



Quality Pavements: What to have in mind?

Jim Grove

ATI Inc

USA

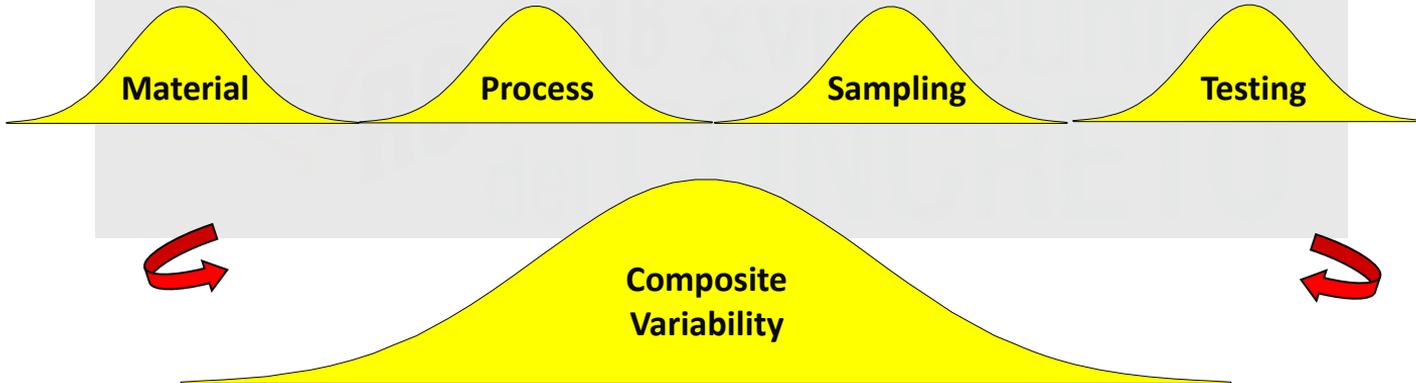
Sources of Variability

Material

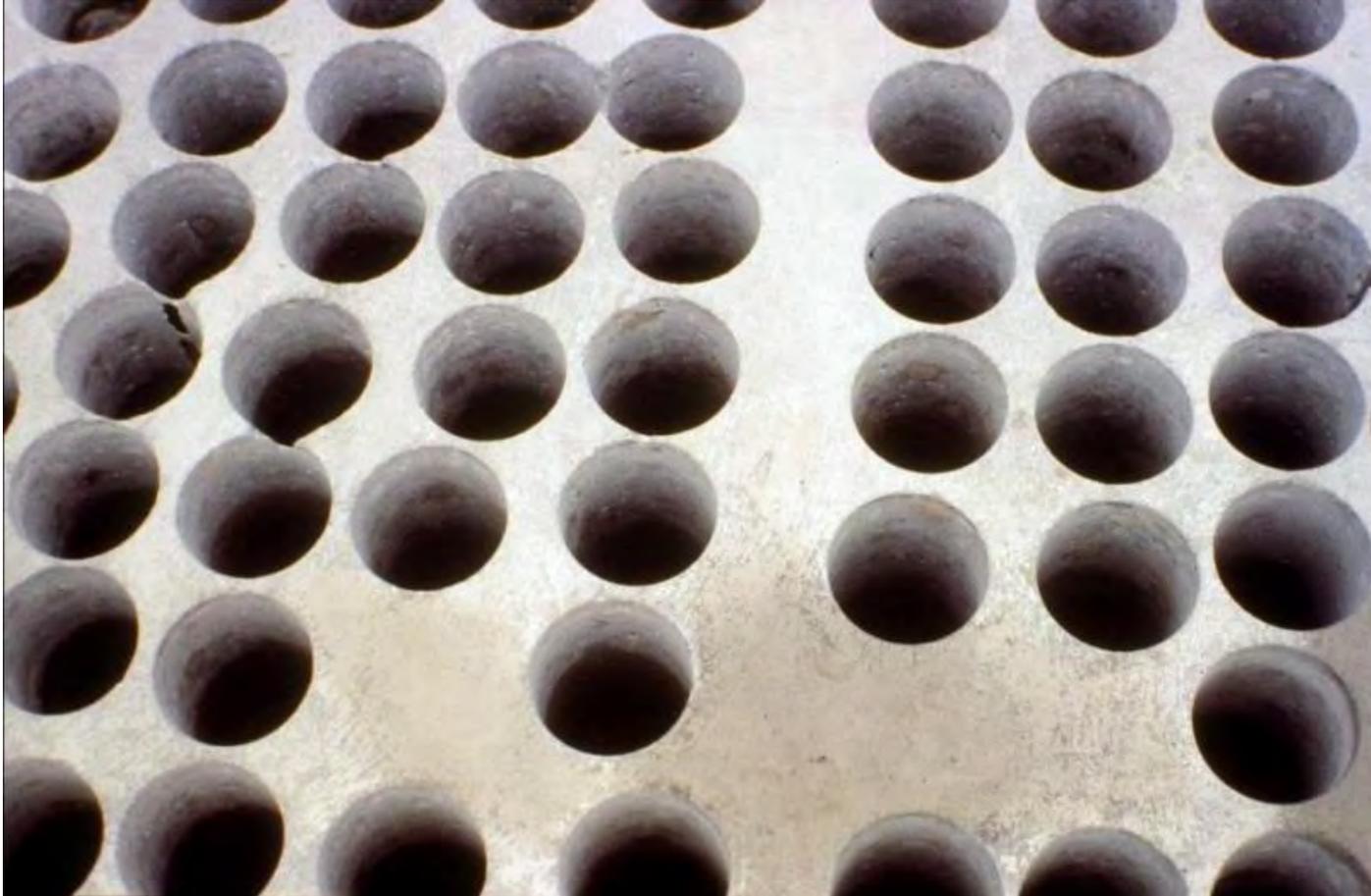
Process

Sampling

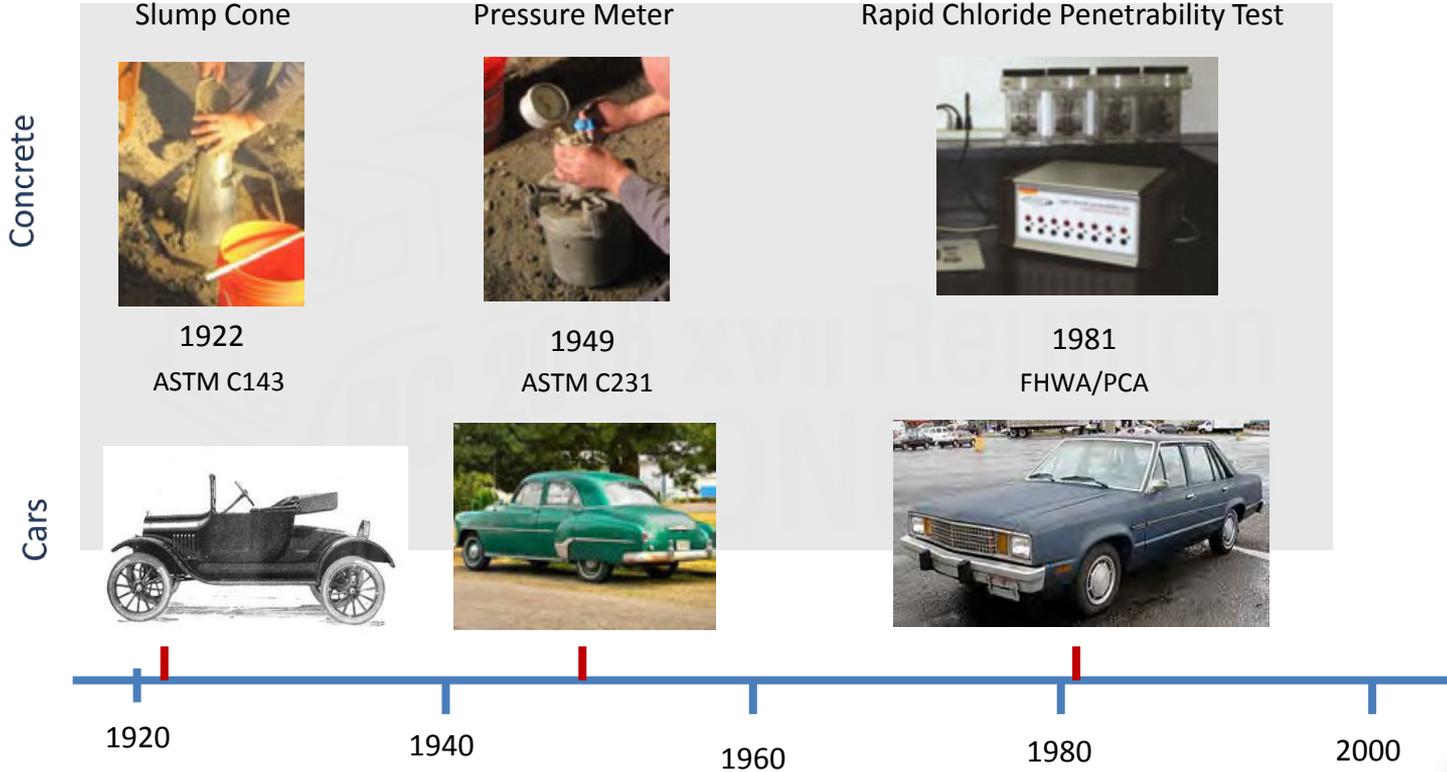
Testing



We can't test it all!



Concrete has Changed-But our tools?



Are we testing the right quality characteristics?

- What really counts?
- How do pavements fail?
- What do we test for acceptance?
 - Slump “A slump test only measures slump”
 - Air content Total air doesn’t insure durability
 - Strength Strength is 28 days too late!
- Can we do better?

YES!

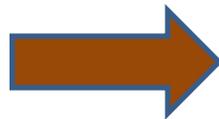


Are we testing in real time?

- Quality Control (QC) testing
 - Need to make changes during construction
 - Prevent problems to insure quality
- Agency Acceptance
 - Risk costs money!
 - Waiting 28 days for strength test results



Real Time Smoothness



California Profilograph

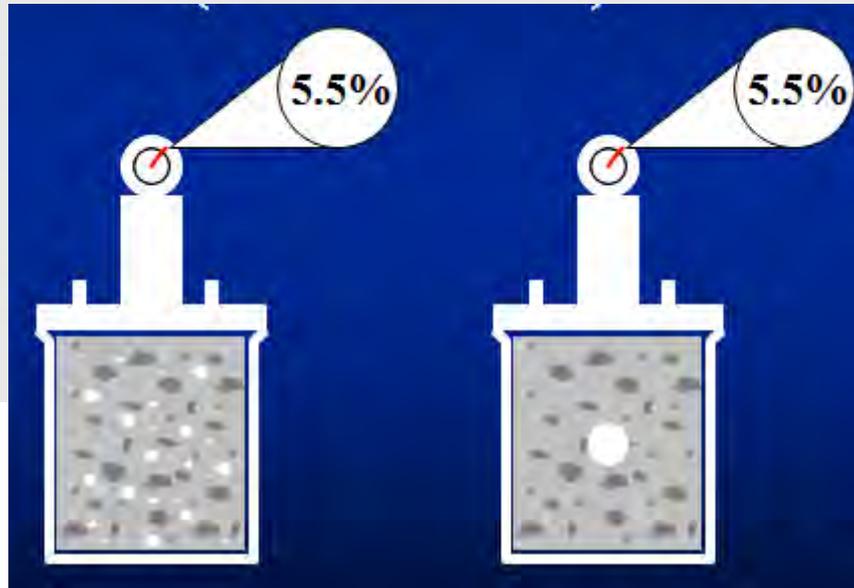


Right Properties with New Tools

- Focus on properties that affect durability
- Utilize tests that measure those properties
- Many are non-destructive
- Easy to use
- Reasonable costs

Air Content

- Total air → Air void system

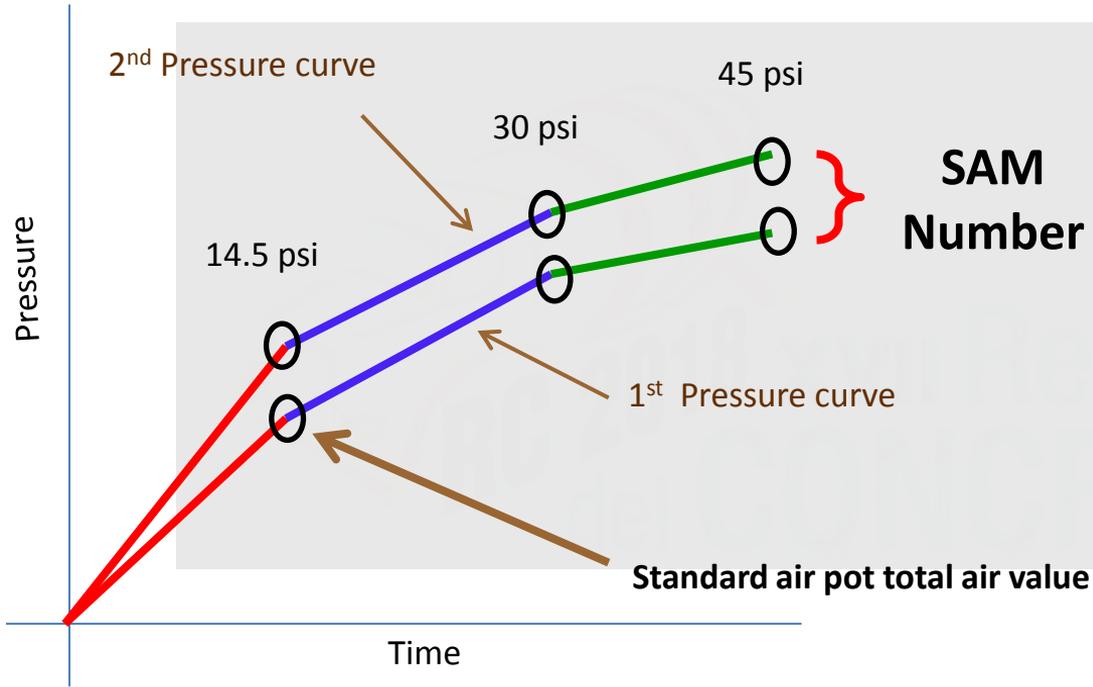


Super Air Meter (SAM)

- Plastic concrete test
- Measures air system quality
- Modification of existing Pressure Air Meter test
 - Field friendly
 - 8-12 Minutes
 - Measures total air content also
- Developed by Dr. Tyler Ley
Oklahoma State University
- **AASHTO TP 118**



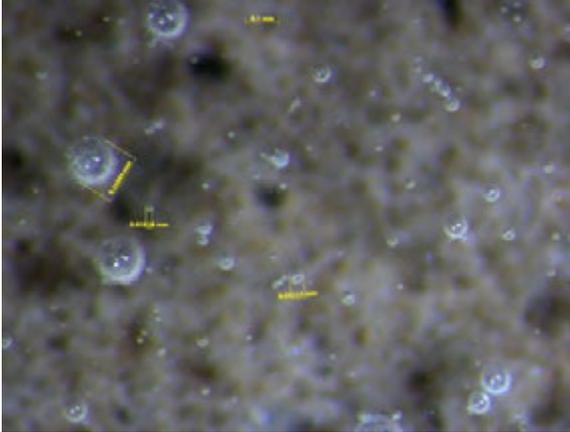
SAM Principle



SAM Principle



- Small bubbles dissolve
- Inverse of bubble coming out of soda after it is opened



Atmospheric pressure

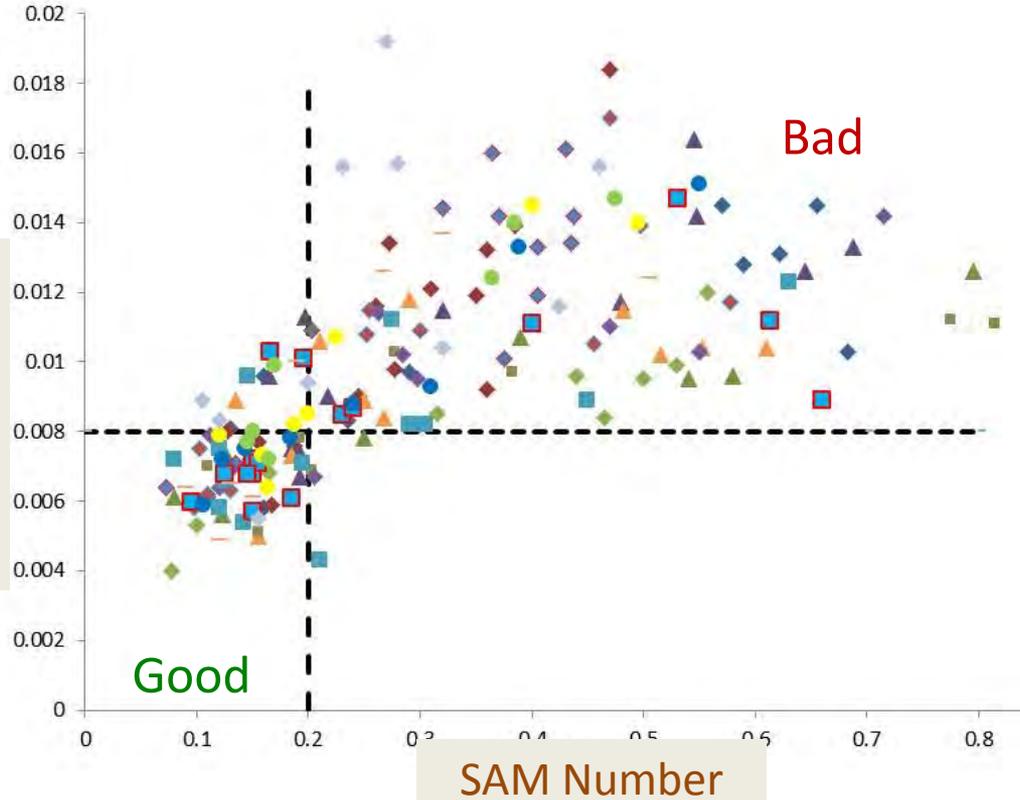


Pressure at 45 psi

SAM Principle



Spacing Factor



Unit Weight

- Used to monitor uniformity
- Easy to do
- Costs almost nothing
- Weigh the air pot before you place the lid on
- **AASHTO T 121**

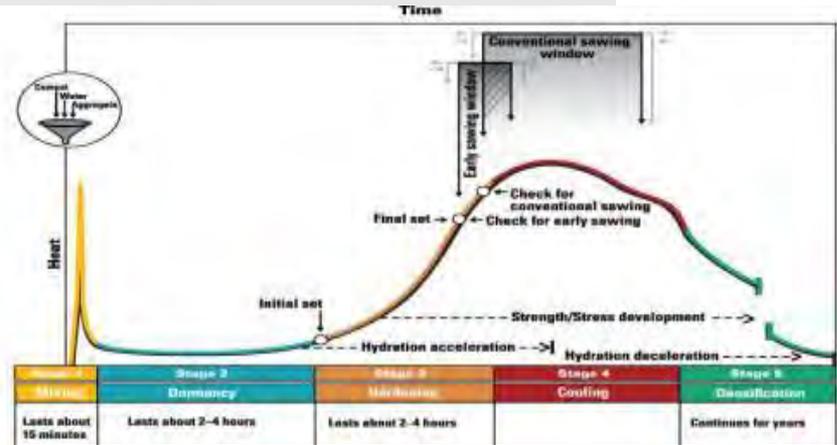


Has something changed?



Heat Signature (Calorimetry)

- Measures the heat of hydration
 - Measure temperature under controlled conditions
 - It's the curve
- About a day to develop the curve
- Equipment is relatively inexpensive
- **ASTM C 1753**



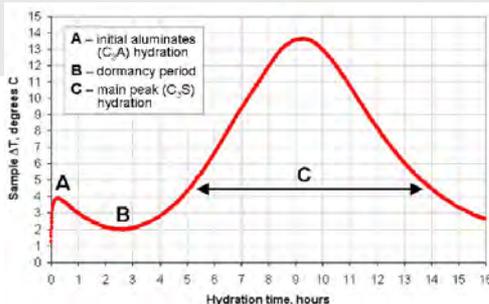
Heat Signature (Calorimetry)

Indicator /Monitor

- Cementitious system
- Strength development
- Time of set
- Sawing window
- Uniformity

Uses

- Identify adverse interactions (Incompatibilities)
- Compare competitive materials
- Troubleshoot field problems



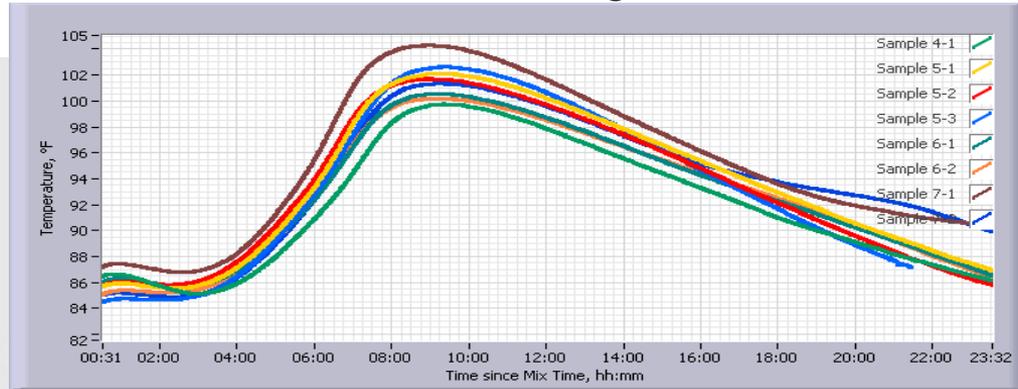
Heat Signature (Calorimetry)

- Procedure is simple:
 1. Cast a standard cylinder
 2. Place it in the calorimeter
 3. Shut the lid

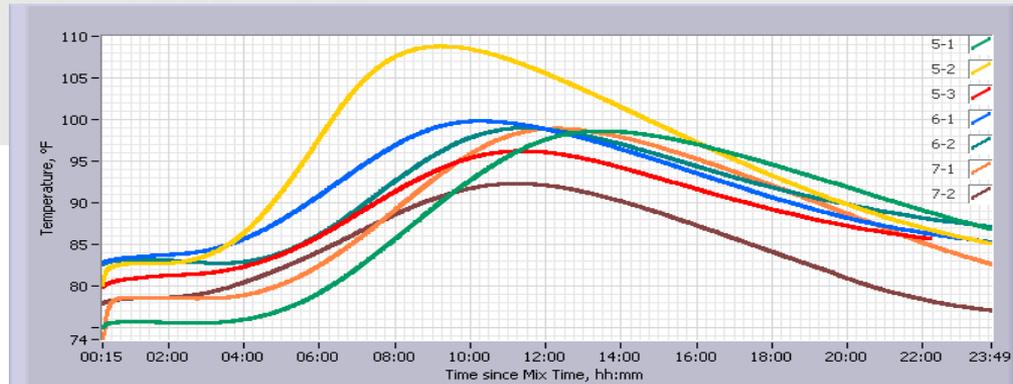


Heat Signature (Calorimetry)

Consistent Heat Signature

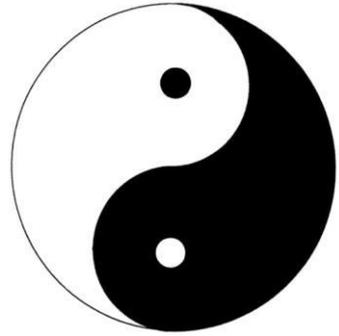


Inconsistent Heat Signature



Yin and Yang of Testing Concrete

• Unit Weight



- Measures change in things that have weight
 - Air (takes up space of things that have weight)
 - Water
 - Aggregates



• Calorimetry

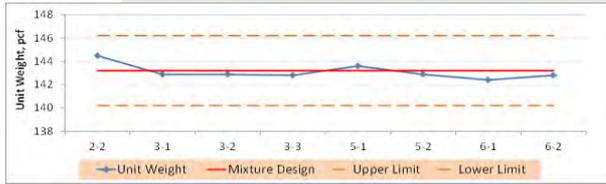
- Measures change in the chemistry
 - Fly ash
 - Cement
 - Admixtures



Together, they should tell you if something changed!

Use QC to Predict Acceptance

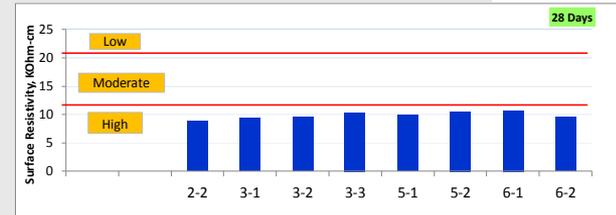
Real Time QC



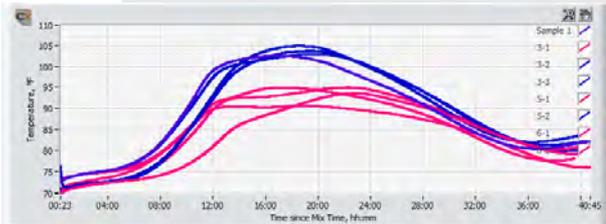
Unit Weight – Real Time



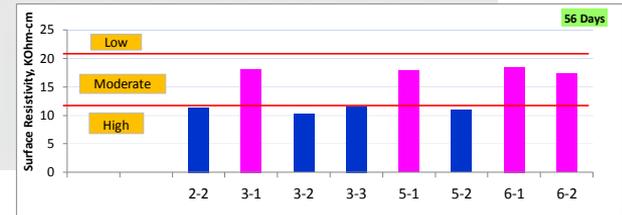
Acceptance



Surface Resistivity – 28 Days



Heat Signature – Info in a day



Surface Resistivity – 56 Days

MCT data

Permeability

- The ease with which fluids can penetrate the concrete
- Only the paste contributes
- Durability damage is governed by permeability
- How do we lower permeability?
 - Use low w/cm
 - Use Supplementary Cementitious Material (SCMs)
 - Minimize paste volume by optimizing the gradation
 - Curing



Permeability

(Surrogate Tests for Durability)

Rapid Chloride Penetrability Test (Indirectly)



AASHTO T 277

- Most common test
- Indicator of vulnerability to water and chloride ingress
- Generally 24 hours to condition and 6 hours for testing

Permeability

(Surrogate Tests for Durability)

Surface Resistivity Test (Indirectly)



- Instant results on hardened concrete
- Non-destructive test
- Easily measures the right property
- State specification
 - Several states
- **AASHTO T 358**

Surface Resistivity versus RCPT

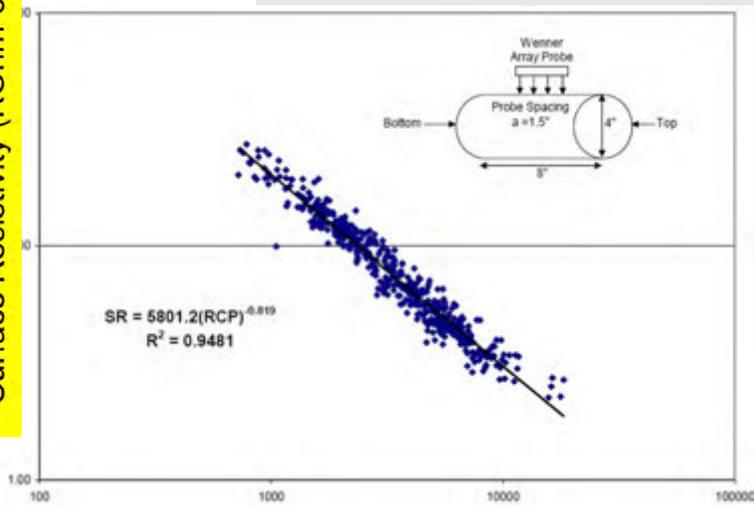
- Significantly faster test
- No sample preparation involved
- Nondestructive
- No chemicals involved
- Lower equipment cost
- Lower labor costs



Permeability

- Surface Resistivity Test matches well with Rapid Chloride Penetrability Test
 - Florida, Louisiana, and Maine

Surface Resistivity (KOhm-cm)



RCP (Coulombs)

Florida DOT



VKelly

- Kelly ball test
 - In use by California DOT
 - Comparable to slump test
- VKelly
 - Developed by Dr. Peter Taylor
National Concrete Pavement Technology Center
 - Add vibrator to the Kelly ball
- It is a tool
 - Evaluate workability of a mixture
 - Used to optimize a concrete mixture



VKelly

- Procedure

Step 1

- Measure initial slump (initial penetration)

Step 2

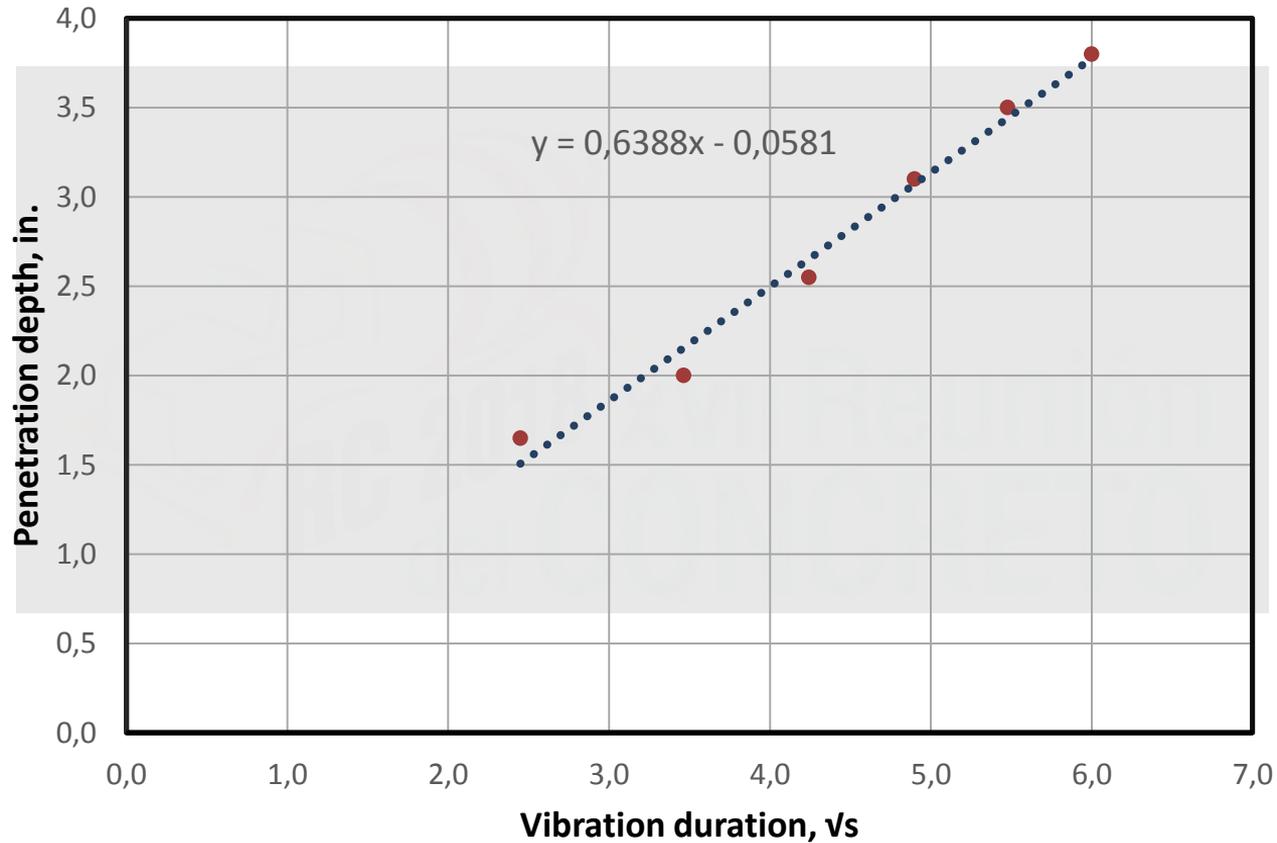
- Start the vibrator and measure for 36 seconds at 8000 vpm
- Record depth every 6 seconds
- Plot on root time scale
- Calculate slope => VKelly Index

Bigger number => more responsive to vibration

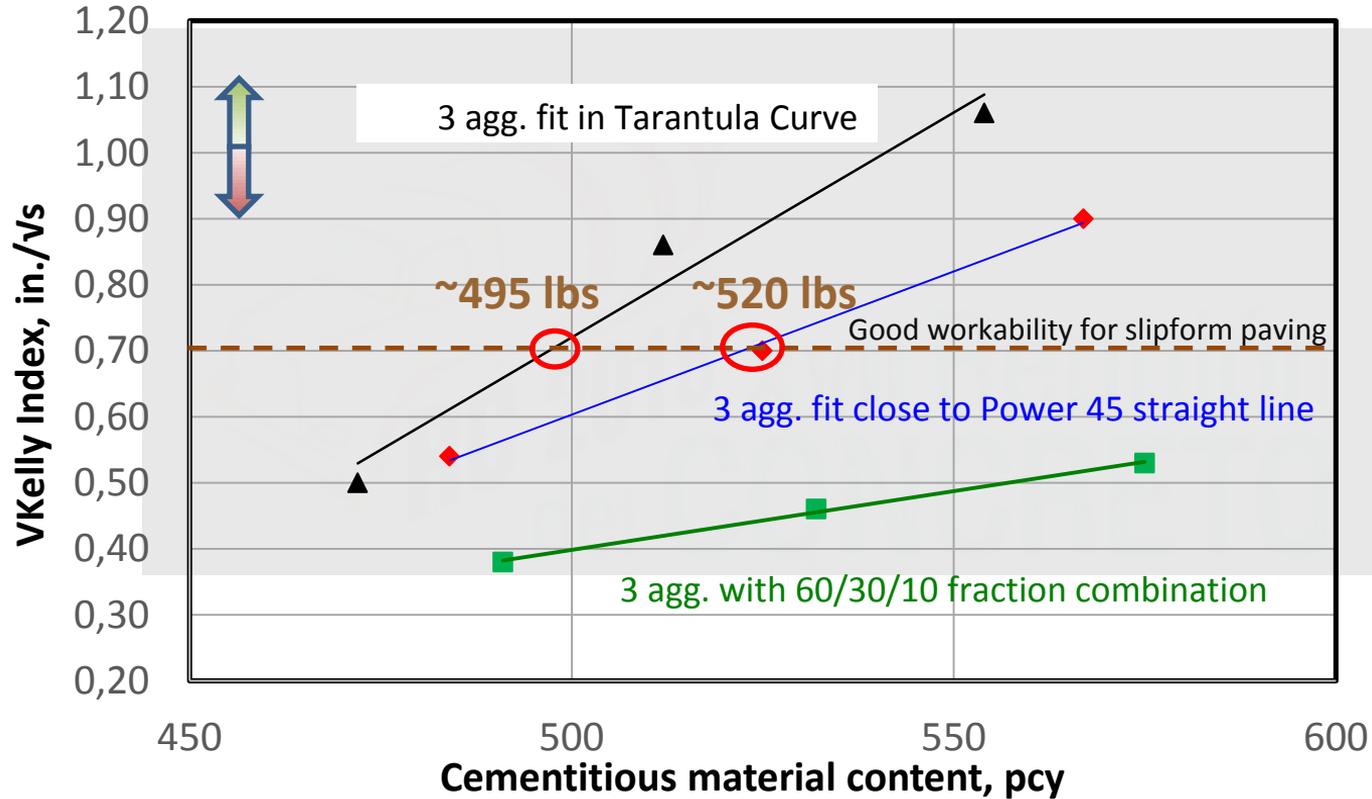
<http://www.cptechcenter.org/pem/documents/Test-Summary-Vibrating-Kelly-Ball-Test.pdf>



VKelly



VKelly



Box Test

- Developed by Dr. Tyler Ley
Oklahoma State University
- Mixture response to vibration
 - Consolidation check
 - Edge slump check
- Easy visual check
- Mix design tool
 - Evaluate the gradation
 - Cementitious content

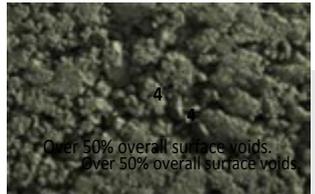
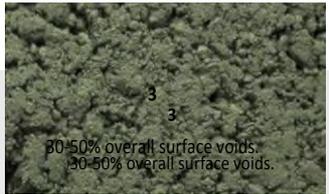
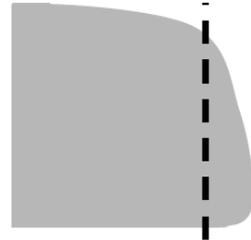
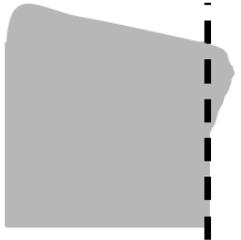
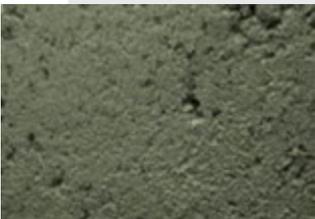
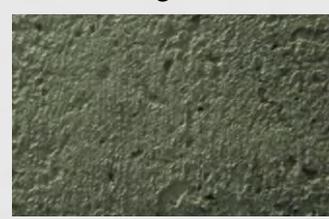


Box Test

- A workability test
- Simple
- Included in AASHTO PP 84 (PEM)
- Anticipated as a AASHTO provisional test method



Box Test

 <p>4 Over 50% overall surface voids. Over 50% overall surface voids.</p>	 <p>3 30-50% overall surface voids. 30-50% overall surface voids.</p>		
 <p>2² 10-30% overall surface voids. 10-30% overall surface voids.</p>	 <p>1¹ Less than 10% overall surface voids. Less than 10% overall surface voids.</p>	<p>Bottom Edge Slumping</p> <p>Top Edge Slumping</p> <p>If deflection is more than 1/4" then it fails</p>	

Consolidation Issues

Edge Slump Issues

Box Test

Project A

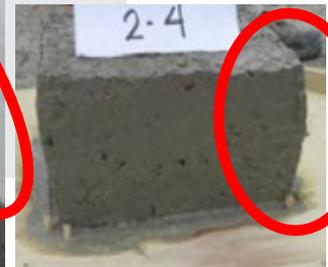


Finishability Issues



Project B

Edge slump Issues



Water Content

- Water / Cementitious Ratio

=>Weight of water divided by weight of cementitious
(cement, fly ash, slag cement)

- Direct relationship with permeability
- Inverse relationship with strength
- Uniformity
- Shrinkage



$$= w / cm$$

Water/Cementitious Ratio

- How close are the duckies in your hot tub?

What you **don't** want

Lots of water, not many duckies



What you **do** want

Lots of duckies, not much water



Microwave Water Content

- Developed in SHRP1
- Sample from the truck
- AASHTO T 318
- Specifics
 - Takes about 20 minutes to run
 - Great care to contain material
 - Labor intensive



Phoenix

- New test to measure the water in fresh concrete
- Developed by Dr. Tyler Ley Oklahoma State University
- Easy to operate
- Once the test begins, no attention is required

Run it on the back of a pickup



A hot plate and a “branding iron”
heat the concrete



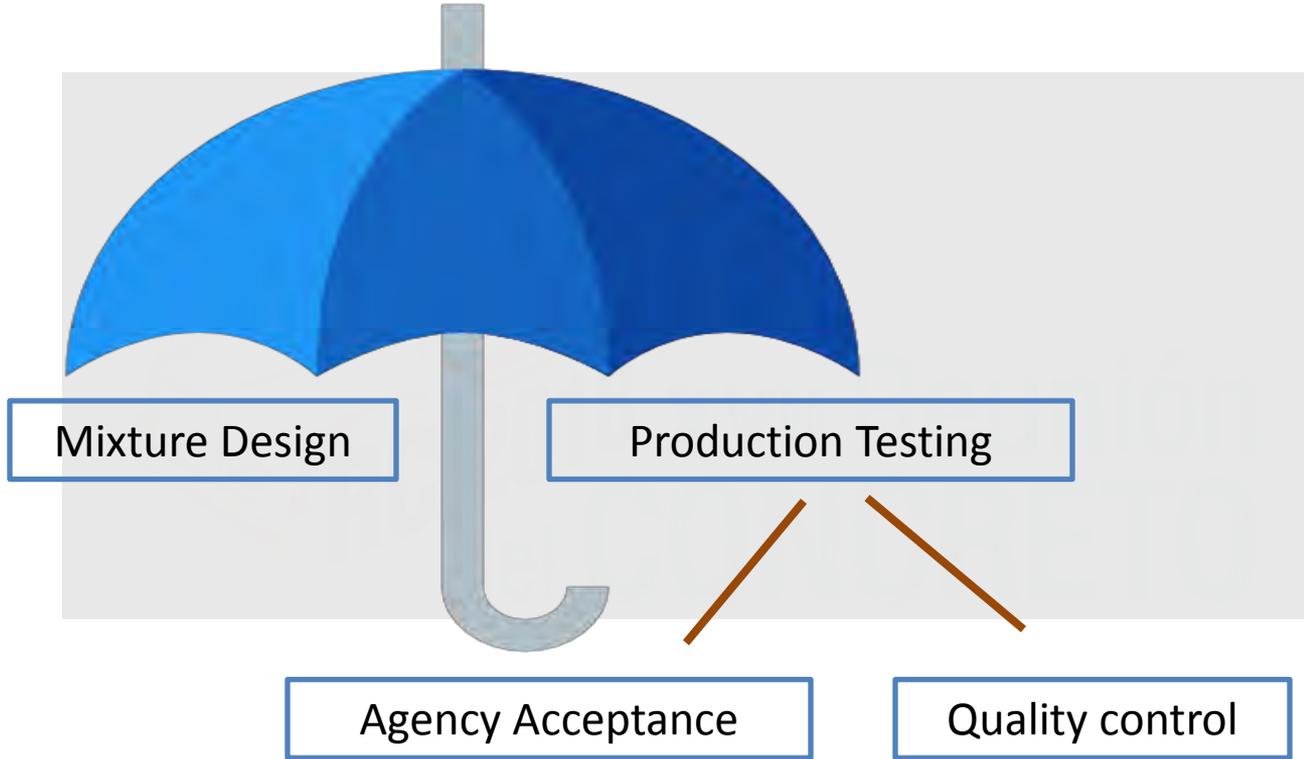
Heats from the top and bottom



Performance Engineered Mixture (PEM) Concept

- Understand
 - What makes concrete last
 - What failure mechanisms we see
- Specify critical properties and test for them
- Prepare the mixtures to meet those specifications
- Starting point
 - For an acceptance program for owner agencies

Performance Engineered Mixtures (PEM)



Keys to Durable Concrete

- Test the right properties (PEM)
 - Strength
 - Cracking tendency
 - Freeze-Thaw durability
 - Permeability
 - Aggregate stability (Durability)
 - Workability
- Test in real time

Jim Grove

ATI Inc. / FHWA

2711 South Loop Drive, Suite 4502

Ames, Iowa 50010

Phone: 515-294-5988

Mobile: 515-450-3399

jim.grove@dot.gov

