Shadow projects
- Investigate ruggedness of test methods
- Develop specification limits
- Collect data for modelling
- Contractor QC Testing
- FHWA Mobile Concrete Trailer

Iowa PEM Shadow Project

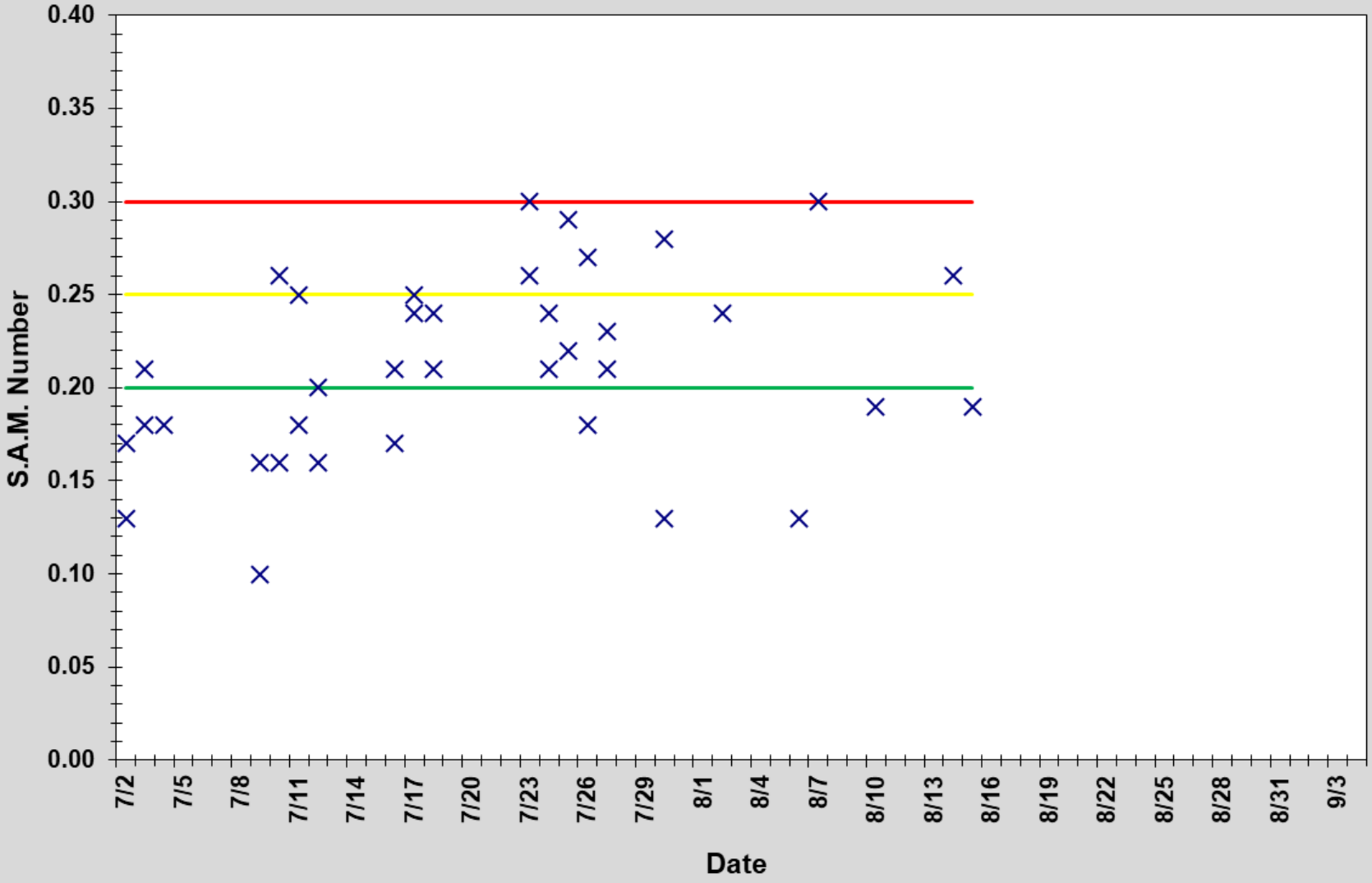
- US 20 Woodbury Co. 2018
- Comprehensive QC Plan
    - Control Charts
    - Air PWL
  - SAM Test
  - Box Test
  - Resistivity/Formation Factor
  - Calcium Oxy Chloride Potential
  - Trial batch mix design reduced cement

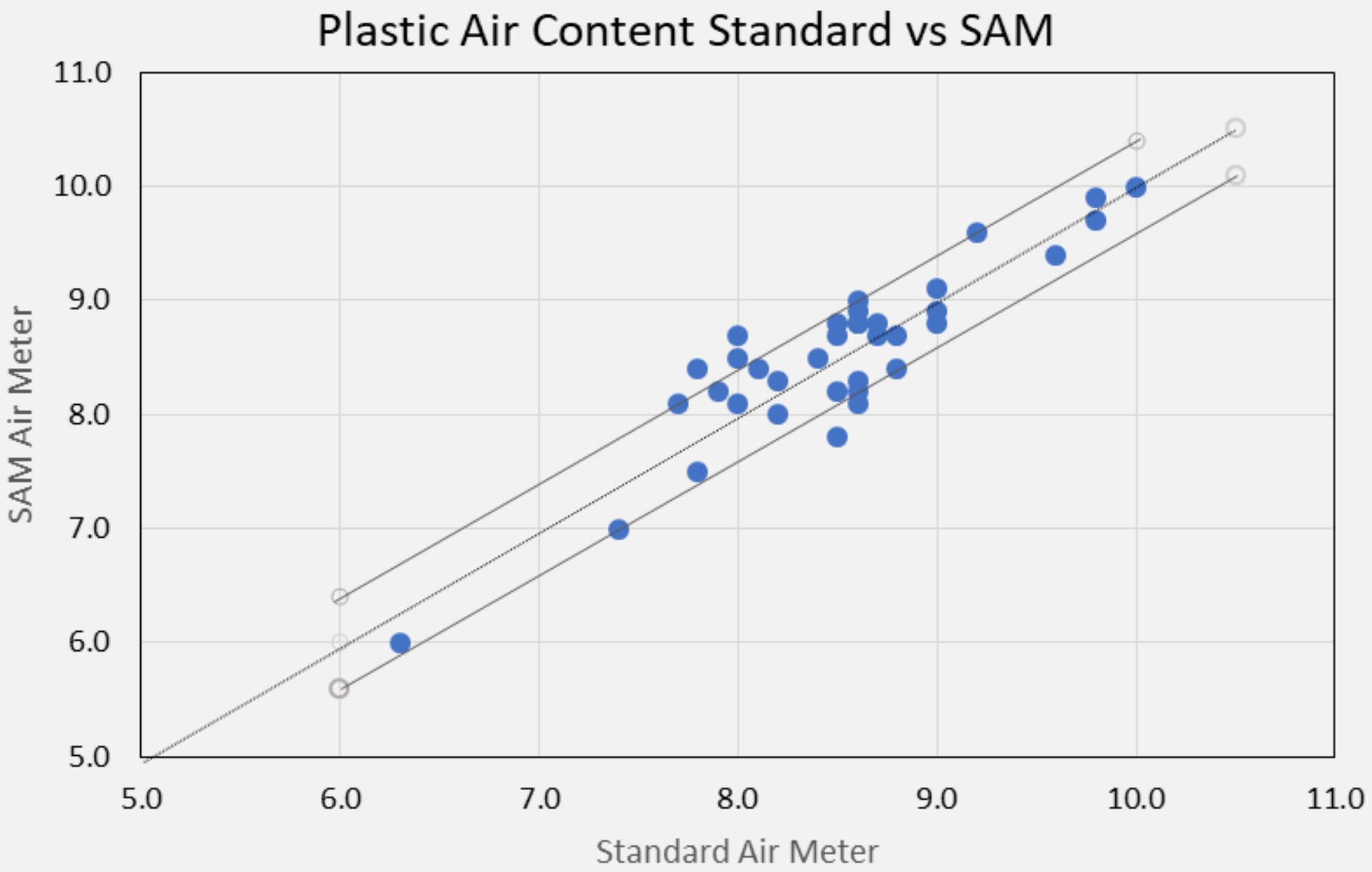
Super Air Meter (SAM)

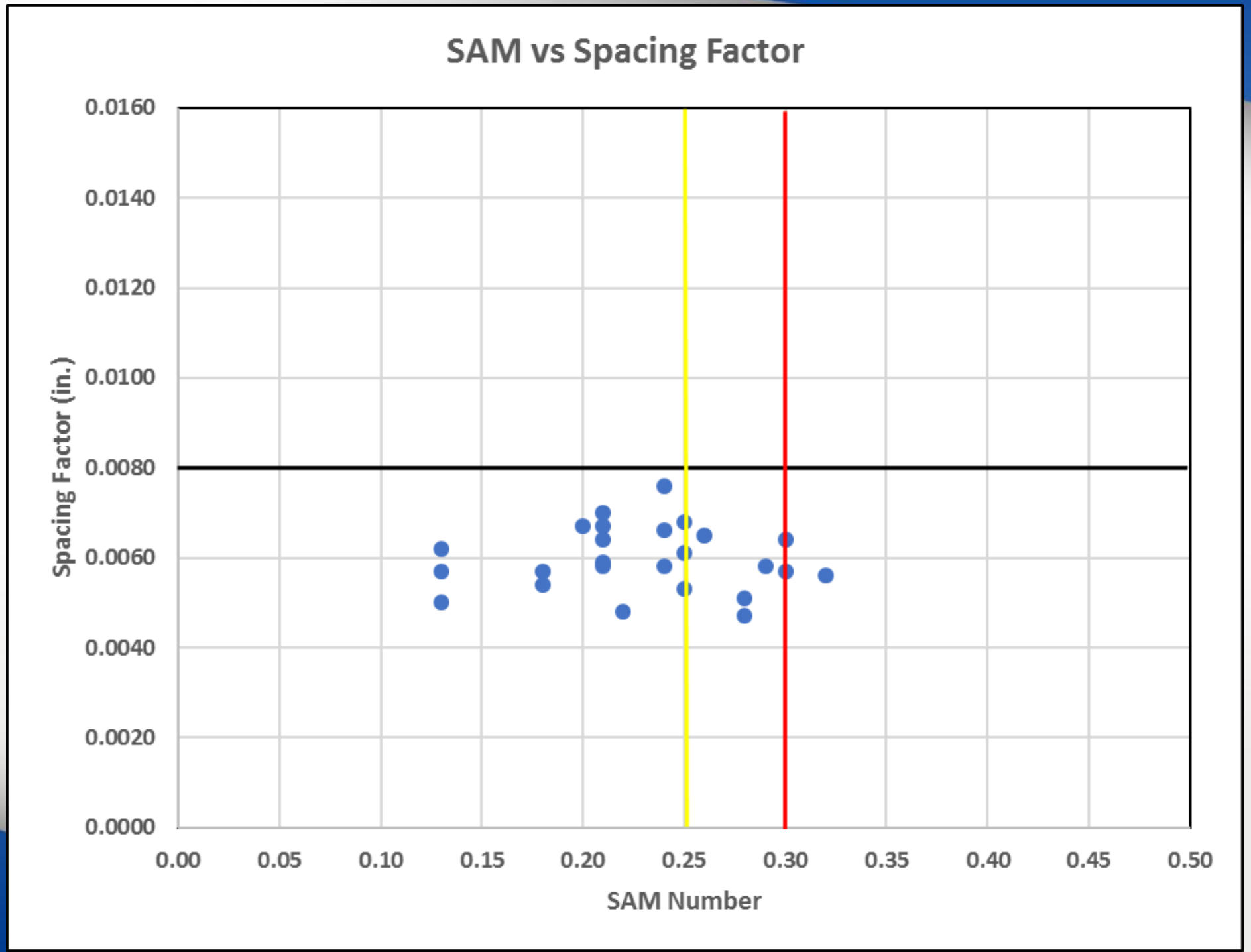
- Test at 14.5, 30 & 45 psi
  - Release and repeat
- Air content & SAM number
- SAM number correlates to spacing factor => F/T Test
- Mix Design SAM # <0.20
- Field SAM # <0.30 & Air>6%



S.A.M. Number
Before Paver




Plastic Air Content Standard vs SAM
SAM Air Meter
Standard Air Meter
11.0
10.0
9.0
8.0
7.0
6.0
5.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0

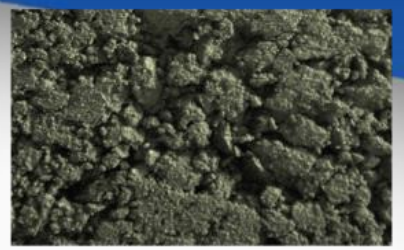

SAM vs Spacing Factor
Spacing Factor (in.)
0.0160
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
SAM Number

Workability

- Slump Test
  - Uniformity Test tells nothing about response to vibration
- Box Test and V-Kelly
  - Response to Vibration
- Factors in Workability
  - Aggregate Gradation
  - Paste Content
  - Admixtures

Workability - Box Test

- Fill box to 9.5 inches
- Insert vibrator 12,500 vpms
  - 3 seconds to bottom
  - 3 seconds out
- Edges of box are removed and inspected
- PEM Limits <30% Voids or Rating of 2 or less

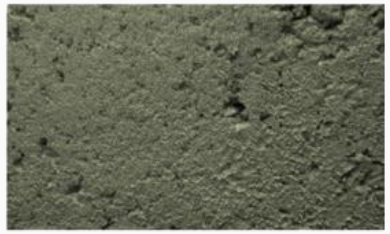


4

Over 50% overall surface voids.

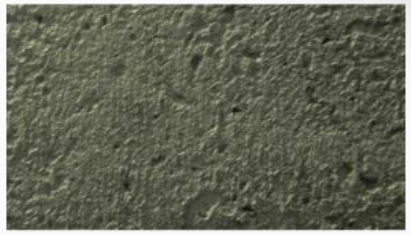
3

30-50% overall surface voids.



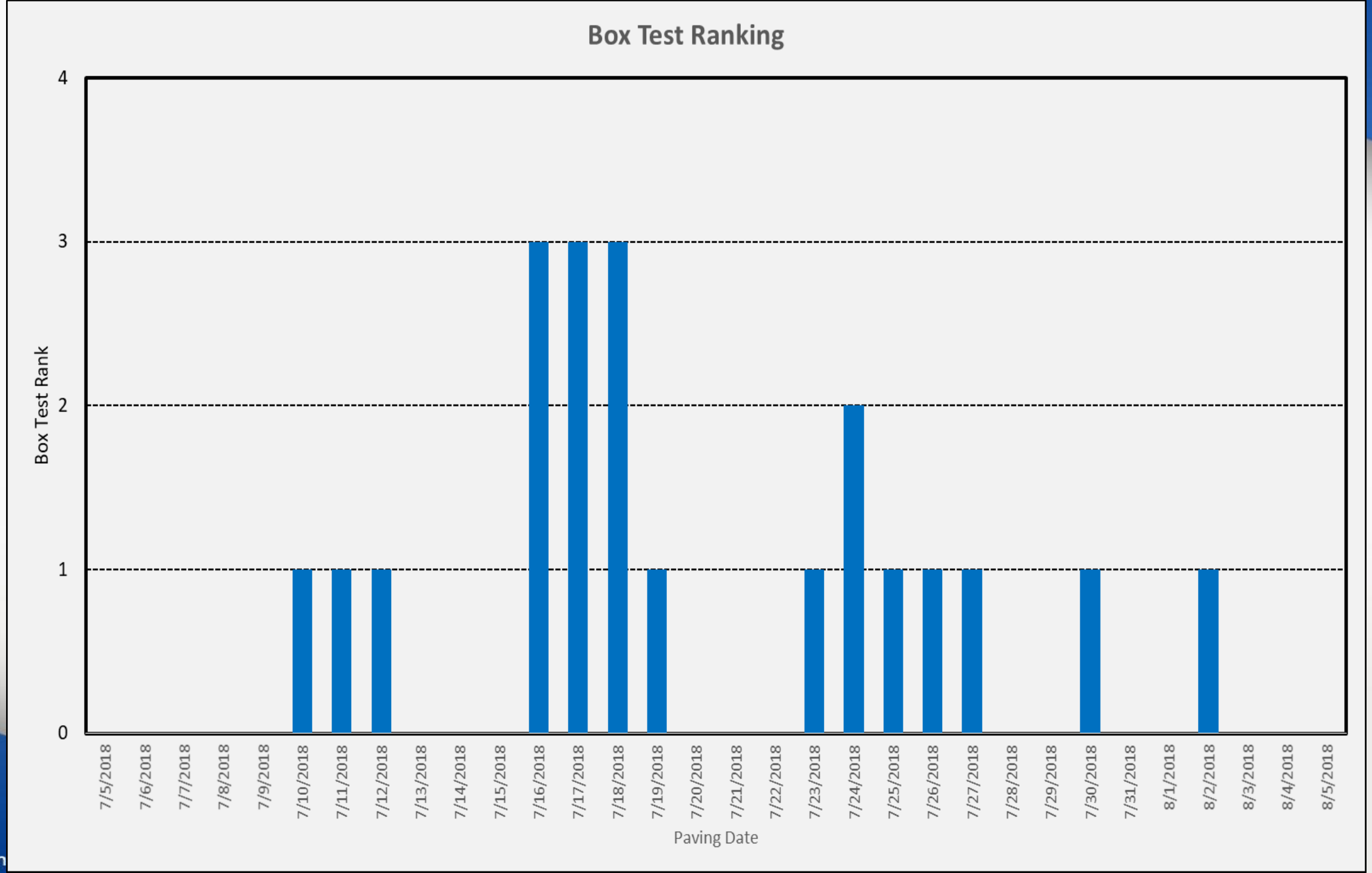
2

10-30% overall surface voids.

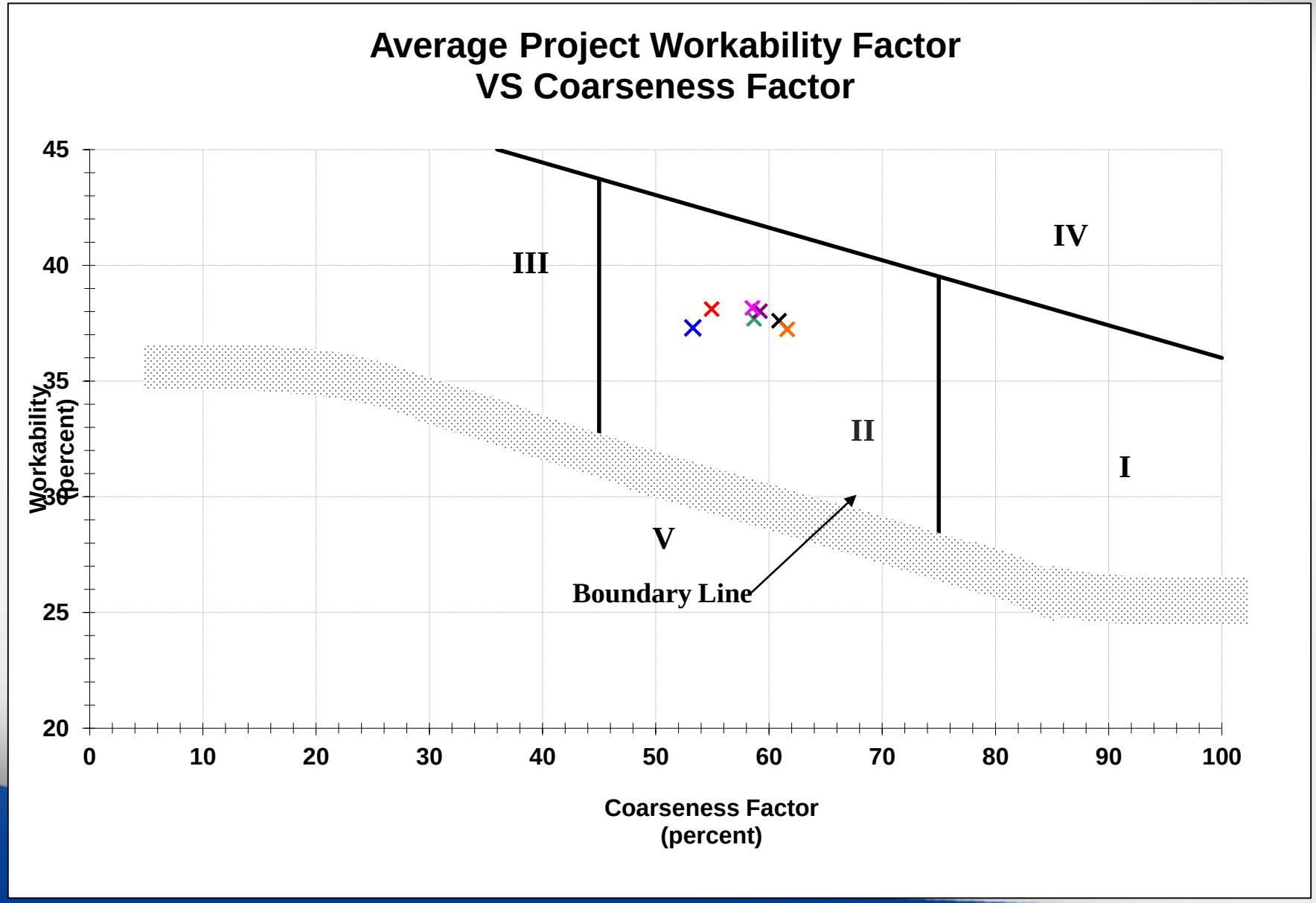


1

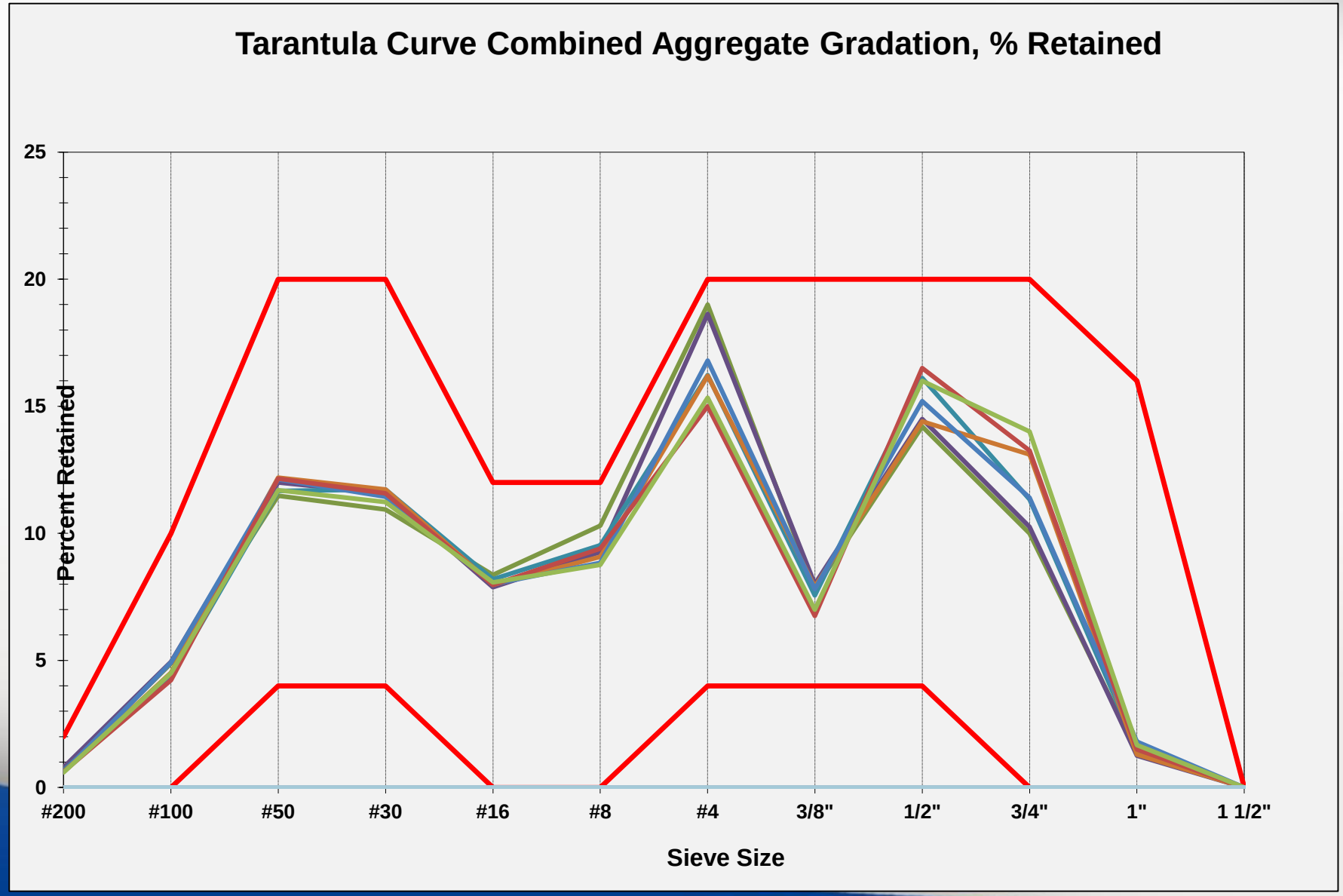
Less than 10% overall surface voids.


Box Test Ranking
Box Test Rank
4
3
2
1
0
7/5/2018
7/6/2018
7/7/2018
7/8/2018
7/9/2018
7/10/2018
7/11/2018
7/12/2018
7/13/2018
7/14/2018
7/15/2018
7/16/2018
7/17/2018
7/18/2018
7/19/2018
7/20/2018
7/21/2018
7/22/2018
7/23/2018
7/24/2018
7/25/2018
7/26/2018
7/27/2018
7/28/2018
7/29/2018
7/30/2018
7/31/2018
8/1/2018
8/2/2018
8/3/2018
8/4/2018
8/5/2018
Paving Date

Combined Aggregate Gradation



Combined Aggregate Gradation



Transport Properties - Resistivity

- Cast Two Cylinders
- Place in bucket with (Ca, Na, K) hydroxide solution
- Test Resistivity at 3, 7, 28, 56 and 91 days

Transport Properties – Formation Factor

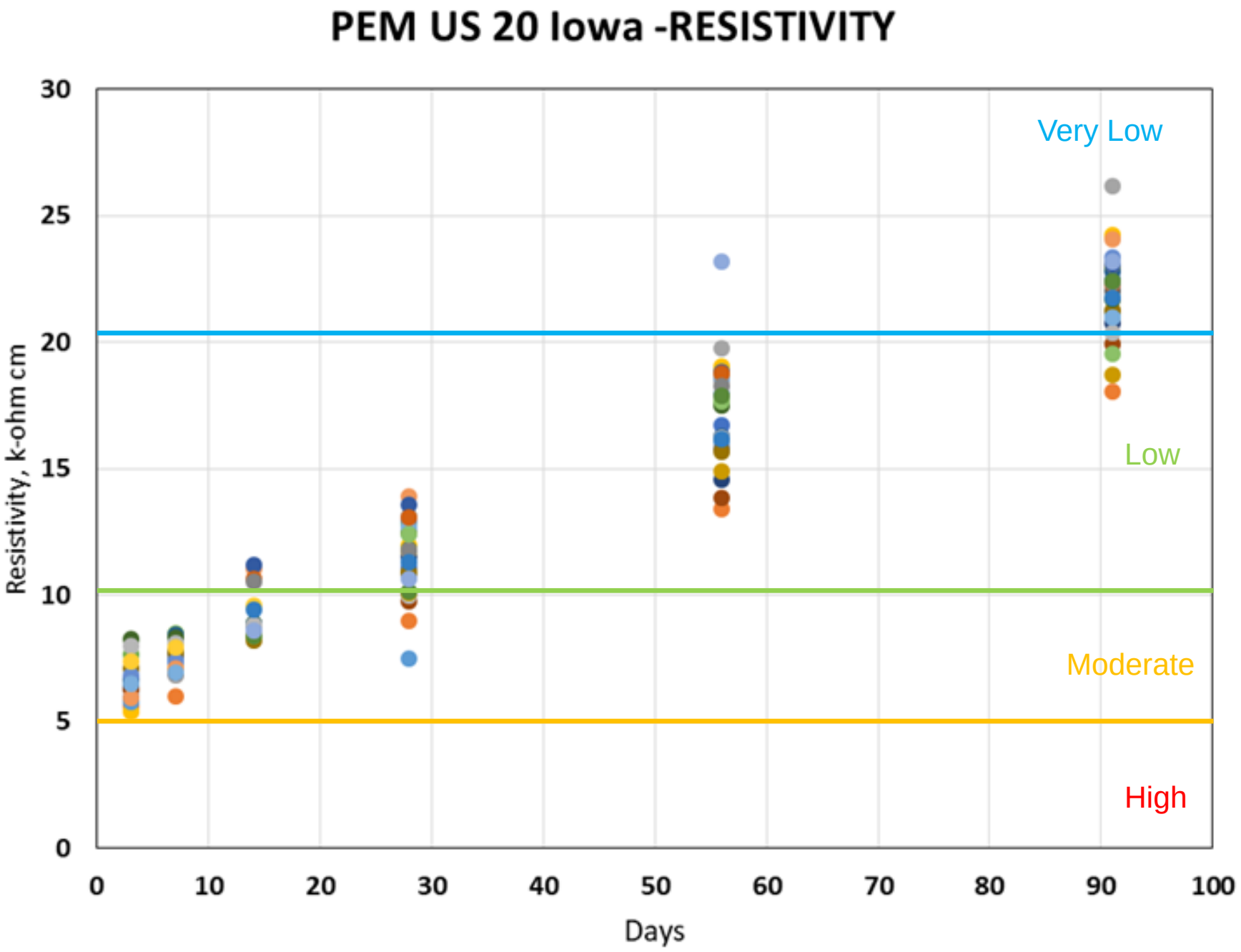
US 20 Test Results w 20% fly ash

- Resistivity Low Range
  - 18-20 k-ohm-cm
- Formation Factor Moderate to Low range - 957

Table X2.1—Relationship between T 277 (ASTM C1202) Results, Resistivity, and the *F* Factor, Assuming a Pore Solution Resistivity of 0.1 Ω · m (based on Spragg et al., 2012)

ASTM C1202 Classification	Charge Passed (Coulombs)	Resistivity (kΩ · cm)[a]	Formation Factor
High	>4,000	<5.2	520
Moderate	2,000–4,000	5.2–10.4	520–1,040
Low	1,000–2,000	10.4–20.8	1,040–2,080
Very low	100–1,000	20.8–207	2,080–20,700
Negligible	<100	>207	20,700

[a] Calculated using first principles.

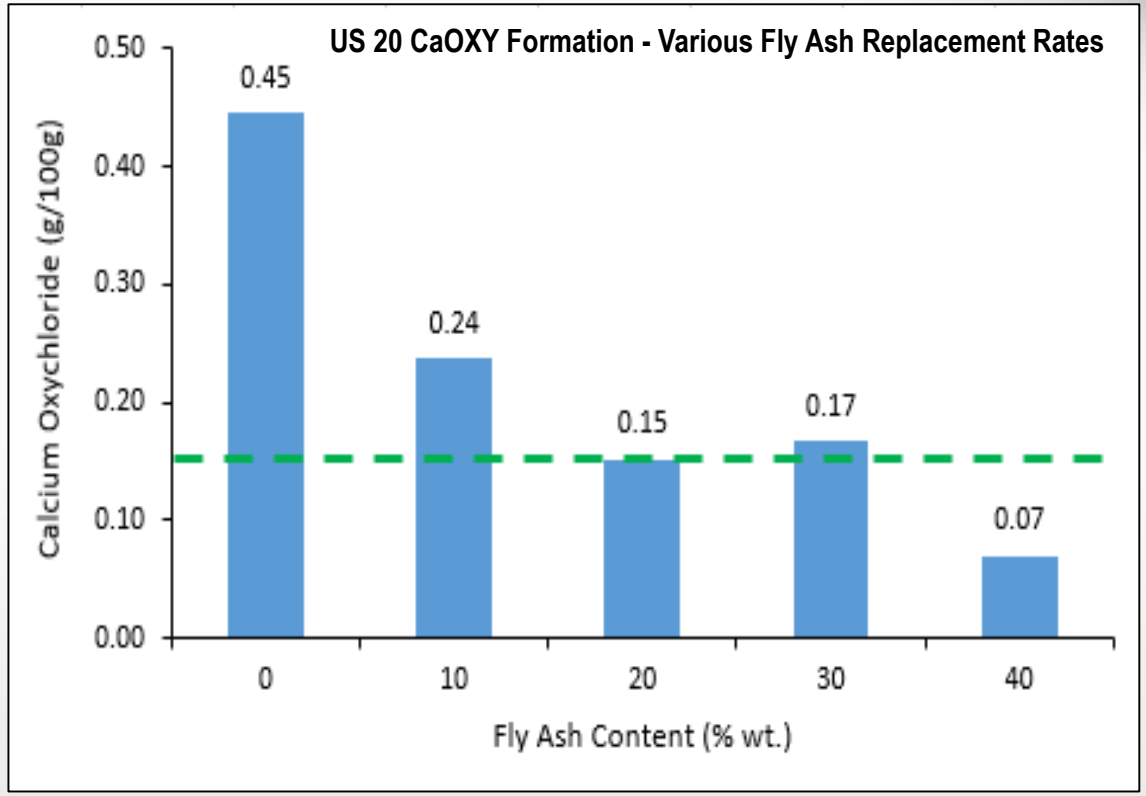

PEM US 20 Iowa -RESISTIVITY
Resistivity, k-ohm cm
Days
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
Very Low
Low
Moderate
High

Calcium Oxychloride Potential

- Salts can cause chemical attack
  - Reaction between $Ca(OH)_2$ and $CaCL_2$ or $MgCl_2$
  - Expands ~30% and forms above 32F
- Low temperature differential scanning calorimetry (LT-DSC)
- Reduce potential with use of SCM's

Calcium Oxychloride Potential

- Limit the CaOXY to less than 0.15 (g/100g)
- 20% Class C fly ash replacement met the limit
- More slag / fly ash replacement further reduces potential



PEM Mix Design w Lower Cement Content

2018 Std. A-3 Mix 550 lbs/cy & 0.474 w/c

PEM Mix – US 20 Shoulders	Abs. Vol.	lbs/CY
CEMENT:	0.078	412
FLY ASH:	0.024	103
WATER: w/c=0.40	0.122	206
FINE AGGREGATE (44%):	0.315	1401
COARSE AGGREGATE (44%):	0.315	1422
INTERMEDIATE AGG. (12%):	0.086	387
AIR:	0.06	0
Paste Content, %	22.4	

2019 Std. A-6 Mix 579 lbs/cy & 0.440 w/c

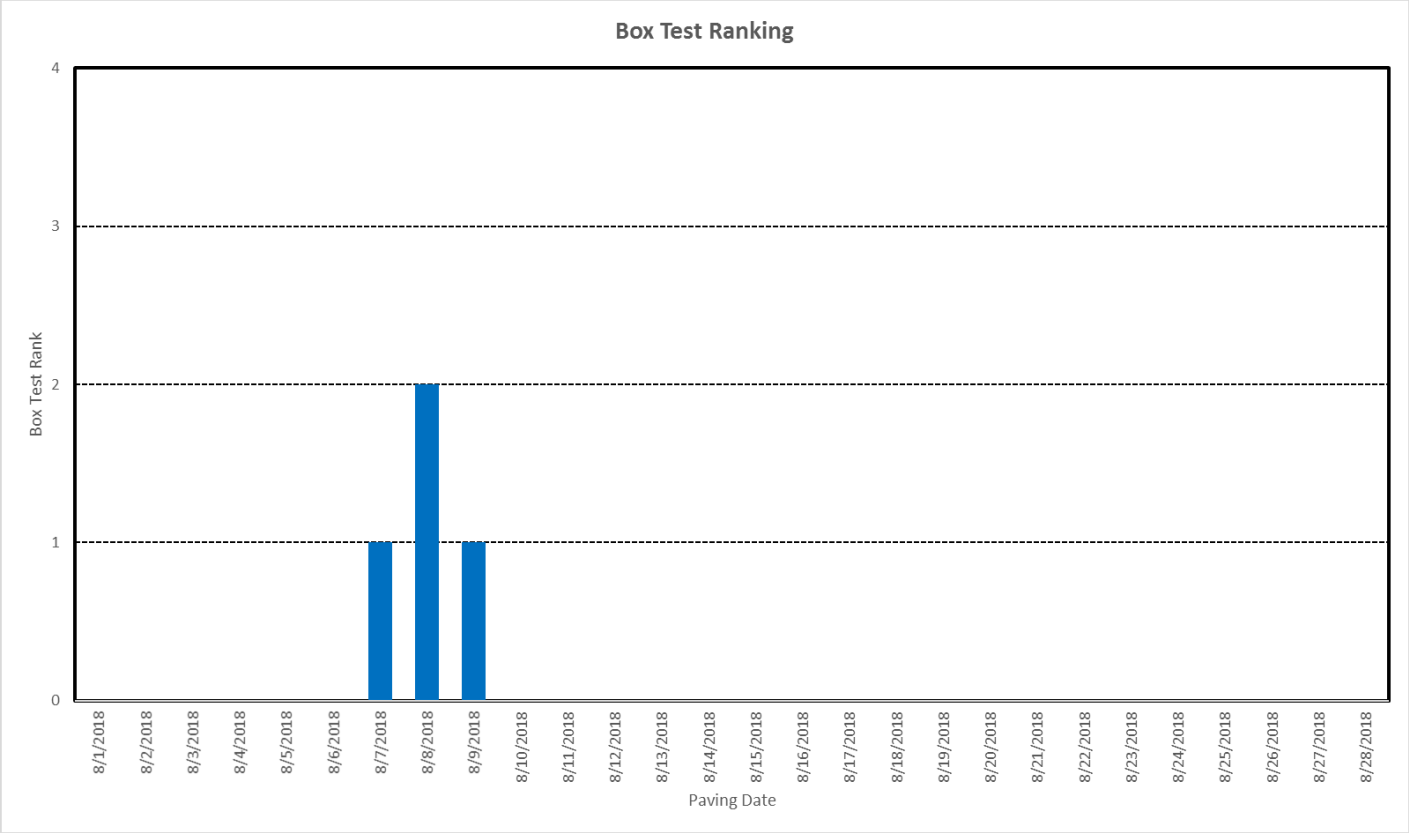
PEM Mix – I-29 Shoulders	Abs. Vol.	lbs/CY
CEMENT:	0.077	387
FLY ASH:	0.022	97
WATER: w/c=0.419	0.120	203
Cl. V AGGREGATE (55%):	0.399	1761
COARSE AGGREGATE (45%):	0.327	1476
INTERMEDIATE AGG.:	0	0
AIR:	0.06	0
Paste Content, %	21.9	

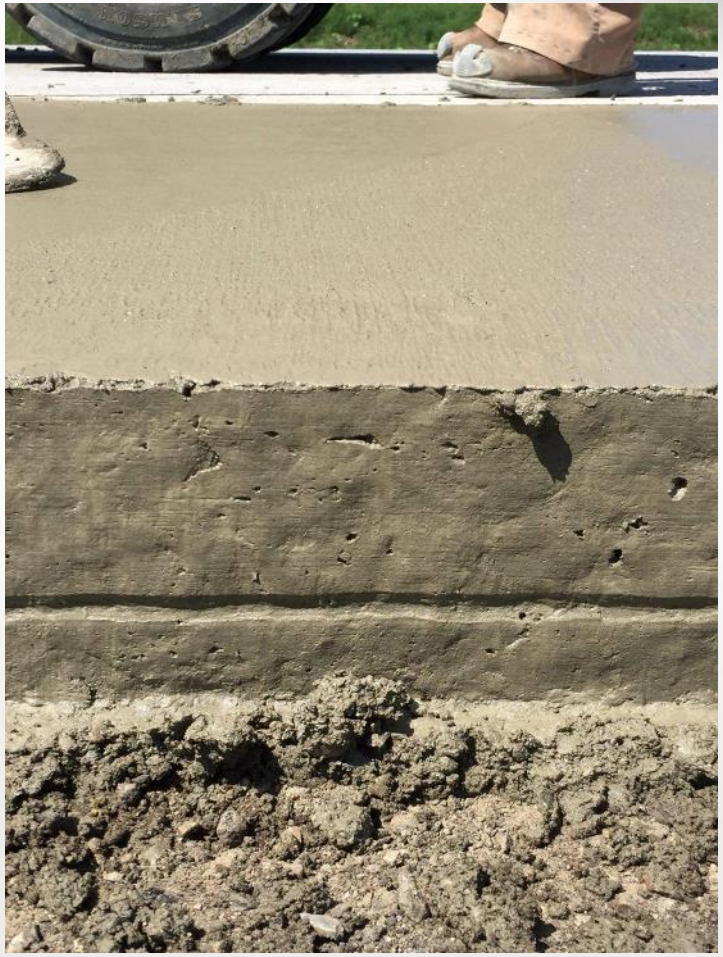
Dr. Taylor estimated cement content based on dry rodded unit weight of combined aggregate.

PEM Mix Design

- Some concerns lowering cement content of standard A mix for shoulder
  - Used QMC proportions
- Performed trial batch
  - Box Test
- Placement went very well

PEM Mix Design





2019 PEM Data

	2019 PROJECT AVERAGES			
Location	**SAM #**	**BOX #**	**W/C**	**Resistivity**
Polk I35	0.23	1.2	0.39	11.89
Harrison I29	0.22	1.1	0.40	15.67
Black Hawk US 20	0.18	1.4	0.40	7.15*
Plymouth US 75	0.20	1.3	0.40	12.64
AVERAGE	0.21	1.25	0.40	11.84

*Aggregates with high absorption affect results

What Did We Learn?

Table X6.6 in PP84-18 Specification Worksheet Comparison with QMC

Table 3—Specification Worksheet

Section	Property	Specified Test	Specified Value		Mixture Qualification	Acceptance	Selection Details
			6.3 Concrete Strength				
6.3.1	Flexural Strength	T 97	4.1 MPa	600 psi	Yes	Yes	Choose either or both
6.3.2	Compressive Strength	T 22	24 MPa	3500 psi	Yes	Yes	
			6.4 Reducing Unwanted Slab Warping and Cracking Due to Shrinkage (if cracking is a concern)				
6.4.1.1	Volume of Paste	—	25%		Yes	No	Choose only one
6.4.1.2	Unrestrained Volume Change	ASTM C157	420 με	At 28 days	Yes	No	
6.4.2.1	Unrestrained Volume Change	ASTM C157	360, 420, 480 με	At 91 days	Yes	No	
6.4.2.2	Restrained Shrinkage	T 334	Crack free	At 180 days	Yes	No	
6.4.2.3	Restrained Shrinkage	TP XXX	$\Sigma < 60\% f'_r$	At 7 days	Yes	No	
6.4.2.4	Probability of Cracking	Appendix X1		As specified	Yes	No	
Commentary	Quality Control Check	—	—	—	No	Yes	
			6.5 Durability of Hydrated Cement Paste for Freeze–Thaw Durability				
6.5.1.1	Water to Cementitious Ratio	—	0.45	—	Yes	Yes	[a]
6.5.1.2	Fresh Air Content	T 152, T 196, TP 118	5 to 8	%	Yes	Yes	Choose only one
6.5.1.3	Fresh Air Content/SAM	T 152, T 196, TP 118	≥4% air; ≤0.2	%, psi	Yes	Yes	
6.5.2.1	Time of Critical Saturation	"Bucket Test" Specification	30	yr	Yes	No	[a, b]
6.5.3.1	Deicing Salt Damage	—	35%	SCM	Yes	Yes	Choose only one
6.5.3.2	Deicing Salt Damage	M 224	—	Topical treatment	Yes	Yes	
6.5.4.1	Calcium Oxychloride Limit	Test sent to AASHTO	<0.15 g CaOXY/g paste		Yes	No	
			6.6 Transport Properties				
6.6.1.1	Water to Cementitious Ratio	—	≤0.45 or ≤0.50	—	Yes	Yes	Choose only one
6.6.1.2	Formation Factor	Table 1	≥500 or ≥1000	—	Yes	Yes	
6.6.2.1	Ionic Penetration, *F* Factor	Appendix X2	25 mm at 30 yr		Yes, F	Through ρ	
			6.7 Aggregate Stability				
6.7.1	D Cracking	T 161, ASTM C1646	—	—	Yes	No	
6.7.2	Alkali Aggregate Reactivity	R 80	—	—	Yes	No	
			6.8 Workability				
6.8.1	Box Test	Appendix X3	<6.25 mm, <30% surface void			No	
6.8.2	Modified VKelly Test	Appendix X4	15–30 mm/root s			No	

Notes:

STRENGTH

Table X6.6—Specification Worksheet for Mixture Proportioning

Section	Property	Specified Test	Specified Value		Mixture Qualification	Acceptance	Selection Details
			6.3 Concrete Strength				
6.3.1	Flexural Strength	T 97	4.1 MPa	600 psi	Yes	Yes	Choose either or both
6.3.2	Compressive Strength	T 22	27.5 MPa	4000 psi	Yes	Yes	

Iowa DOT Current Practices QMC

- Average 635 PSI Flexural
- Average 5800 PSI Compressive Class C

SHRINKAGE - CRACKING

	6.4 Reducing Unwanted Slab Warping and Cracking Due to Shrinkage (if cracking is a concern)						
6.4.1.1	Volume of Paste	—	≤ 25%	←	Yes	No	Choose only one
6.4.1.2	Unrestrained Volume Change	ASTM C157	420 με	At 28 days	Yes	No	
6.4.2.1	Unrestrained Volume Change	ASTM C157	360, 420, 480 με	At 91 days	Yes	No	
6.4.2.2	Restrained Shrinkage	T 334	Crack free	At 180 days	Yes	No	
6.4.2.3	Restrained Shrinkage	T 363	$\sigma_\theta(R_{IC}) < 60\% f'_r$	At 7 days	Yes	No	
6.4.2.4	Probability of Cracking	Appendix X1		As specified	Yes	No	
Commentary	Quality Control Check	—	—	—	No	Yes	

Iowa DOT Current Practices QMC

- Volume of Paste = 24.3%

FREEZE-THAW DURABILITY

		6.5 Durability of Hydrated Cement Paste for Freeze–Thaw Durability					
6.5.1.1	Water to Cementitious Ratio	—	0.45	—	Yes	Yes	[a]
6.5.1.2	Fresh Air Content	T 152, T 196, TP 118	5 to 8	%	Yes	Yes	Choose only one
6.5.1.3	Fresh Air Content/SAM	T 152, T 196, TP 118	≥4 to 8% air; ≤0.2	%, psi	Yes	Yes	
6.5.2.1	Time of Critical Saturation	ASTM C1585	30	year	Yes	No	[a, b]
6.5.3.1	Deicing Salt Damage	—	35%	SCM	Yes	Yes	Choose only one if concrete will be exposed to deicing salts
6.5.3.2	Deicing Salt Damage	M 224	—	Topical treatment	Yes	Yes	
6.5.4.1	Calcium Oxychloride Limit	T 365	<0.15 g CaOXY/g paste		Yes	No	

Iowa DOT Current Practices QMC

- w/c Ratio = 0.42 max.
- Air Content 6 to 10%
  - SAM Results all below 0.30
- Calcium Oxychloride Limit =0.15 g/100g

TRANSPORT PROPERTIES

			6.6 Transport Properties				
6.6.1.1	Water to Cementitious Ratio	—	≤0.45 or ≤0.50	—	Yes	Yes	Choose only one
6.6.1.2	Formation Factor	Table 1	≥500 or ≥1000	—	Yes	Yes	
6.6.2.1	Ionic Penetration, *F* Factor	Appendix X2	25 mm at 30 yr		Yes, F	Through ρ	

Iowa DOT Current Practices QMC

- w/c Ratio = 0.42 max.
- Formation Factor ~1000 w 20% C ash
- Lower when using blended cements and fly ash

AGGREGATE STABILIITY

			6.7 Aggregate Stability			
6.7.1	D Cracking	T 161, ASTM C666	—	—	Yes	No
6.7.2	Alkali Aggregate Reactivity	R 80	—	—	Yes	No

Iowa DOT Current Practices QMC

- Aggregates – Iowa DOT Methods

WORKABILITY

Table X6.6—*Specification Worksheet for Mixture Proportioning (Continued)*

Section	Property	Specified Test	Specified Value	Mixture Qualification	Acceptance	Selection Details
			6.8 Workability			
6.8.1	Box Test	Appendix X3	<6.25 mm, <30% surface void		No	—
6.8.2	Modified VKelly Test	TP 129	15–30 mm/root s		No	—

[a] Choose either 6.5.1.1 or 6.5.2.1.

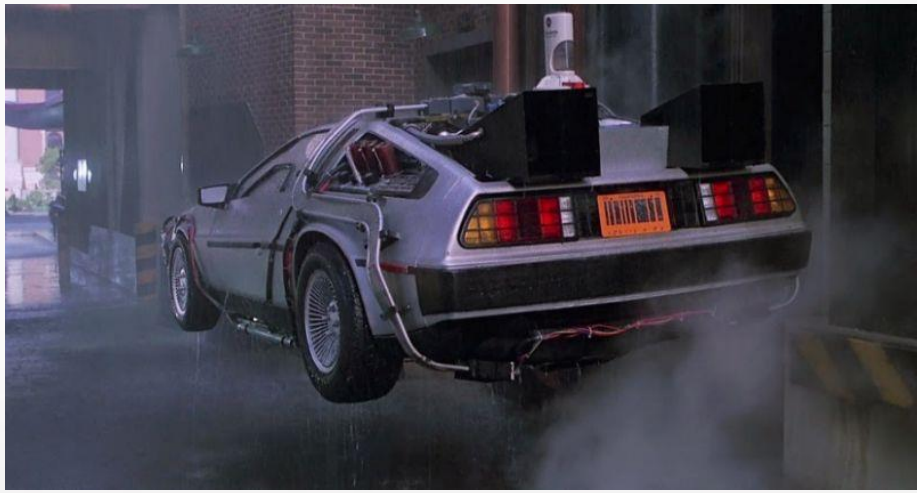
[b] Choose either 6.5.1.2, 6.5.1.3, or 6.5.2.1.

Iowa DOT Current Practices QMC

- Workability Typically Good
  - Combined Aggregate Grading for 20 years

Where are we going?

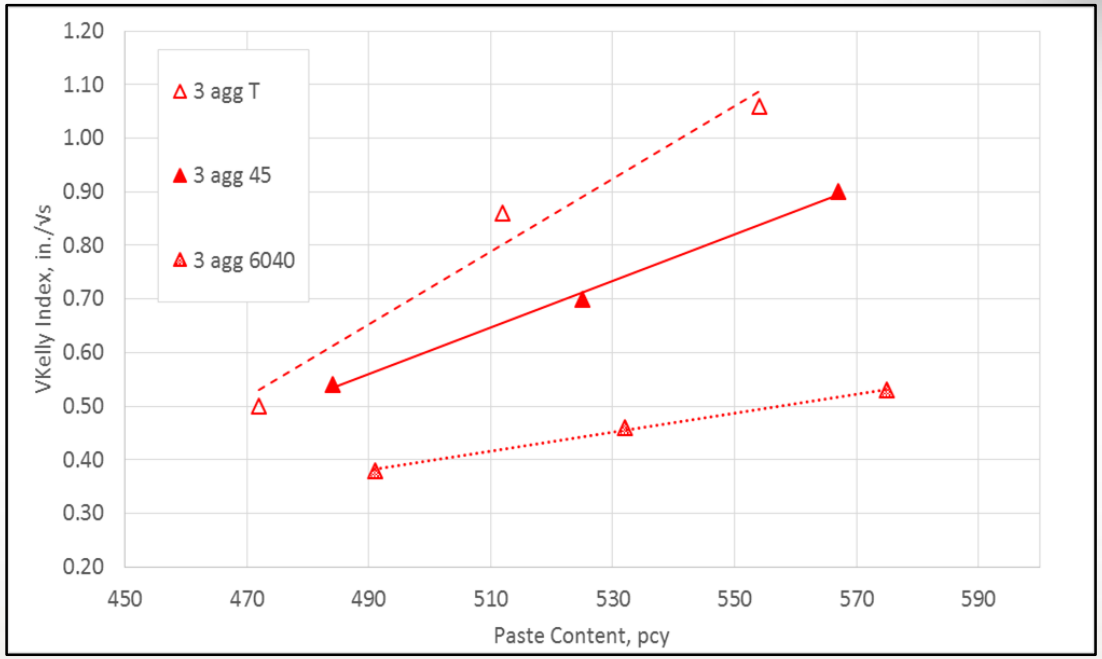
- Iowa QMC Mixes compare close with PEM
- Use PEM testing to validate QMC Mixes at Reduced Cement Content
  - 0.099 Abs Vol Cement – (1st Iteration)
    - 524 lbs/cy Type I/II
    - 517 lbs/cy Type IS(20)
    - 499 lbs/cy Type IP(25)
  - Trial Mix Design - SAM Air Test and Box Test
  - **QC** Testing - SAM Meter 1/day, Box Test – 1/wk
- Eventually, modify QMC DS



What can you do?

- Gathering data on SAM testing, workability, resistivity, etc.
- Get a SAM Meter and practice using
  - Purchase
  - FHWA or ICPA equipment loan
- Box Test – Build box
  - Vibrator requirements
  - https://www.minnich-mfg.com/products/vibrators/flex-shaft/csv
- Try lower cement mix on shoulders

V-Kelly Workability



Questions ?

For More Information

https://cptechcenter.org/performance-engineered-mixtures-pem/