Concrete 101 – What's Changed or What Might Change?

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NCE

This Talk

- What has changed?
  - Nothing
  - A lot
- The better question is “What will change?”
  - Trends
  - Design
  - Materials
  - Tests

Trends: A Shifting Environment

- The climate is changing
  - What was is not necessarily what is to be
    - Cannot depend on historical data alone
  - Shifting average temperatures, temperature extremes, and precipitation patterns all have an impact on pavements
  - Rising oceans/coastal flooding and drought driven wildfires are an associated impact
  - Changes in frost depth and number of F-T cycles

Resiliency and Concrete Pavements

- Overall, concrete is not too sensitive to climate change
  - Potential for greater blow ups
  - Increased risk of pumping
- Concrete may be the answer
  - Use concrete pavement solutions in roadways identified as being susceptible to flooding or from the impact of high temperatures
  - Strengthen supporting layers with cement-based stabilizer

Emerging Regulations to Address Anthropogenic Climate Change

- Cap and reduce CO_2 equivalents
- California "leads" the way, others are following
- This needs to be done rationally
- The results need to be quantifiable
- Must have actionable responses

Changing Traffic

- Regardless of what operates on the surface, a surface will be necessary in the foreseeable future
- Increased urbanization and the growth of megaregions will increase the need for mass transportation
  - Electric/hybrid buses are HEAVY
- Freight movement is expected to increase significantly
  - Heavier autonomous trucks

The Future of Asphalt

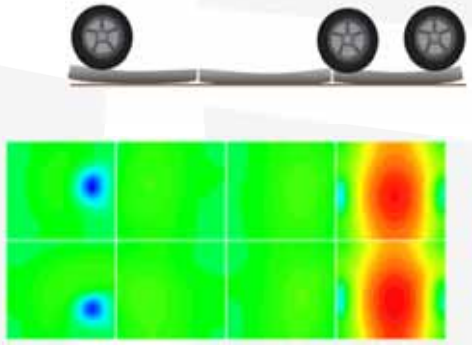
- Many new sources of oil (fracked, deep marine) are low in asphaltenes
  - Oil from Canadian oil sands are the exception
- The recent shift toward low sulfur marine fuel has had a surprising impact on asphalt availability
  - Refiners are coking asphalt to make marine fuel
- Net result is emerging shortages of asphalt

So What's New In Design?

- Long-life concrete pavements
  - Designed to be preserved into perpetuity
  - Keep it safe, smooth, and quiet with NGCS
- Thin concrete pavement technology (TCP)
  - Thin (3 to 5 inches), short-jointed (4 to 6 ft), fiber-reinforced concrete on stiff base
  - Designed using OptiPave

OptiPave™ Design

Slab Size = 6' x 6'
(1.8 m x 1.8 m)



Max Top Stress = 363 psi (2.5 MPa)
Thickness = 6.3" (160 mm)

So What's New In Design?

- Limited use of modular (precast) pavements
  - When you have the need for speed
- Continued evolution of concrete overlay design
- Composite pavements
  - Hate to say it, but there are those that prefer a black surface
  - Overlay rigid concrete "base" with thin, polymerized/rubberized asphalt layer

What Does The Future Hold For Materials?

- The basics of cement hydration have remained unchanged for millennium
  - Lime (CaO) chemically reacts with a source of silica/alumina and water to create calcium silicate hydrate (C-S-H) and calcium aluminate silicate hydrate (C-A-S-H)
- Yet there have been phenomenal advances that make concrete more workable, stronger, and more durable

Better Living Through Chemistry

- Admixtures make modern concrete technology possible
  - Air entrainers, water-reducers, set-modifying
  - Shrinkage-reducing, viscosity-modifying, waterproofing, densifiers
- What does the future hold
  - Nano-silica, carbon nanotubes
  - Others?

The Demise of Fly Ash?

- U.S. Energy Information Administration estimates coal production will drop 8% in 2019 and another 4.5% in 2020 (3/13/19)
  - Renewable energy production will rise 30% over same period
- Major coal-fired power generating stations are closing
  - E.g., Navajo Generating Station near Page, AZ

Fly Ash Will Still Be Available, But At A Cost

- Roughly 23% of U.S. electricity will be generated by coal in 2020
  - Regional shortages for fly ash will exist
- Fly ash reclaimed from landfills and beneficiated is increasing in supply
  - Does this meet ASTM C618?
- Cost will increase due to lack of supply and increased processing and transportation
  - Increasing carbon footprint

Natural Pozzolans

- In some markets, natural pozzolans will emerge as a major source of needed SCM
  - Already true to some degree in Western US
- ASTM is working to establish new test methods to assess the pozzolonicity of natural pozzolans
  - Is it actually reactive or is it rock flour

Cement Advancements

- Increased use of ASTM C595 blended cements
  - Types IP, IS, IL, and IT
- Geopolymers
  - Based on a geopolymerization reaction, not hydration
- Carbon capture technologies
- Others

Other Materials

- Increased use of fibers
  - Not unusual to see combinations of synthetic micro- and macro-fibers
- Improved wear-resistance to studded tires
- Durable high-early strength materials
  - Calcium sulfoaluminates and calcium aluminate systems
  - Polymeric materials

New Test Methods

- Traditionally, we have measured concrete properties that are only peripherally related to performance, if at all
  - Slump
  - Air content
  - Strength
- Yet we know that volume stability and durability are critical parameters left unmeasured

AASHTO PP-84: Approach to Testing

- Require the things that matter
  - Strength
  - Warping and shrinkage
  - Freeze-thaw resistance
  - Chemical deicer resistance
  - Transport properties
  - Aggregate stability
  - Workability

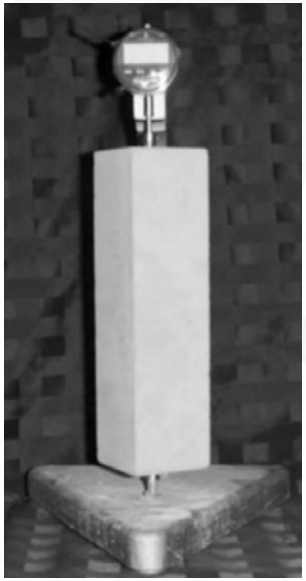
Strength

	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 by 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 by Tyler Ley

Restrained Shrinkage

Slide by Tyler Ley

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

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 by Tyler Ley

Deicer Salts

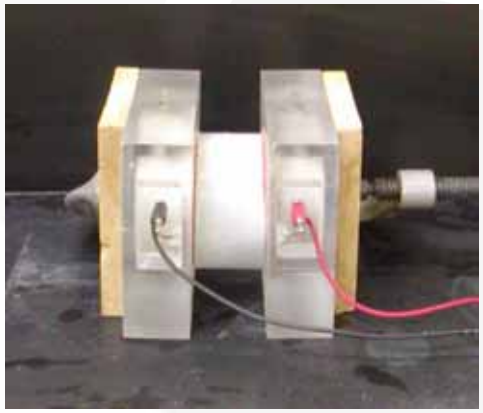
Are calcium or magnesium chloride deicer salts used?

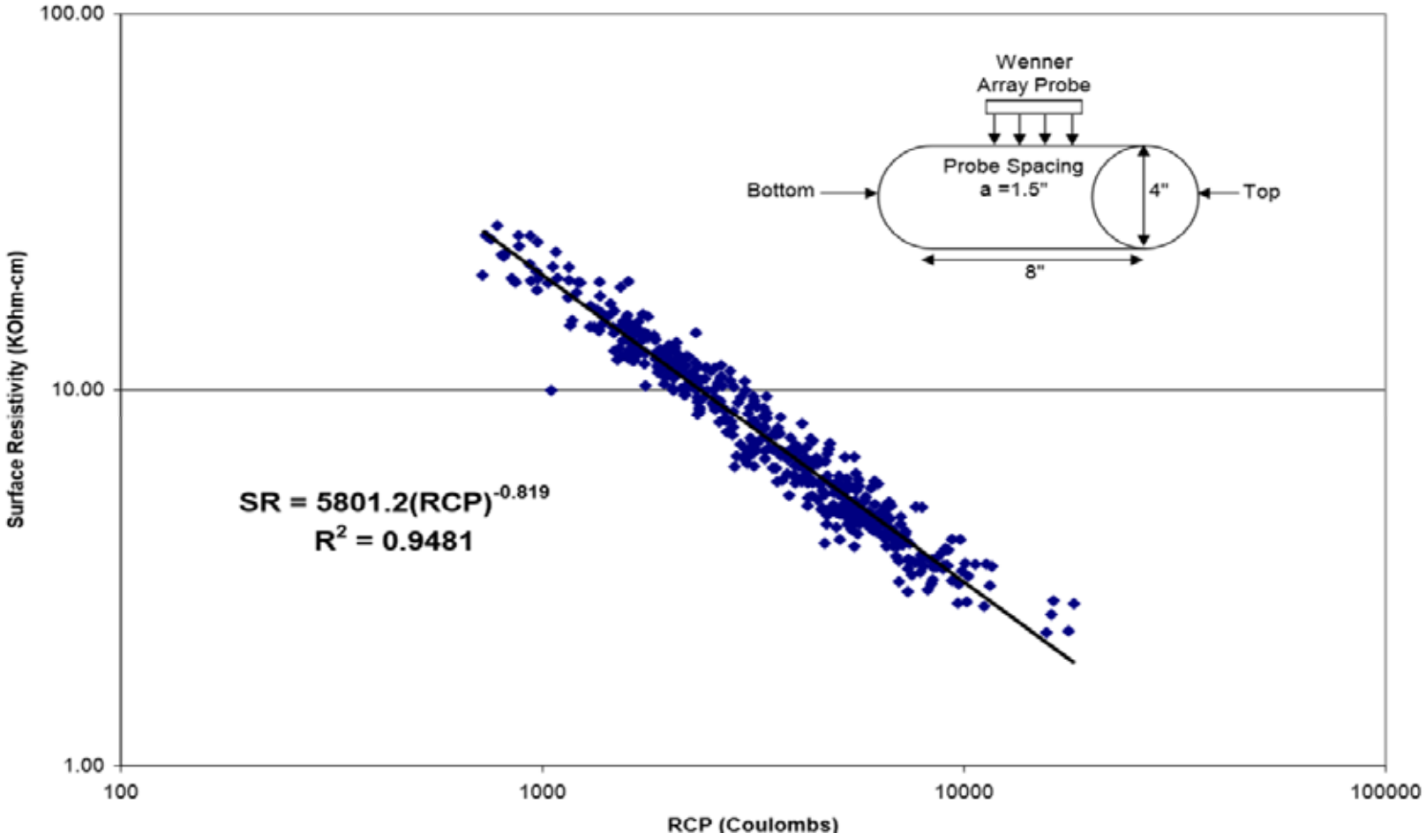
Approach	use SCMs	use sealer	AASHTO T 365
Value	> 35%	-	< 0.15g CaOXY/g paste
Approval?	Yes	Yes	Yes
Acceptance?	Yes	Yes	No

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





Chini, A.R., Muszynski, L.C., Hicks, J., "Determination of Acceptance Permeability Characteristics for Performance-Related Specifications for Portland Cement Concrete", Final Report submitted to Florida Department of Transportation (Contract No. BC 35441)

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

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

Quality Control

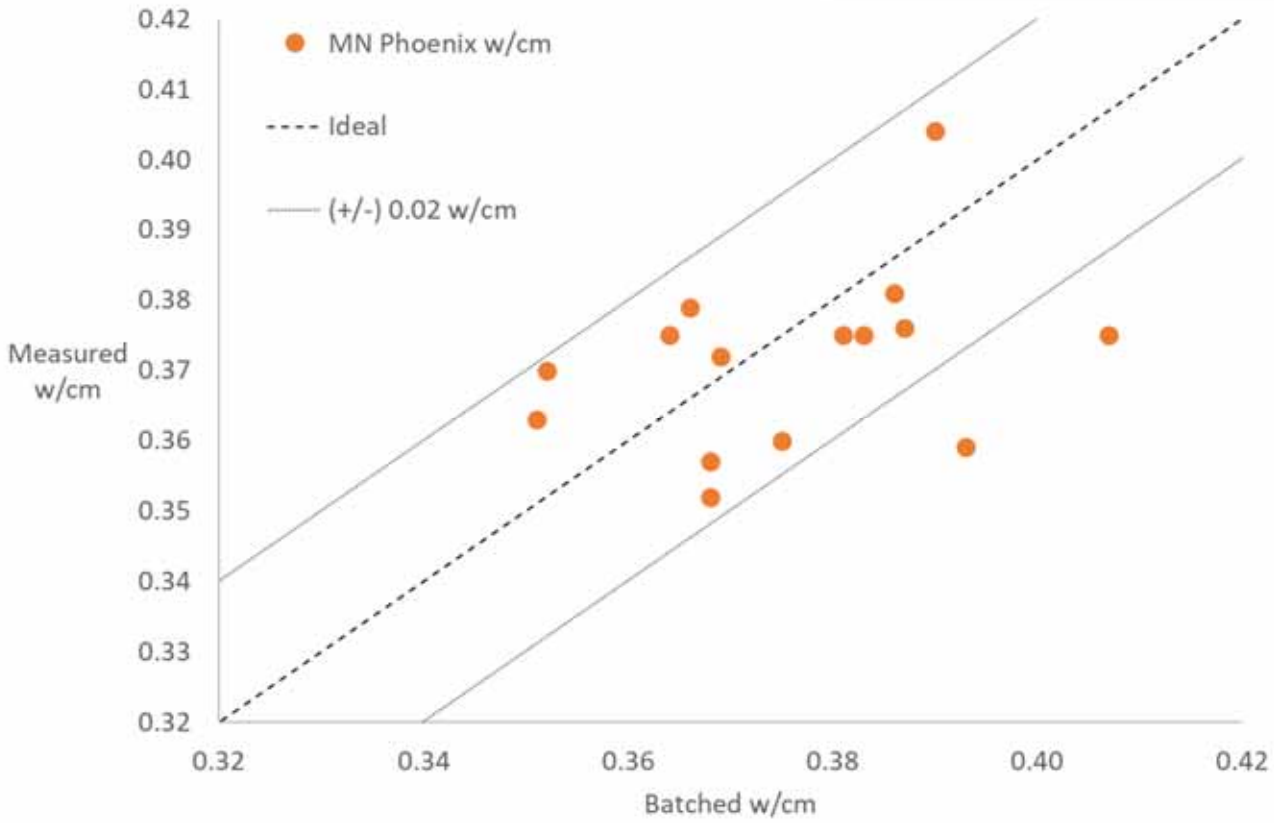
- Tracking how our concrete varies
  - Unit weight
  - Air content/SAM
  - Water content
  - Formation factor
  - Strength
- This is important information that we are ignoring
- AASHTO PP-84 provides guidance for QC
  - Testing targets, frequency, and action limits
  - Guidance will be expanded

Other Tests

- Water-to-cement ratio is a critical parameter
  - Emerging test: Phoenix
  - Can use resistivity/Formation Factor in lieu of w/cm determination?
- Emerging tests for ASR
  - Improved predictability
  - Shorter duration

MN Phoenix Data (From Tyler Ley)

Batched w/cm	MN Phoenix w/cm
0.36	0.38
0.35	0.36
0.38	0.38
0.39	0.38
0.38	0.36
0.37	0.38
0.37	0.37
0.37	0.35
0.41	0.38
0.35	0.37
0.37	0.36
0.39	0.40
0.39	0.38
0.38	0.38
0.39	0.36



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