

Evolution of Durability for Concrete Pavements

Dr Peter Taylor, PE (IL), FACI

THE WORLD'S GATHERING PLACE FOR ADVANCING CONCRETE



Introduction

- Durability past
 - Add cement
 - Make it strong
 - Add air
 - Watch the slump

(All based on improving w/cm)



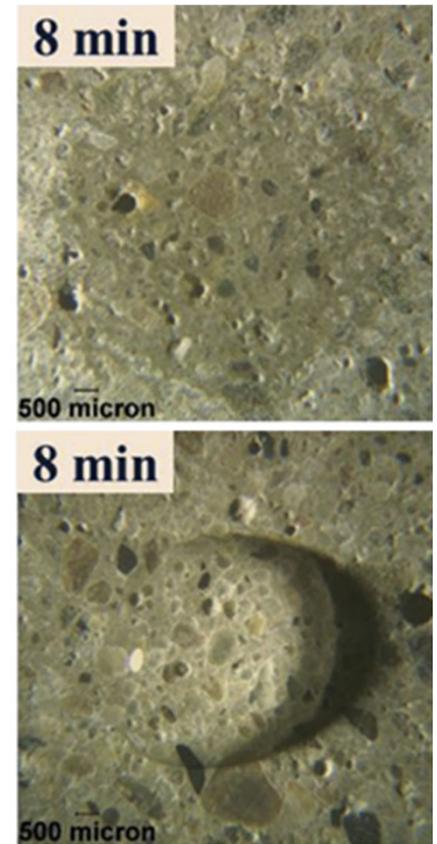
Introduction

- Durability recent
 - w/cm
 - SCMs
 - Better air void system
 - Sealants

Keep the water out!

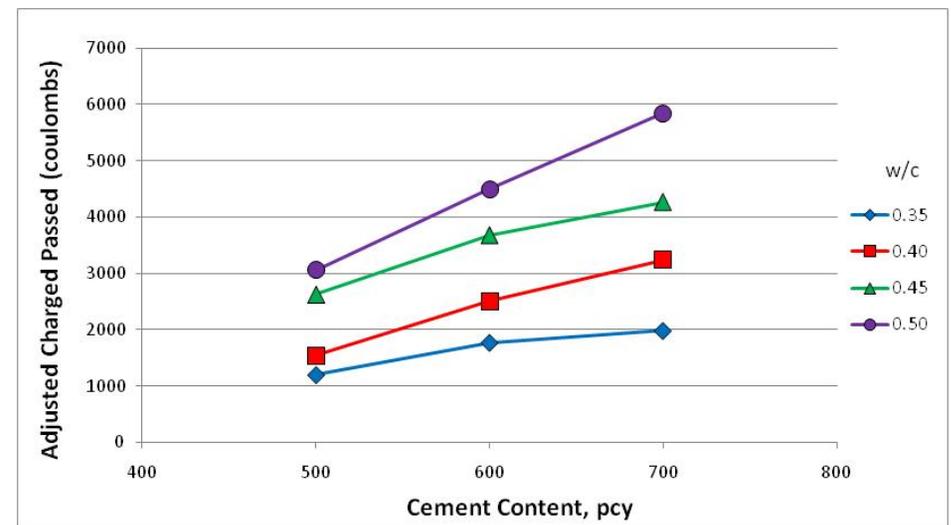
SCMs and WRAs removed the links between

- Slump and w/cm
- Strength and permeability



Introduction

- Durability future
 - What is the exposure?
 - What are the mechanisms?
 - How do we control responses to those mechanisms?



Potential Durability

Ability of the concrete to survive the environment to which it is exposed:

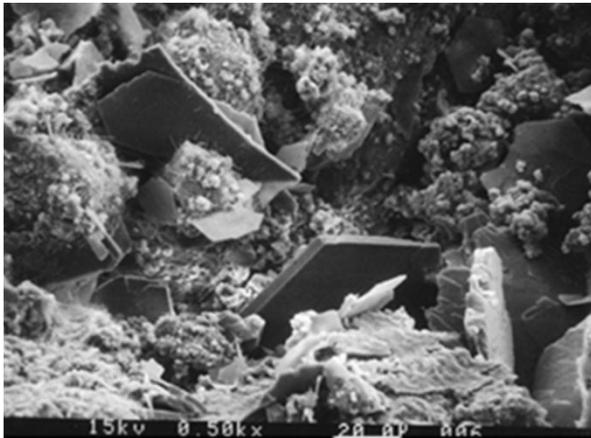
- Fluid transport
- Cold weather
- Alkali aggregate reaction
- Sulfates



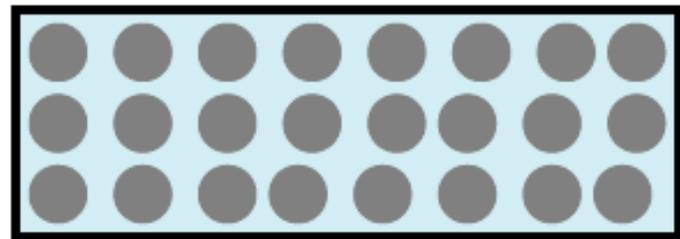
Potential Durability

Controlled by:

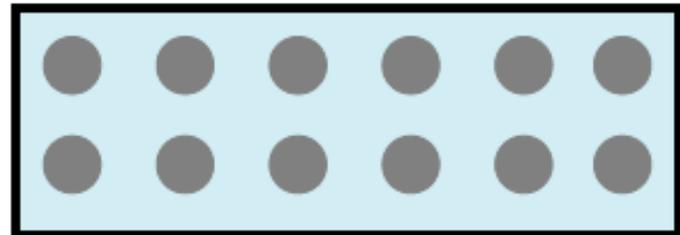
- w/c
- System chemistry



$w/c = \text{Low}$



$w/c = \text{High}$



The Things that Matter (PEM)

- Transport properties (everywhere)
- Aggregate stability (everywhere)
- Cold weather resistance (cold locations)

- Strength (everywhere)
- Shrinkage (dry locations)
- Workability (everywhere)



Measure at the Right Time

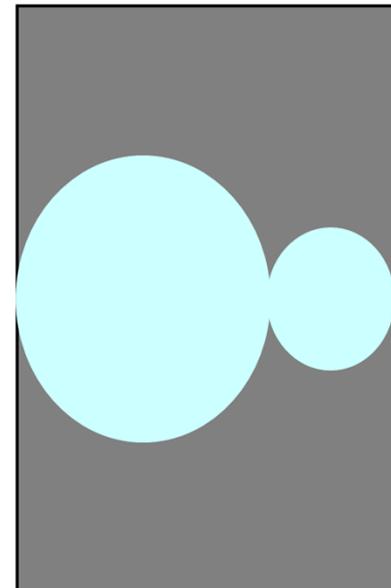
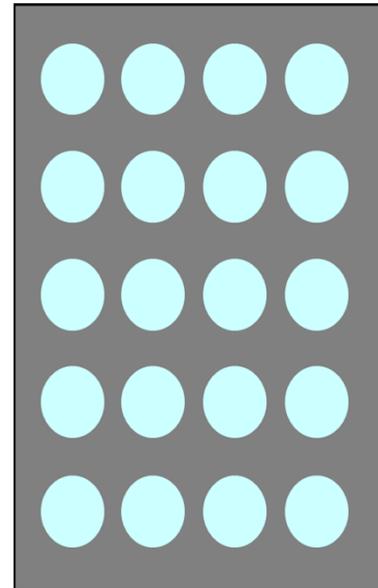
- Prequalification
 - Everything – including calibration curves
- Process control
 - Check the activities that affect performance
- Acceptance
 - To pay or not to pay...



Fluid Transport

The ease with which fluids can penetrate concrete

- Significance
 - All durability damage is governed by permeability
- Factors
 - w/cm
 - SCM type and dose
 - Hydration
 - Cracking



Transport

- Testing
 - RCPT (ASTM C1202)
 - Resistivity (AASHTO T 358, TP 119)
 - Store a cylinder in a fixed salt solution
 - Pull out at desired age
 - Read and put back
 - Repeat
 - $F = \frac{\text{Resistivity (bulk)}}{\text{Resistivity (solution)}}$
- Acceptance



Cold Weather

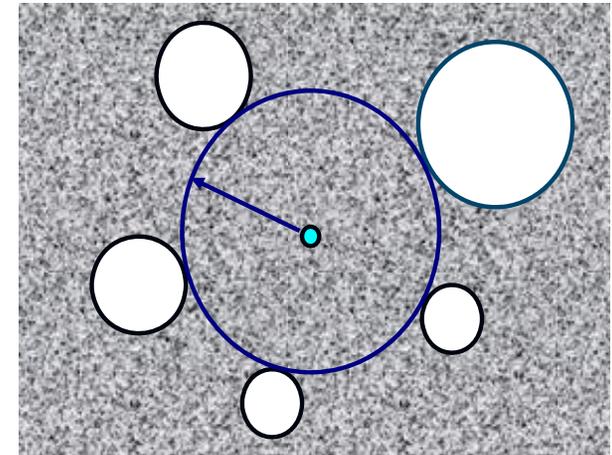
Two mechanisms:

- Saturated freeze thaw
- Oxychloride formation



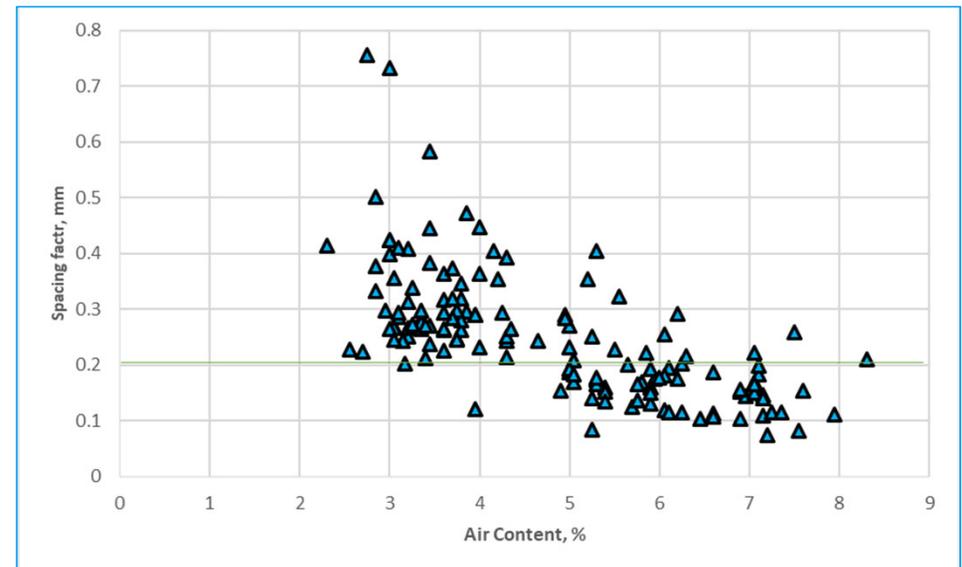
Air-Void System

- Why?
 - Bubbles slow the rate of saturation
- What are we looking for?
 - Air void system is more important than total air content
 - Spacing factor: maximum distance of any point in a cement paste from periphery of an air void, $< 0.008''$
 - $SAM > 0.2$



Air-Void System

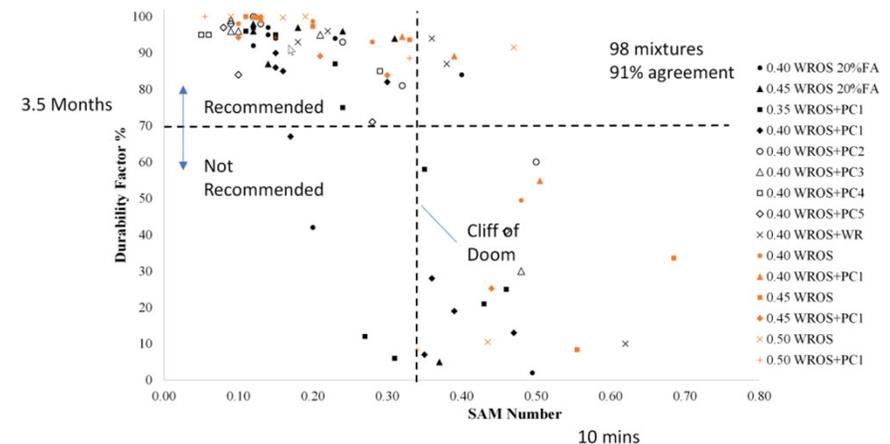
- Where?
 - At the batch plant
 - At delivery
 - At point of placement
- When?
 - Prequalification
 - In the field
 - At the central lab
- How?



Air-Void System

- Pressure Test, ASTM C 231 / AASHTO T 152
- Volumetric, ASTM C 173 / AASHTO T 196
- Gravimetric, ASTM C 138 / AASHTO T 121
- Super Air Meter AASHTO TP 118
- Microscopy ASTM C 457

- Acceptance



Salt attack

- Calcium oxychloride
 - Reaction between $\text{Ca}(\text{OH})_2$ and calcium or mag chloride
 - Expands
 - Forms above 32F
- Prevention
 - Enough SCM



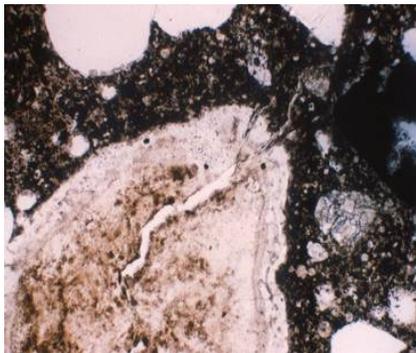
Tests for Oxychloride

- Low temperature differential scanning calorimetry (LT-DSC)
- Expansion
- Prequalification



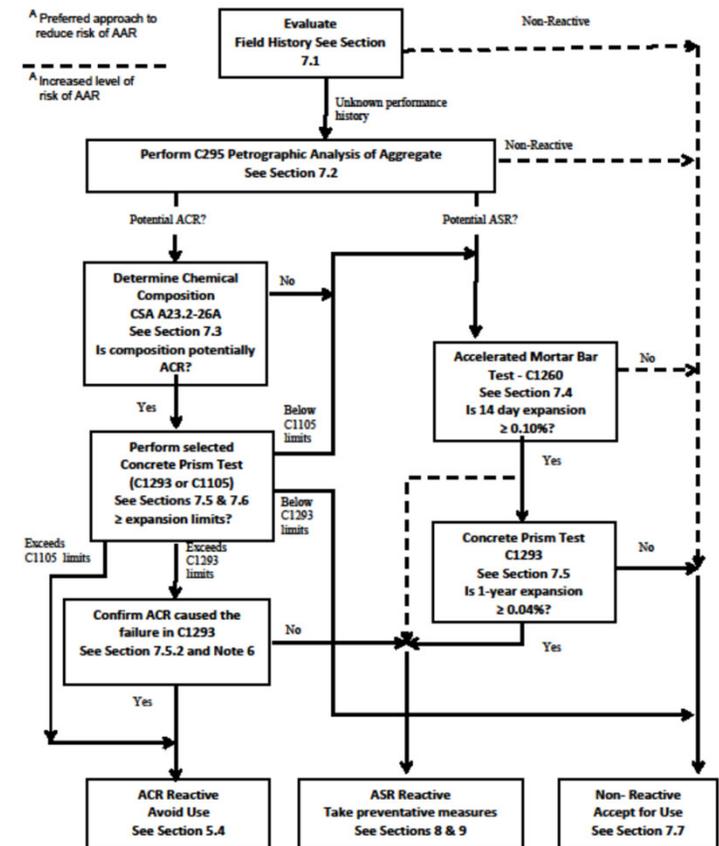
Alkali-Silica Reaction

- Water + alkali hydroxide + reactive silicate aggregate → alkali silicates
- Alkali silicates + water → gel + expansion
- Silicates from aggregates
- Alkalis from cement (Na and K)



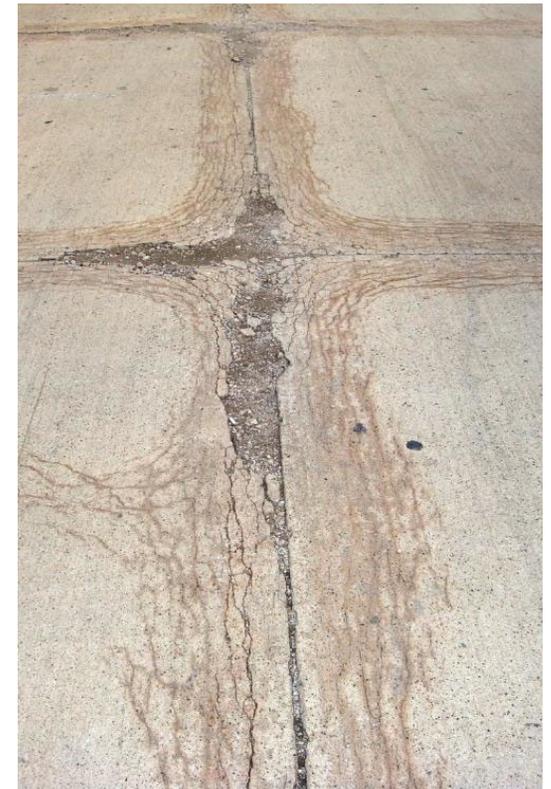
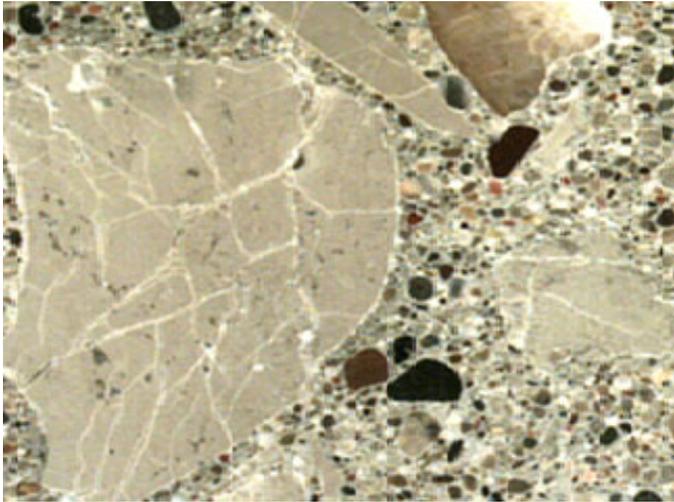
Alkali-Silica Reaction

- Prevention
 - Choose aggregates
 - Use SCMs (low-calcium fly ash)
 - Combinations of the above
- Testing / Specification
 - AASHTO R80 / ASTM C1778
- Prequalification



D-Cracking

- Certain calcareous aggregates absorb water
- Pore size prevents water leaving the system
- Freezing causes damage



Testing

- Iowa Pore Index Procedure
- Freeze thaw test of standard mixture
- Indiana Hydraulic Fracture Test
- Ledge control

- Prequalification



Quality Control

- QC should include
 - Unit weight
 - Calorimetry
 - Maturity
 - Strength development
 - Air void stability
- And a response...
- Risk management



But...

- Too many tests!
 - That variability!!
 - Too much change!!!
-

But...

- My mixtures will be changed!!!!
 - Most of the time our concrete is great!
 - IA, PA, MN experience is positive

		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	Type, gradation	✓✓	-	-	-	-	✓✓
Paste quality	Air, w/cm, SCM type and dose	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	Vp/Vv	✓	-	-	-	✓✓	-

Shiraz

- Thanks for
 - Many hours of conversations
 - Hard questions
 - Opportunities
 - Encouragement and support



National Concrete Pavement Technology Center



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