

Discussion of a Plan to Move Resistivity (Formation Factor) Specifications Ahead

Group Gary Crawford, Jagan, Tyson Rupnow, Gina Alstrom, Jim Grove, Jason Ideker, Jason Weiss, wjweiss@purdue.edu, Purdue University





A thought as we begin

- Many people are asking for a resistivity value that can be used to insure 'durability'
- Can relate resistivity to RCPT (known value) - 1st principles

$$Q = \int_{0h}^{6h} \frac{V}{\kappa} \frac{1}{\rho} dt$$

$$\rho = \frac{V}{\kappa} \frac{1}{Q} t = \frac{60V}{\frac{5cm}{\pi 5^2 cm^2} 2000 Amp \sec} 6hr \frac{60 \min}{1hr} \frac{60 \sec}{1 \min} = 10.4 \, k\Omega \cdot cm$$

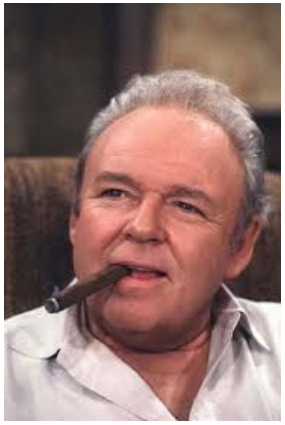
- This results in a table
- However is this is dependent on curing and sample storage

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

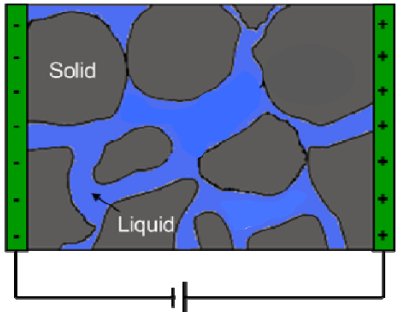
[1] from ASTM C1202-12
[2] calculated using first principles

Spragg et al. 2010

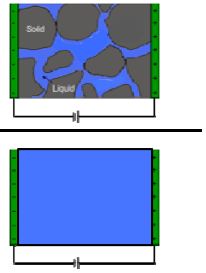
Archie's Law and The Formation Factor



- Empirical relationship that is the ratio of the bulk resistivity (ρ) of a saturated medium and the fluid (ρ_O) that is in the medium



$$F = \frac{\rho}{\rho_O} =$$



- This makes the assumption that it is only the fluid that is conductive (Weiss et al.)
- There are solutions for other cases; but this works most of the time

Maybe We Should Look at the Formation Factor

- Maybe it makes sense to look at the formation factor instead for specifications

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

- These numbers are just place holders however they illustrate how to get to the most fundamental value
- With this one can to go in two directions
  - 1) This relates to service life
  - 2) This enables various constituents

Formation Factors – Determine the Pore Solution

- Determine the correct value for the pore solution resistivity (obtain in the trial batch or mixture acceptance, know for QC/QA)

Three approaches to obtain ρ_O (for const.)

1) Extraction – Doable
2) Sensor –Promising (Rajabipour et al)
3) Calculation http://ciks.cbt.nist.gov/poresolncalc.html

Ask for the binder to be sent

Research to determine/confirm approach

General Approach

- Moving Forward
  - Want to Exchange Samples
  - Want to Confirm Solution Correction
  - Want to Confirm The Effects of Temperature and Saturation
- Developed a Request for a PCA Fellowship
- Developed a NCHRP Need Statement

Requested Volunteers

- States Will Be Requested to Send Two Samples (Binder Powders, Mill Certificates, and 30ish Cylinders)
- Each State will receive and test 3 samples from each state
- One or Two labs (OSU, LaDOT, FHWA Purdue etc) will examine pore solution, RCPT, and saturation in more detail
- We want a sampling of bridge and pavement mixtures and binders

Which States are Interested

Approach

- Sample circulation
- PCA fellowship – endorsement of this group
- AASHTO proposal submission
- Obtain states at NCC to submit real mixture proportions like Round Robin

Potential

- #1 Target a TRB publication for next year (or the following depending on timing) that combines all the data (it seems early however we would need to move quickly)
- #2 Target examples that could relate this to a performance specification (discuss with ETG)

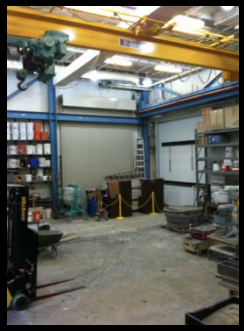
- Pore solution – to one lab (Purdue, Oregon State, others etc)
- Samples to each lab (2 RCPT, 3 sealed, 3 bucket at two ages)
- Are we interested in the solution
- How many labs are samples sent to

- Which states
- Production variation ? (on Site)

Third, Use Cold Plate to Determine Activation Energy following (Farnam et al 2015)



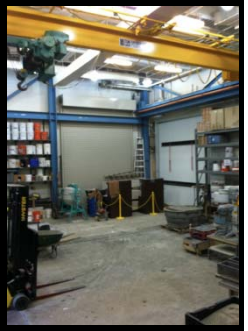




First, Real Discussion of Saturation







Incorporating Aspects of Curing

- Spragg developed a program to investigate factors that could influence curing (not discussing temp or RH here that change DOH)

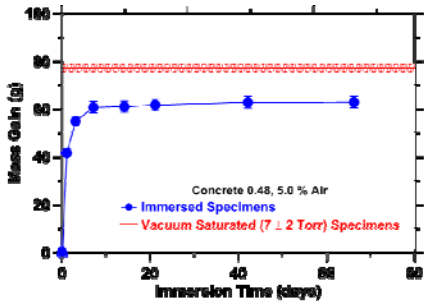
$$\rho = \rho_o^* \cdot F \cdot f(S) \cdot f(T_{Testing}) \cdot f(Leach)$$

- ρ is the resistivity at an equivalent age $t_{equivalent}$
- ρ_o^*: pore solution resistivity at saturation
- $f(S)$ saturation function
- $f(T_{testing})$ testing temperature correction
- $f(Leach)$ leaching function

Spragg et al. 2013

Testing Plan

- We think that there are two/three approaches to use
- First, saturation is related to RCPT
- Second, determine a ‘typical saturation level’ using a ‘bucket’ that is the filled in matrix
- Third, use a ‘sealed sample’ as this may be able to be easily used in the field



- Issue here is the air content and we want to keep air unsaturated

Second, Preparing for Formation Factors