

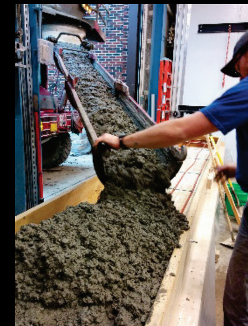


Joint Durability and Formation Factor Sample Exchange

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National Concrete Consortium

Milwaukee, WI

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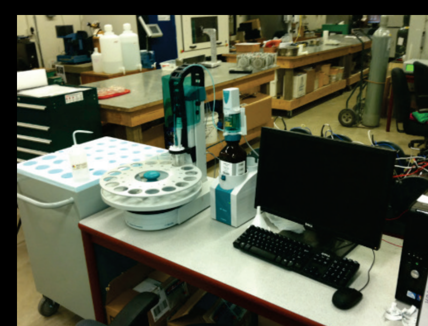


Outline

- Joint Durability Sample Exchange
  - Calcium Oxychloride
- Formation Factor Sample Exchange
  - Electrical Testing and pore solution
  - Formation factor
  - Sample conditioning
  - Test Method
- Data we've received so far

Joint Deterioration and Calcium Oxychloride

- CH plays a role in salt/joint durability (Ca-oxychloride)
- Recent research from Peterson et al. and Farnam et al. That CH reacts with the $CaCl_2$

$$3Ca(OH)_2 + CaCl_2 + 12H_2O \rightarrow CaCl_2 \cdot 3Ca(OH)_2 \cdot 12H_2O$$

- Phase change that results in a massive volume change (~ 30%)

Joint Durability
What We Need

Outline

Background on Joints

What we need for binder study

What we will provide

Electrical Testing

Formation Factor

Test Method

Expectation

Schedule

Incoming Data

1) The name of the contact person
2) The name and location of the project
3) The GPS coordinates of the project if possible as we would like to be able to find these in the coming years so the more description the better (start or finish mile markers)
4) The mixture proportions and measured air content being used on the project
5) The mill test report the cement, and any SCM being used
6) Any photos of the pavement joints on the project for comparison at a later date
7) Any additional notes that you think may be useful on the joint sealing.
8) Type of salt being used
9) other

Containers can be provided with an email to jason.weiss@oregonstate.edu

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Joint Durability Expectation

Outline
Background on Joints
What we need for binder study
What we will provide
Electrical Testing
Formation Factor
Test Method
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Schedule
Incoming Data

- During the year, testing will be conducted to characterize the amount of oxychloride that forms
- A report of the oxychloride formation will be returned to the providing agency
- We will ask your agency for a visual survey of the location in coming years to correlate with field performance

Electrical Methods

- Concrete is a porous composite
- Solid Phase (reactants, products, and aggregates)

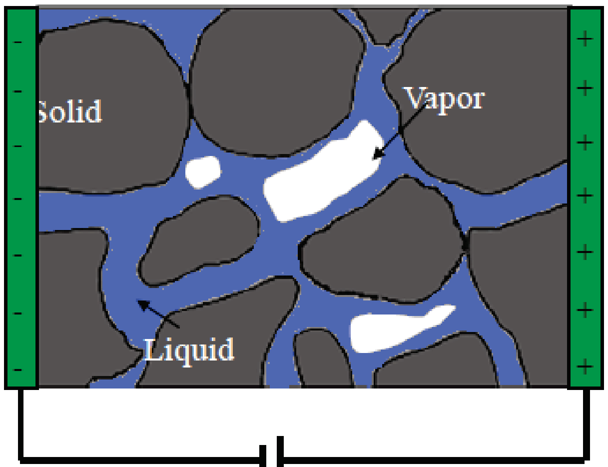
$$\rho_{solids} \approx 10^{9}\ \Omega \cdot \mathrm{m}$$

- Vapor Phase

$$\rho_{vapor} \approx 10^{15}\ \Omega \cdot \mathrm{m}$$

- Liquid Phase
  - Ionic pore solution

$$\rho_{liquid} < 1\ \Omega \cdot \mathrm{m}$$



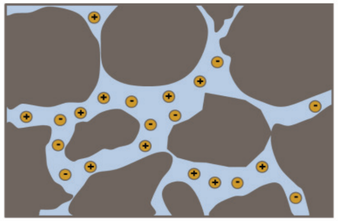
Weiss ('05), Rajabipour ('06)

Electricity is conducted primarily through the liquid phase and depends on concentration

Modified Parallel Law

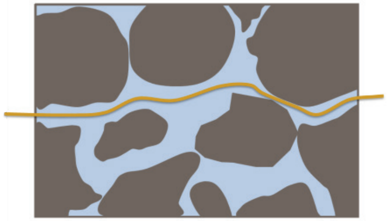
- Total Electrical Response
  - Single conductive phase
  - $\rho = \rho_o \cdot \frac{1}{\phi\beta}$
- ρ_o: pore solution resistivity
- ϕ: Conductive Volume
- β: Connectivity
- We are primarily interested in ϕ and β terms and define the product as formation factor

$$F = \frac{1}{\phi\beta}$$



ρ_o

ϕ



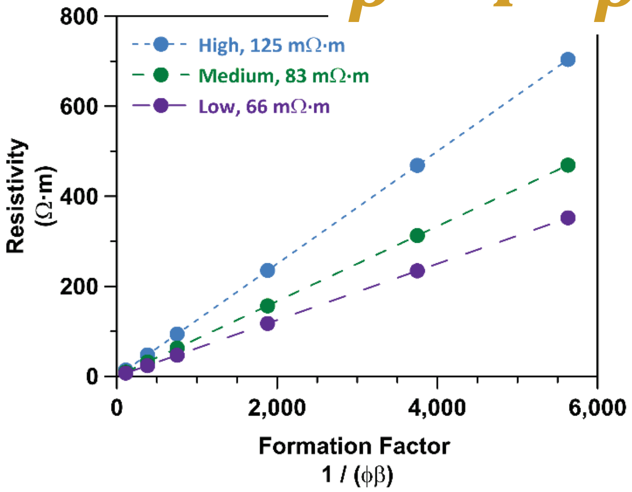
β

Archie, 1942
Garboczi, 1990
Samson and Marchand, 2007

Let's consider….

- F is a unique descriptor of microstructure
  - ρ is not!
- Three binder systems
- For the same microstructure, ρ is different because of different ρ_o

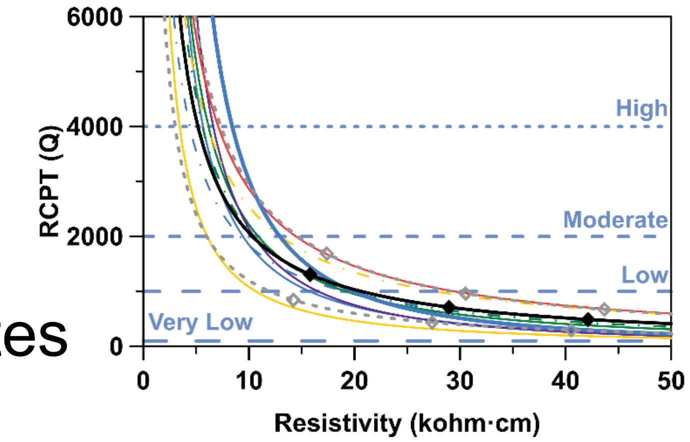
$$\rho = F \cdot \rho_o$$



- Lower alkali meet ρ limits easier
- F can be related to:
  - Service life
  - Simple field measurement

Sample Conditioning

- RCPT vs ρ
  - 2” samples saturated before testing
  - Water cured ρ correlates reasonably well
  - Influence by volume of air



- Sealed conditioning
  - More similar to what we observe in the field
  - Evaluates the matrix porosity
  - Testing is more consistent and faster

Formation Factor
What we are asking for

- 8 4x8 cylinders to OSU
- 3 4x8 cylinders to other labs
- Ship them sealed in a mold and plastic bags
  - 6 mil plastic bags
  - http://www.uline.com/Product/Detail/S-14407/
- Maintain them in a sealed condition between tests

Test Method

- Sealed Condition
  - Minimize water loss/gain from environment
  - This is the reason that we are interested in the weight of the specimen

Sample in cylinder mold

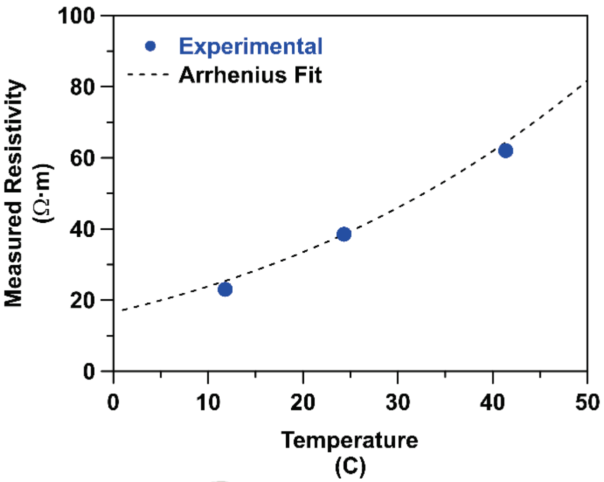
Sealed between tests

$\Delta weight$ between receiving and demolding

Weight before testing

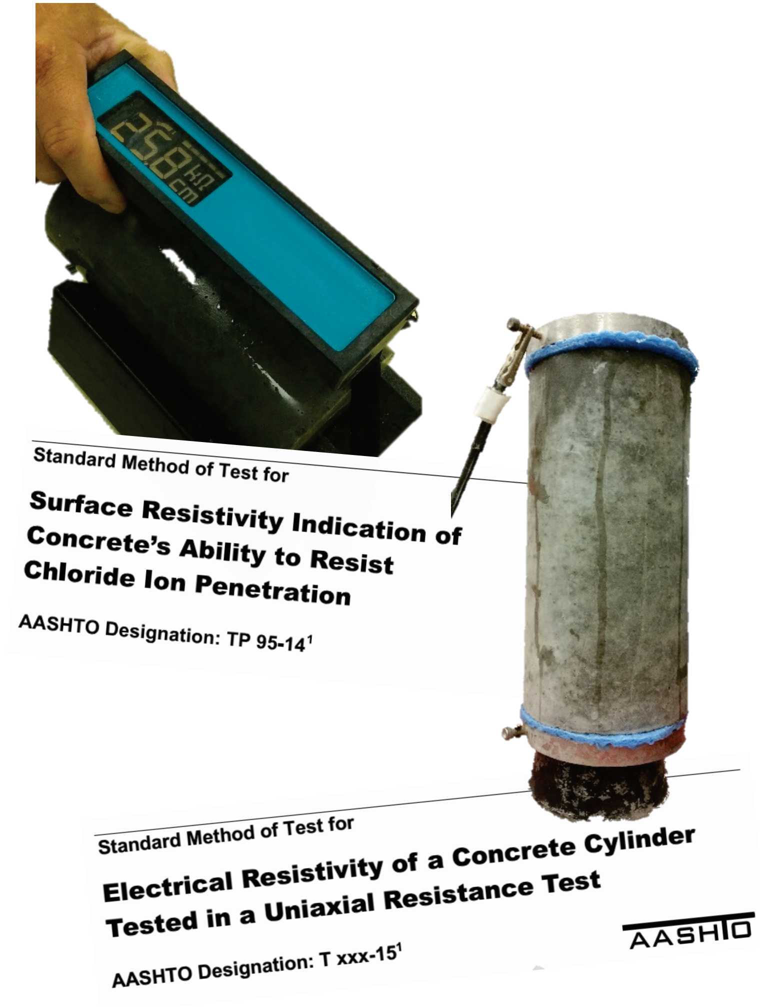
Testing Temperature

- Specimen temperature
  - Ideally 23+/- 1 °C
  - Normal lab temperature variation can influence ρ
  - Measure with an infrared thermometer
- We will investigate this correction for all the mixtures
- Goal is to reduce testing variation



Resistivity Testing

- Resistivity Test according to your test method
  - Surface (TP 95)
  - Uniaxial (Draft AASHTO)
  - Only difference, is that we do not moist cure
  - There will be some water from probe tips / sponges



Formation Factor Expectation

- Develop a database for development of a formation factor specification with a wide range of materials
- We can relate ρ and RCPT, the relationship with F is not unique
- Simple, cost effective, consistent replacement for RCPT testing

ASTM C1202 Classification[1]	Charge Passed (Coulombs)[1]	Resistivity (kOhm·cm)[2]	Formation Factor
High	>4,000	< 5.2	520 ?
Moderate	2,000 - 4,000	5.2 - 10.4	520-1040 ?
Low	1,000 - 2,000	10.4 - 20.8	1040-2080 ?
Very Low	100 - 1,000	20.8 - 207	2080-20700 ?
Negligible	< 100	> 207	20700 ?

[1] from ASTM C1202-12
[2] calculated using first principles

Testing Schedule

- Updated versions on the PEM Dropbox and Iowa State FTP site
- Electronic version at https://goo.gl/4SmlcN
- Following testing, data can be sent to rspragg@purdue.edu

Date	Description
~~8/18/2015~~	~~INDOT/Purdue 28 d testing date~~
~~8/25/2015~~	~~FHWA 1 - Idaho 28 d test~~
~~8/27/2015~~	~~Michigan DOT 28 d testing date~~
~~8/28/2015~~	~~Iowa DOT 28 d testing date~~
9/15/2015	INDOT/Purdue 56 d (optional testing) testing date
9/16/2015	South Dakota DOT 28 d testing date
9/17/2015	Manitoba IT 28 d testing date
9/22/2015	FHWA 1 - Idaho 56 d(optional testing days) test
9/23/2015	FHWA 2 - Ohio 28d
9/24/2015	Michigan DOT 56 d (optional testing) testing date
9/25/2015	Iowa DOT 56 d (optional testing) testing date
10/14/2015	South Dakota DOT 56 d (optional testing) testing date
10/15/2015	Manitoba IT 56 d (optional testing) testing date
10/20/2015	INDOT/Purdue 91 d testing date
10/21/2015	FHWA 2 - Ohio 56d (optional)
10/27/2015	FHWA 1 - Idaho 91 d test
10/29/2015	Michigan DOT 91 d testing date
10/30/2015	Iowa DOT 91 d testing date
11/18/2015	South Dakota DOT 91 d testing date
11/19/2015	Manitoba IT 91 d testing date
11/25/2015	FHWA 2 - Ohio 91d

Mixtures in the RR so far

- Range of materials and alkali contents

Mixture ID	w/c	Portland Cement	Fly Ash	Slag	Water	Air (%)
FHWA 1 - Idaho	0.37	560	138	-	257	4.2
FHWA 2 - Ohio	0.43	416.5	-	138.8	236.6	8
INDOT/Purdue	0.42	564	-	-	237	7
Iowa	0.41	442	111	-	228.3	7.4
Kansas	0.42	440	110	-	231	6.5
Manitoba	0.39	418	104	-	205	6.8
Michigan	0.41	658	-	-	271	7.1
South Dakota						7

Data Collected So Far

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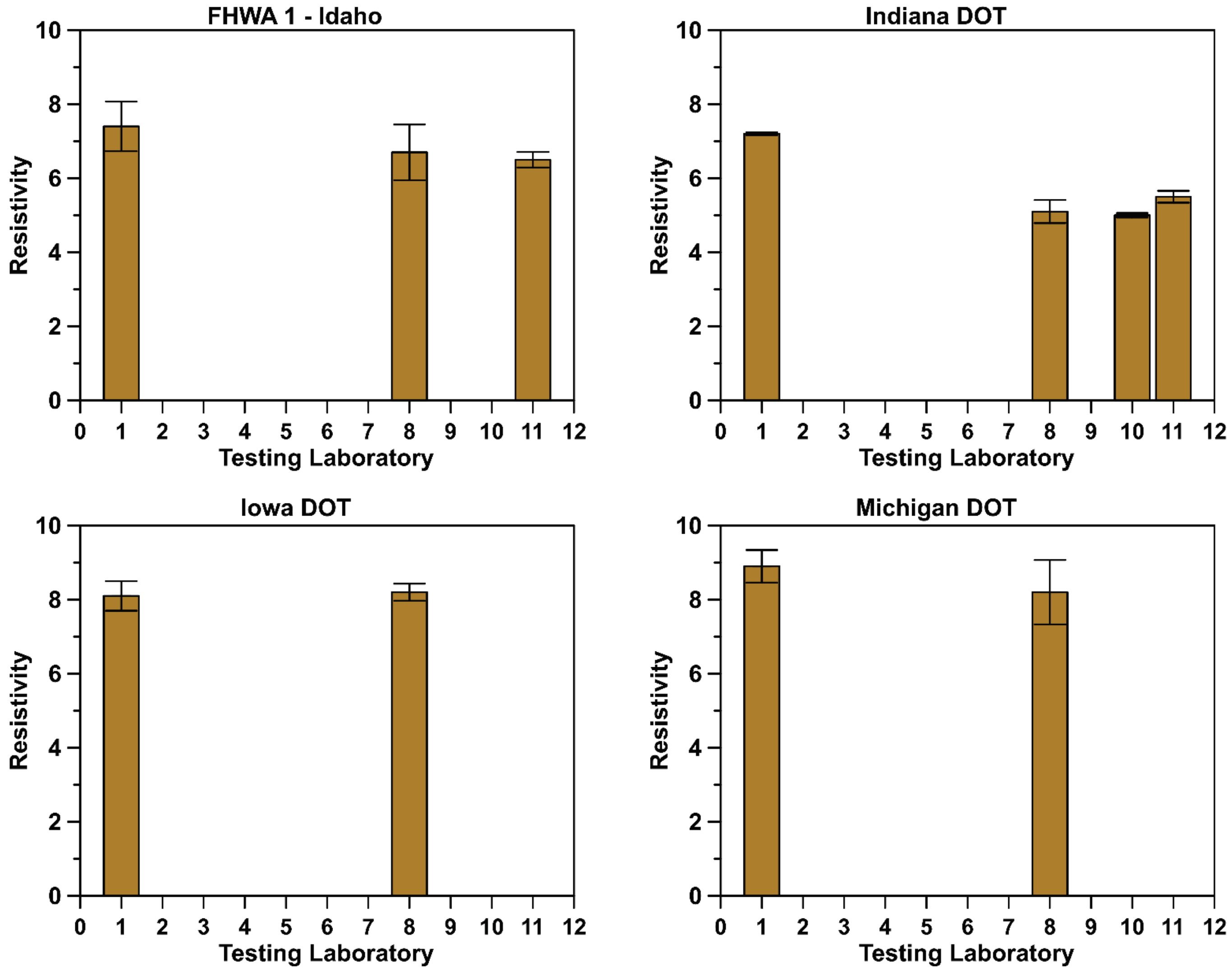

Thank You!

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