Collaboration. Commitment. Confidence.℠

Performance Engineered Concrete Mixtures

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Acknowledgements

- Development Team
  - Dr. Peter Taylor, Director CP Tech Center
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  - Dr. Tyler Ley, Oklahoma State University
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  - ACPA National
  - PCA
  - NRMCA

AASHTO PP84-17: Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures

- Provisional standard practice that continues to evolve
- Team is now working under a five-year pooled fund study to refine and validate
- The goal is to strengthen the link between specified material properties and performance

PEM - The Path to Implementation

- Improved understanding of concrete performance
  - Structural and durability considerations
- Specify critical properties and test for them
  - Essential to link specified properties to performance
- Obtain mixtures that meet specifications
  - Mixture design
  - Acceptance

Prescriptive Specifications

- Historically used to accommodate a fixed amount of knowledge and a low skilled workforce
  - DOTs specify means and method dictated by experience
  - Each successive generation adds more experience (and specific directions) to the specifications
- Negative: Builds on a 90-year old platform; opportunities to innovate are limited
  - Like driving through the rearview mirror

Performance-Based Specifications

- Take advantage of the knowledge gained from recent research and experience
  - DOTs specify criteria and tests methods linked to desired performance
    - Can form the basis for pay factors
  - Promotes innovative ideas and solutions
- Negative: Knowledge base needs to grow
  - It takes time for everyone to become comfortable
  - Requires greater technical sophistication throughout the workforce

PEM Concept

- Provide a standard practice based on tests linked to performance
  - Tests completed during mixture design or at placement or both
- Allow DOTs to take what they like from the document and make it their own
- DOTs are not expected to give up what they already know is important to them

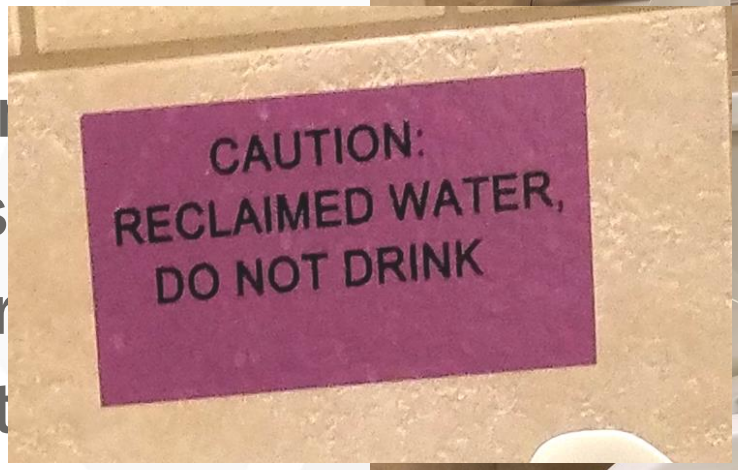
What is in PP-84?

- Standard practice with test methods and recommended limits
  - There are both prescriptive and performance approaches
  - A commentary is included that gives the technical background behind the tests and limits
- This is a tool to help improve concrete pavement performance
- The document is not designed to be used without modifying for local practice and experience

Thinks of it as a Buffet From Which You Choose What You Like

PEM: Approach to Testing

- Require the things that matte
  - Strength
  - Warping and shri
  - Freeze-thaw resis
  - Chemical deicer r
  - Transport propert
  - Aggregate stability
  - Workability



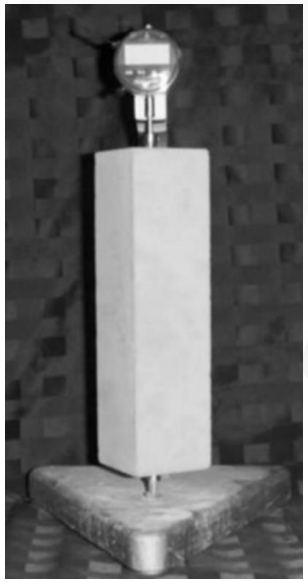
Strength

	Flexural Strength	Compressive Strength
Test method	AASHTO T 97	AASHTO T 22
Value	4.1 MPa 600 psi	24 MPa 3500 psi
Approval?	Yes	Yes
Acceptance?	Yes	Yes

Slide from Tyler Ley

Axial Drying Shrinkage

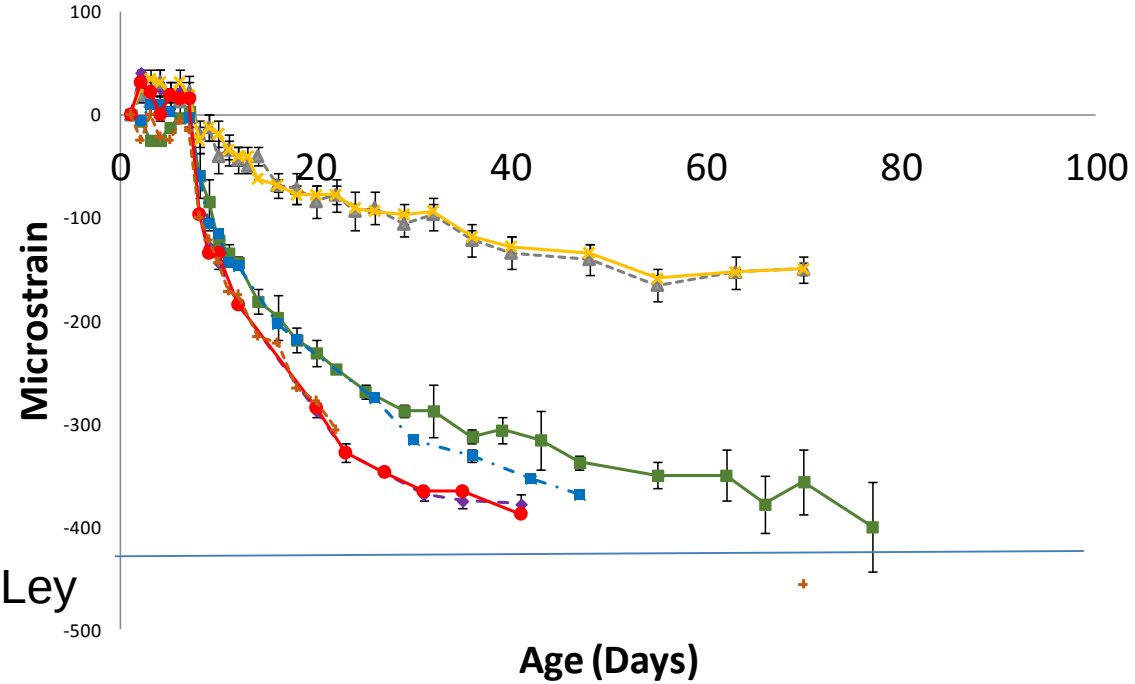
	Volume of paste	Axial shrinkage 1	Axial shrinkage 2
Test method		ASTM C157	ASTM C157
Value	< 25%	< 420 με	< 360, 420, 480 με
Time		28 days	91 days
Approval?	Yes	Yes	Yes
Acceptance?	No	No	No



Slide from Tyler Ley

ASTM C157

- Cure samples for 28 days in fog room
- Demold and place in drying room (50% RH and 73F)
- Measure their length change over time



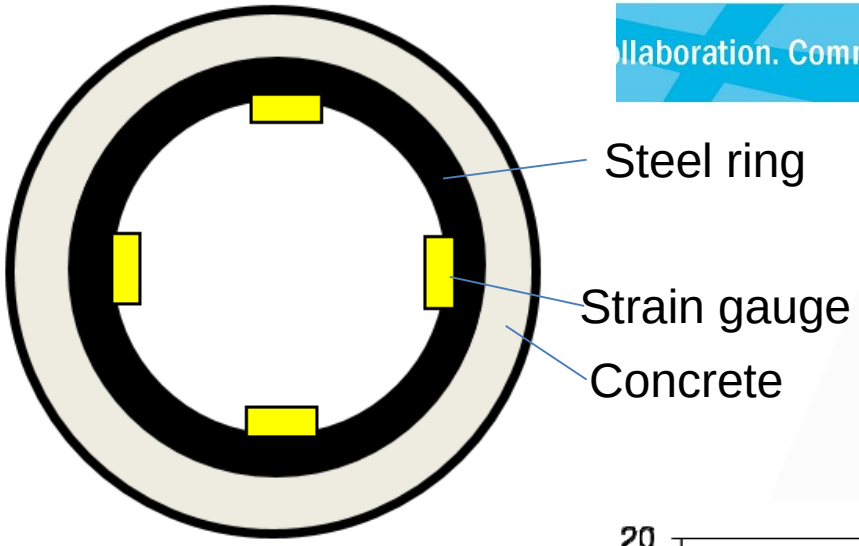
Slide from Tyler Ley

Drying Shrinkage Cracking

	Ring Test	Dual Ring	Modeling
Test method	AASHTO T 334	AASHTO TP363	-
Value	crack free	σ < 60% f'r	5, 20, 50% cracking prob
Time	180 days	7 days	
Approval?	Yes	Yes	Yes
Acceptance?	No	No	No

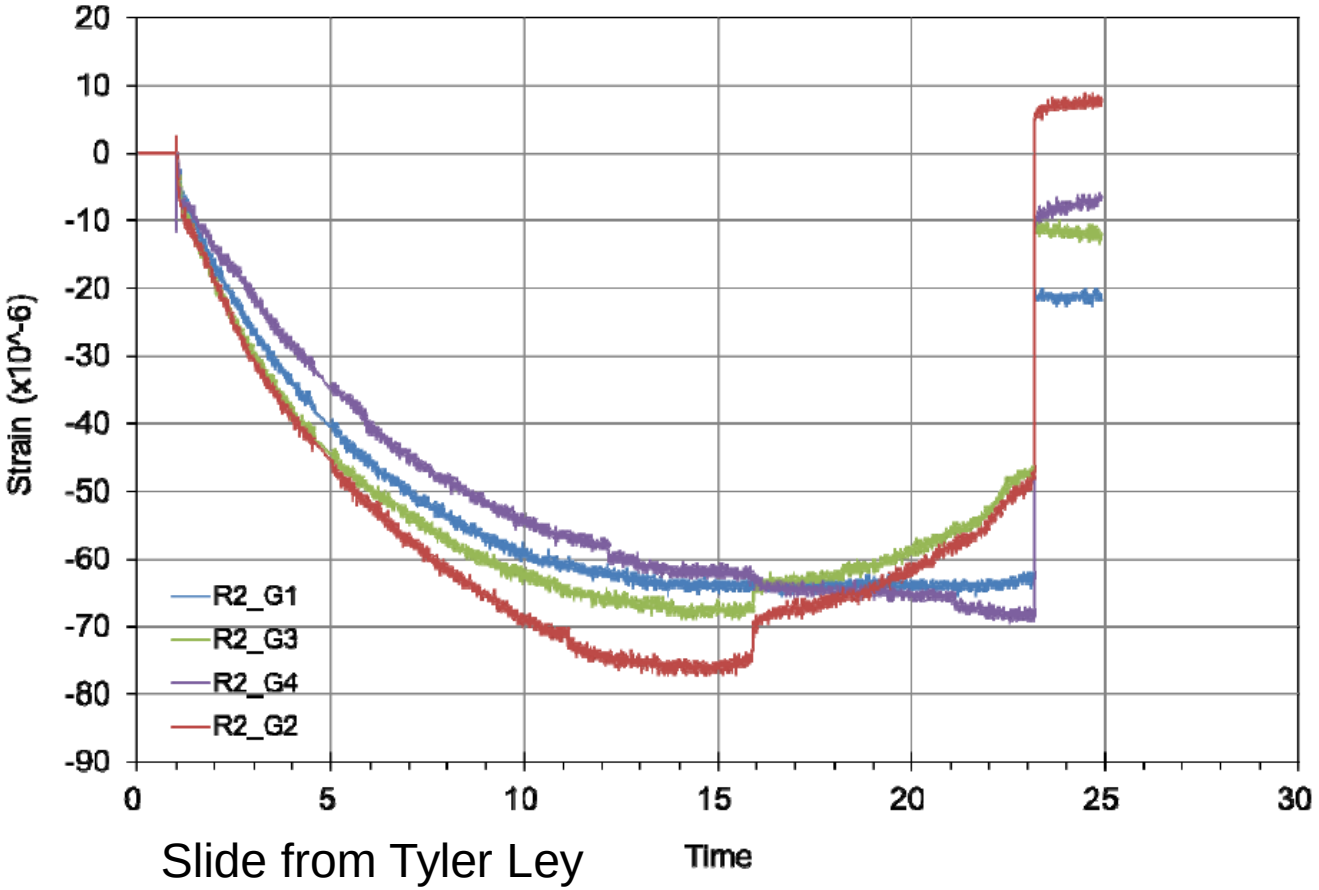
Slide from Tyler Ley

Ring Test



Plan View

Store in 73F and 50% RH



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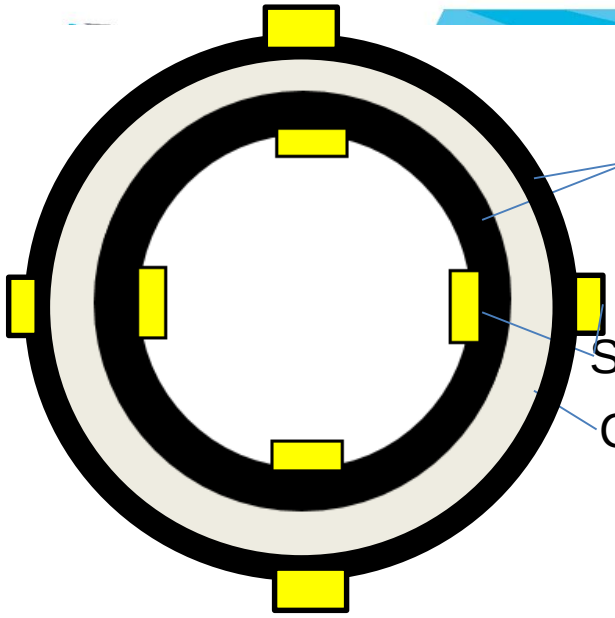
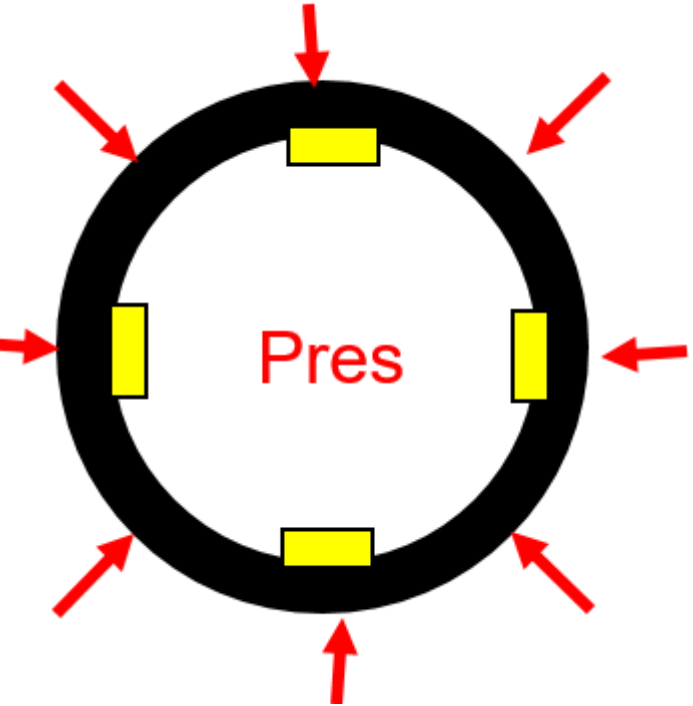


Plan View



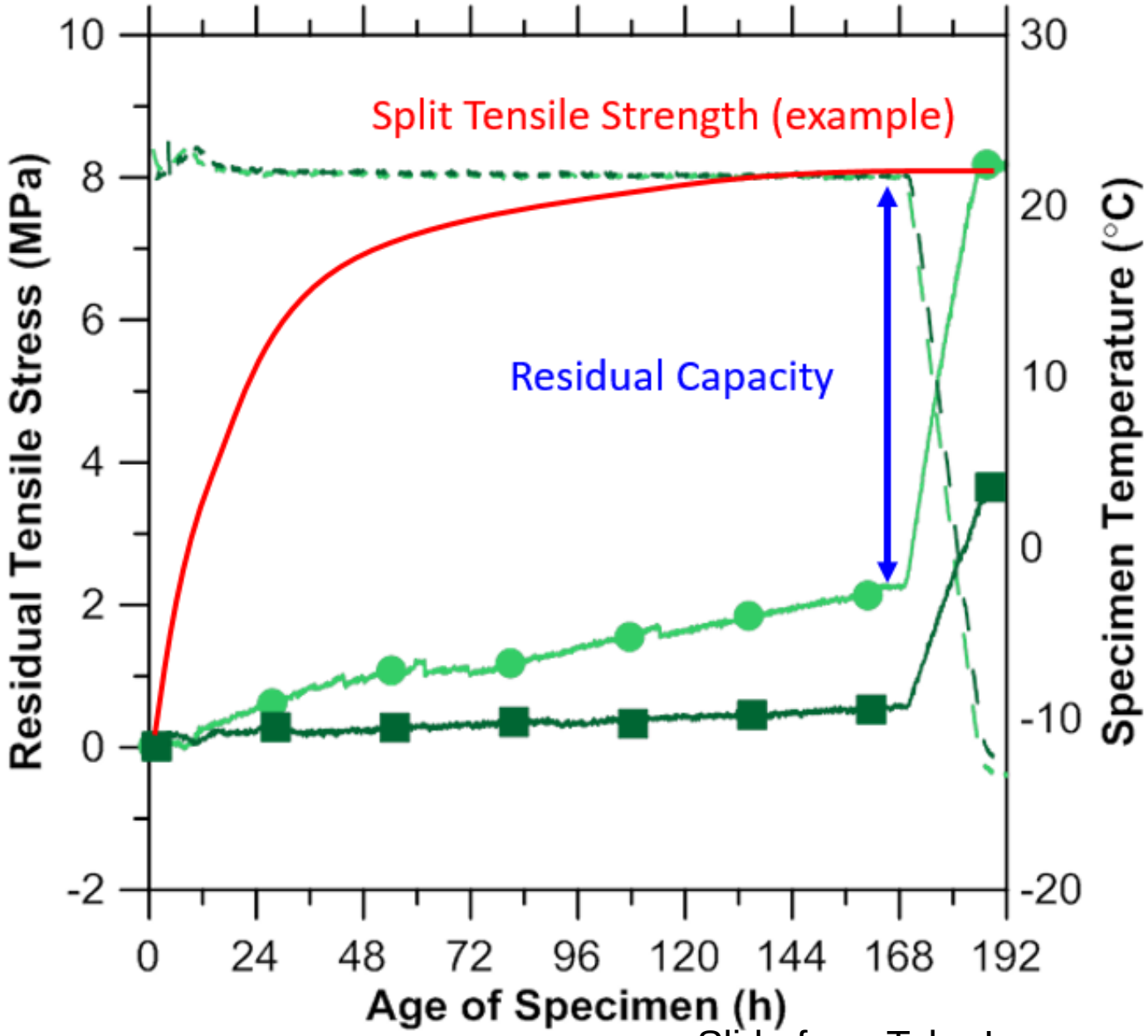
Dual Ring Test

This ring can measure both expansion and contraction.

As the concrete shrinks the ring can measure the strains that occur.

We force a temperature gradient in the concrete and make it crack and compare that to 60% of the split tension capacity after 7 days.

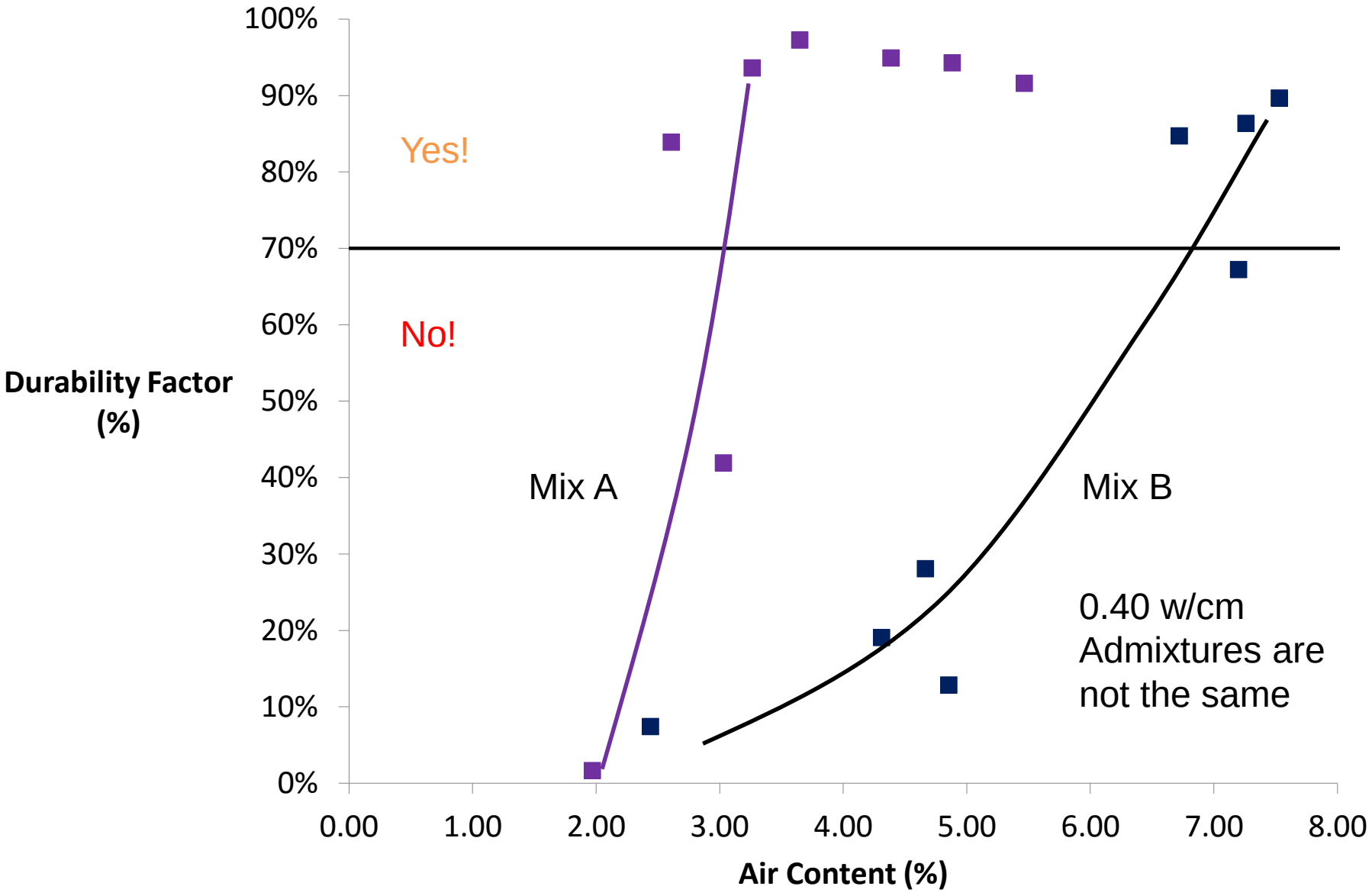
Slide from Tyler Ley

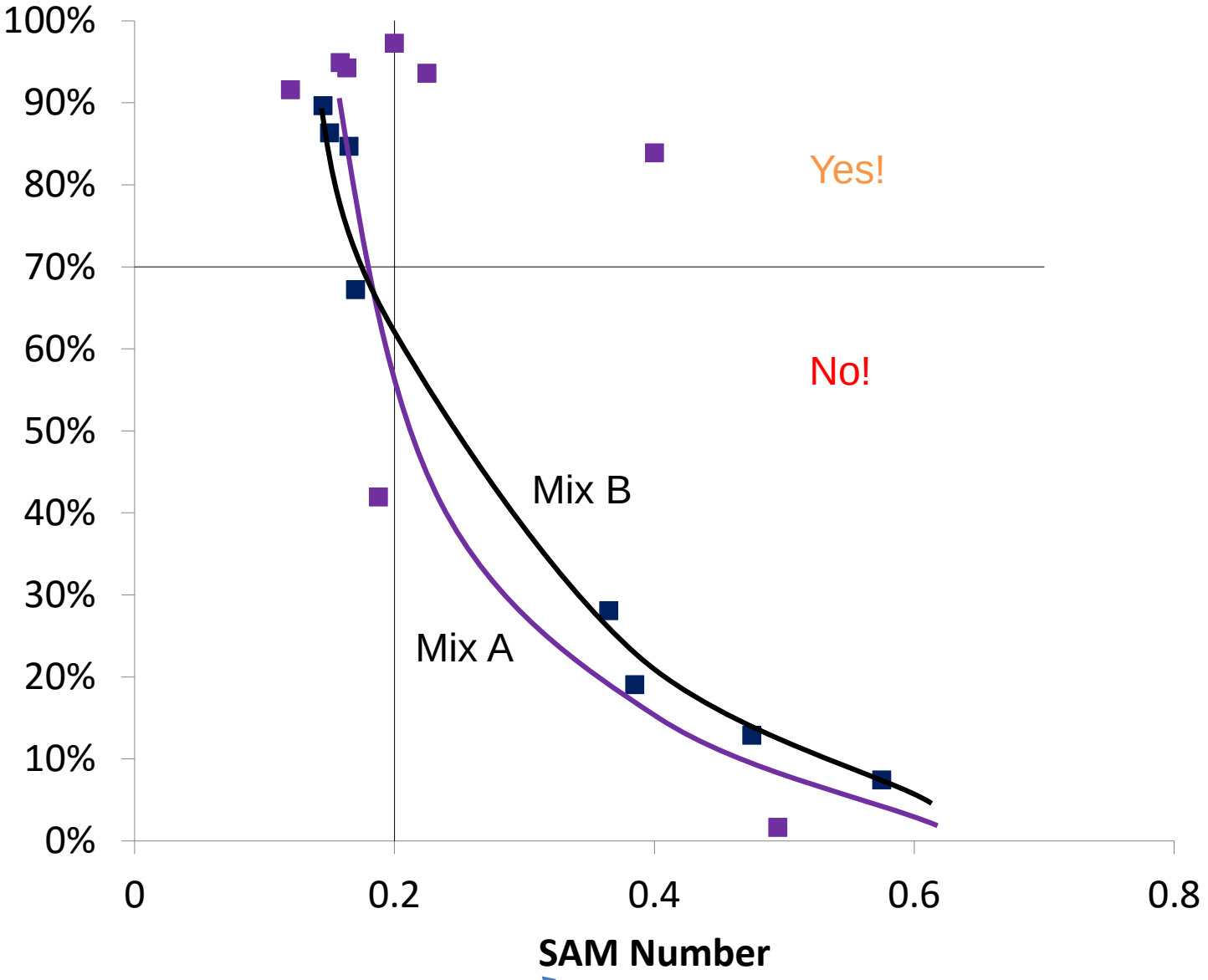

Split Tensile Strength (example)
Residual Capacity
Residual Tensile Stress (MPa)
Specimen Temperature (°C)
Age of Specimen (h)
10
8
6
4
2
0
-2
30
20
10
0
-10
-20
0
24
48
72
96
120
144
168
192

Freeze Thaw durability

	w/cm	Air void volume	Air void system	Time to Critical Saturation
Test method	-	AASHTO T 152, T196, TP 118	AASHTO TP 118	-
Value	< 0.45	5 to 8%	≥ 4% Air SAM ≤ 0.20	30 Yrs
Approval?	Yes	Yes	Yes	Yes
Acceptance?	Yes	Yes	Yes	No

Slide from Tyler Ley


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Durability Factor (%)
Yes!
No!
Mix A
Mix B
0.40 w/cm
Admixtures are
not the same
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
Air Content (%)



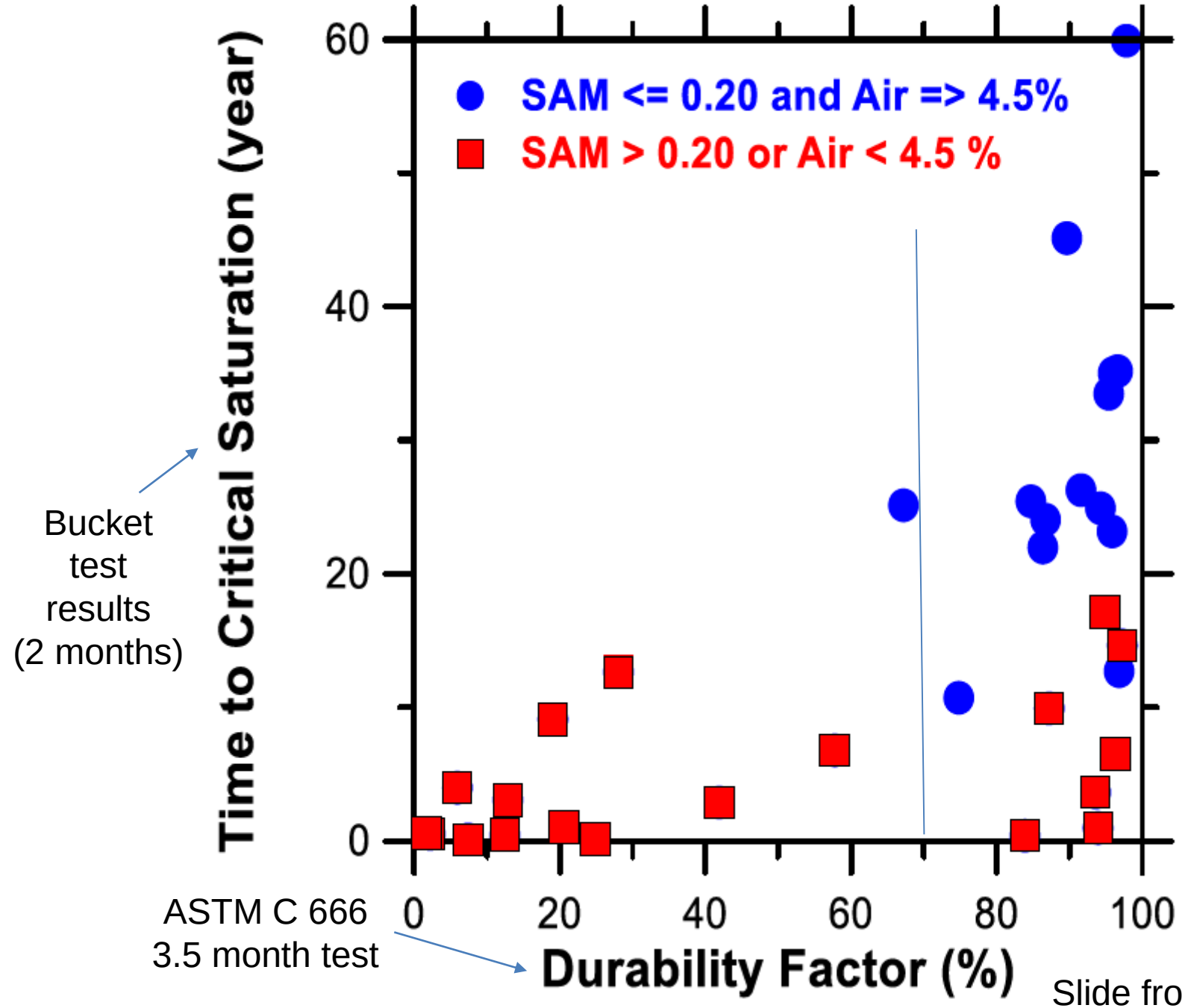
From Super Air Meter

Slide from Tyler Ley

The Bucket Test

- Cast concrete and keep sealed for 14 days
- Measure the cylinder mass after demolding
- Place three concrete cylinders in lime water
- Measure their mass at 5 days
- Measure their mass again every 10 days until they are 60 days old
- Oven dry cylinder and take mass
- Vacuum saturate cylinder and take mass
- Calculate the time to critical degree of saturation

Slide from Tyler Ley



Slide from Tyler Ley

Deicer Salts

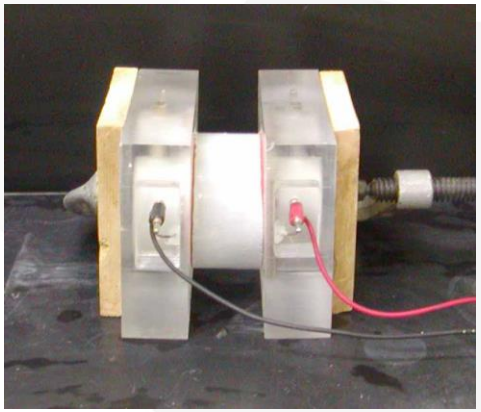
Are calcium or magnesium chloride deicer salts used?

Approach	use SCMs	use sealer	AASHTO T 365
Value	> 35%	-	< 0.15g CaOXY/g paste
Approval?	Yes	Yes	Yes
Acceptance?	Yes	Yes	No

Slide from Tyler Ley

Transport Properties

	w/cm	RCPT Value	Formation Factor
Test method	-	AASHTO T 277	AASHTO T 358
Value	0.45	< 2000	> 500
Approval?	Yes	Yes	Yes
Acceptance?	Yes	Yes	Yes



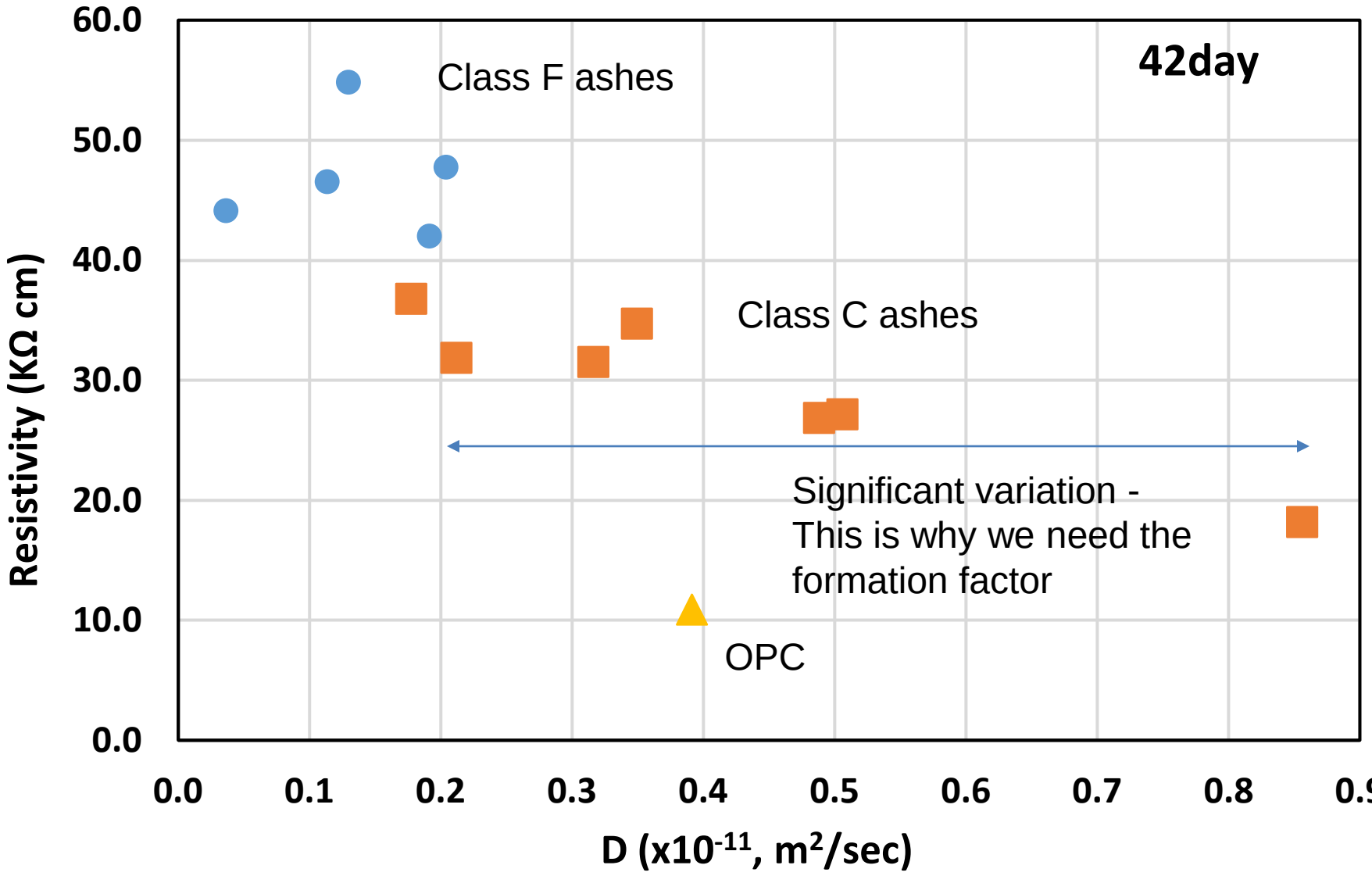
Slide from Tyler Ley

The Formation Factor

- It is a true measurement of how hard it is for solution to move through concrete
  - Reflects volume and connectivity of pores
- Can derive it from RCPT or resistivity test results
  - Must used standardized specimen geometry and condition (temperature and moisture)
  - Must correct for pore solution resistivity

Pore Solution Resistivity

- Three approaches are provided to determine pore solution resistivity
  - Assume a value (this is what we currently do for RCPT)
- Calculate a value based on the cement and SCMs using on-line calculator
  - Based on mill certificates or XRF results
- Squeeze out the pore solution and measure it



Ley lab data 2017

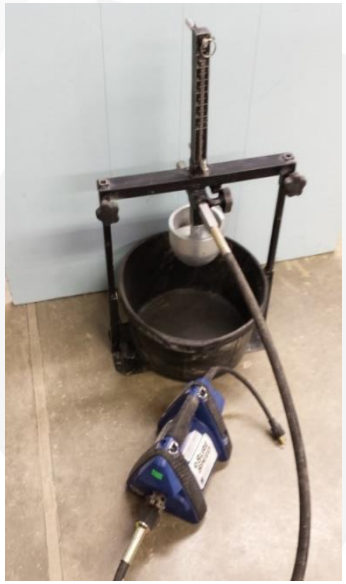
Diffusion Coefficient

Aggregate Stability

	D Cracking	Alkali Aggregate Reactivity
Test method	AASHTO T 161 ASTM C 1646	AASHTO PP 65
Approval?	Yes	Yes
Acceptance?	No	No

Constructability

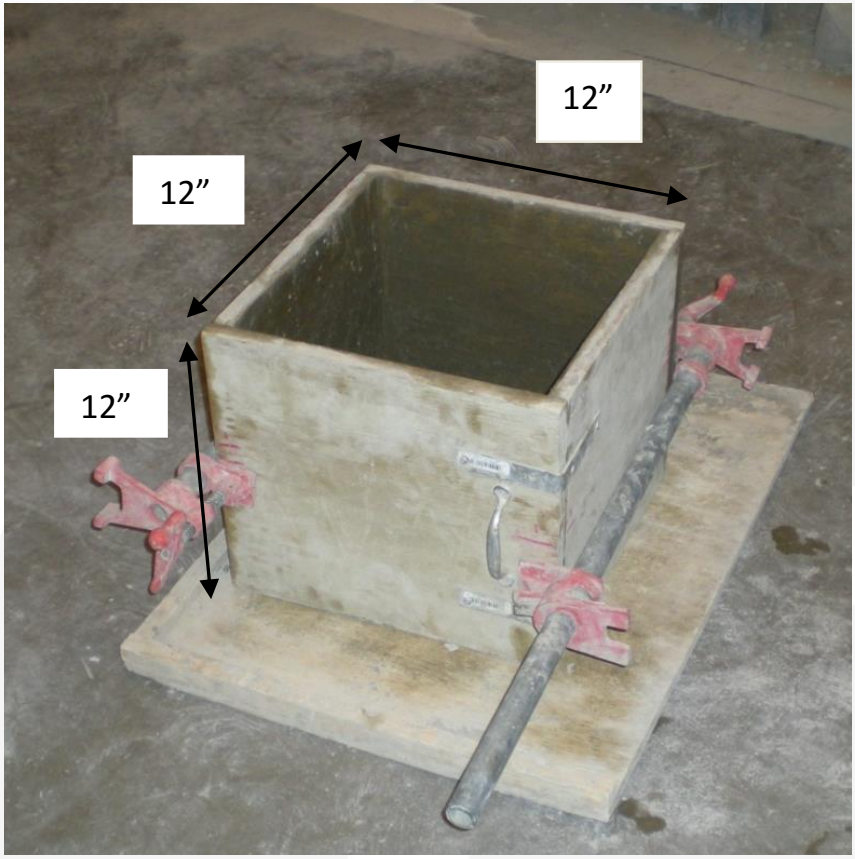
	Box Test	V-Kelly
Criteria	<6.25 mm, < 30% Surf. Void	15-30 mm per root seconds
Approval?	Yes	Yes



Slide from Tyler Ley

Box Test

- A simple test that examines:
  - Response to vibration
  - Filling ability of the grout (avoid internal voids)
  - Ability of the concrete to hold an edge



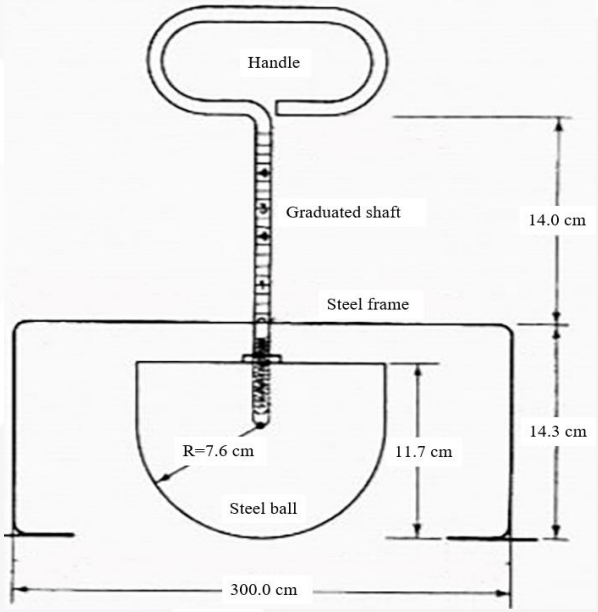
Box Test

- Add 9.5” of unconsolidated concrete to the box
- Insert 1” diameter stinger vibrator (8000 vpm) into the center of the box over a three count and then remove over a three count
- The edges of the box are then removed and inspected for honey combing and edge slump

Slide from Tyler Ley

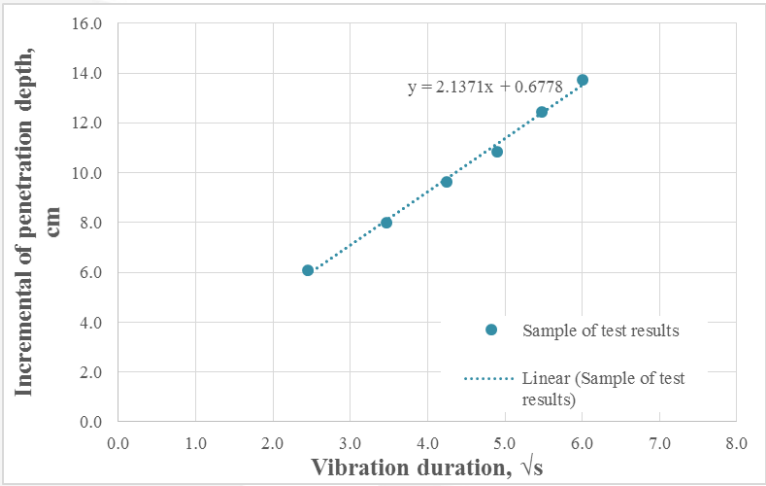
VKelly

- Kelly ball test
  - Developed in the 1950s in US
  - Standardized in California DOT test
  - Comparable to slump test
    - 1.1 to 2.0 times the Kelly ball reading



VKelly

- Measure initial slump (initial penetration)
- Start vibrator for 36 seconds at 8000 vpm
- Record depth every 6 seconds
- Repeat
- Plot on root time
- Calculate slope = VKelly Index



From Peter Taylor

Quality Control

- Tracking how our concrete varies
  - Unit weight
  - Air content/SAM
  - Water content
  - Formation factor
  - Strength
- This is important information that we are ignoring
- AASHTO PP-84 provides guidance for QC
  - Testing targets, frequency, and action limits
  - Guidance will be expanded

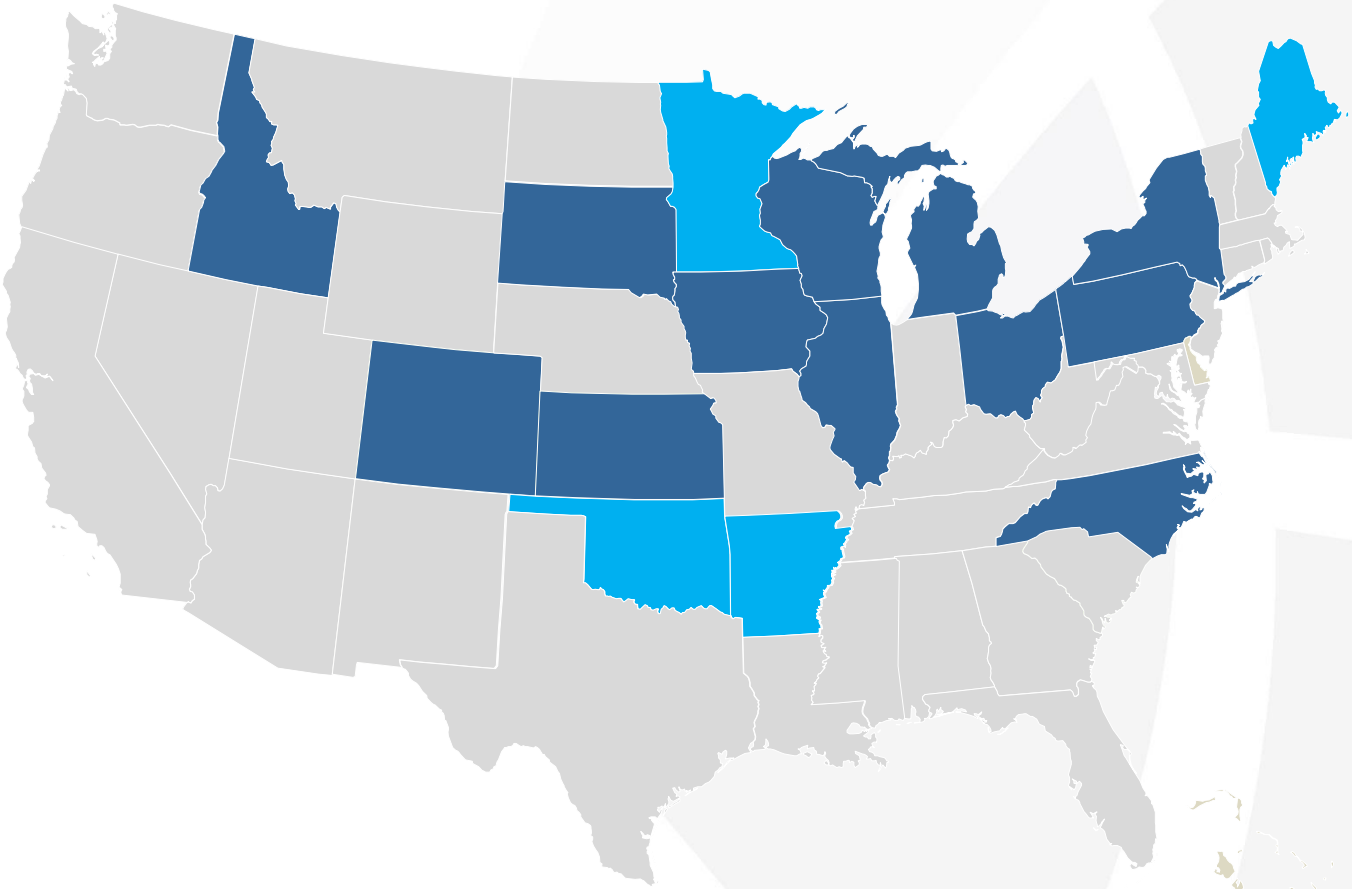
This is Just the Beginning

- Best approaches to provide guidance on critical durability issues are provided
- Detailed commentary provides background
- Over time everything will improve:
  - Tests
  - Specification
  - Commentary
  - Implementation
  - People's attitude
  - Our concrete

New Pooled Fund Study

- PEM Pooled Fund - TPF-5(368)
- Provide technical support to try portions of PEM
  - Introduce PEM to concrete acceptance programs
  - Support PEM with Mobile Concrete Trailer
  - Provide guidance on tests/implementation
  - Develop quality control guidance
  - Incentive Fund Program
  - Develop the next generation of tests to evaluate durability in fresh concrete

New Pooled Fund States



Questions?