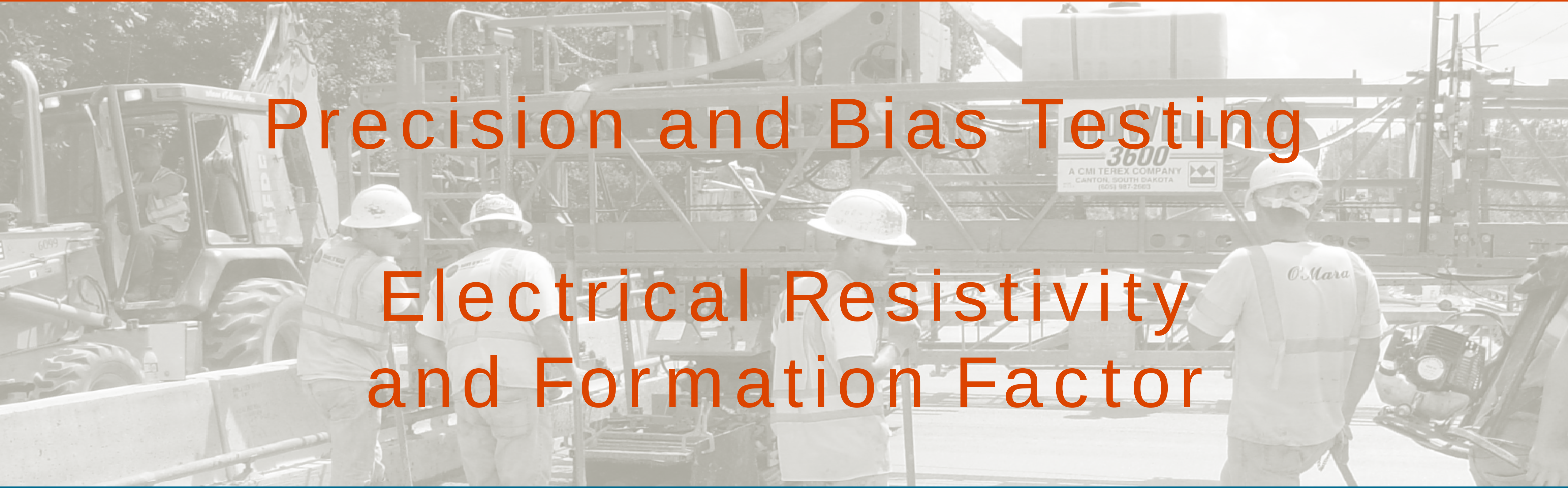
Oregon State University

COLLEGE OF ENGINEERING | School of Civil and Construction Engineering

Precision and Bias Testing

Electrical Resistivity and Formation Factor



September 27th – National Concrete Consortium

Siva Chopperla, Burkan Isgor, and Jason Weiss,
Edwards Distinguished Professor, Oregon State University

NATIONAL CONCRETE CONSORTIUM

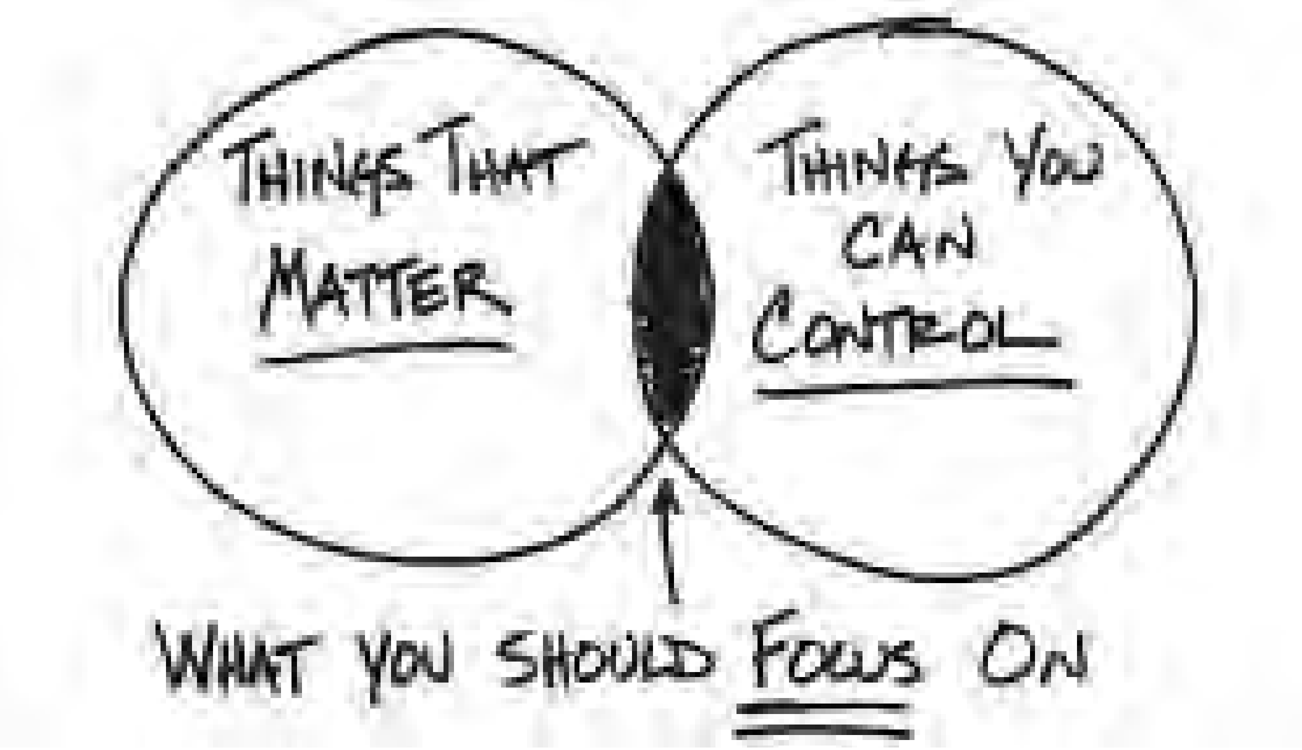
Concrete Quality

Oregon State University
College of Engineering

Concrete Quality

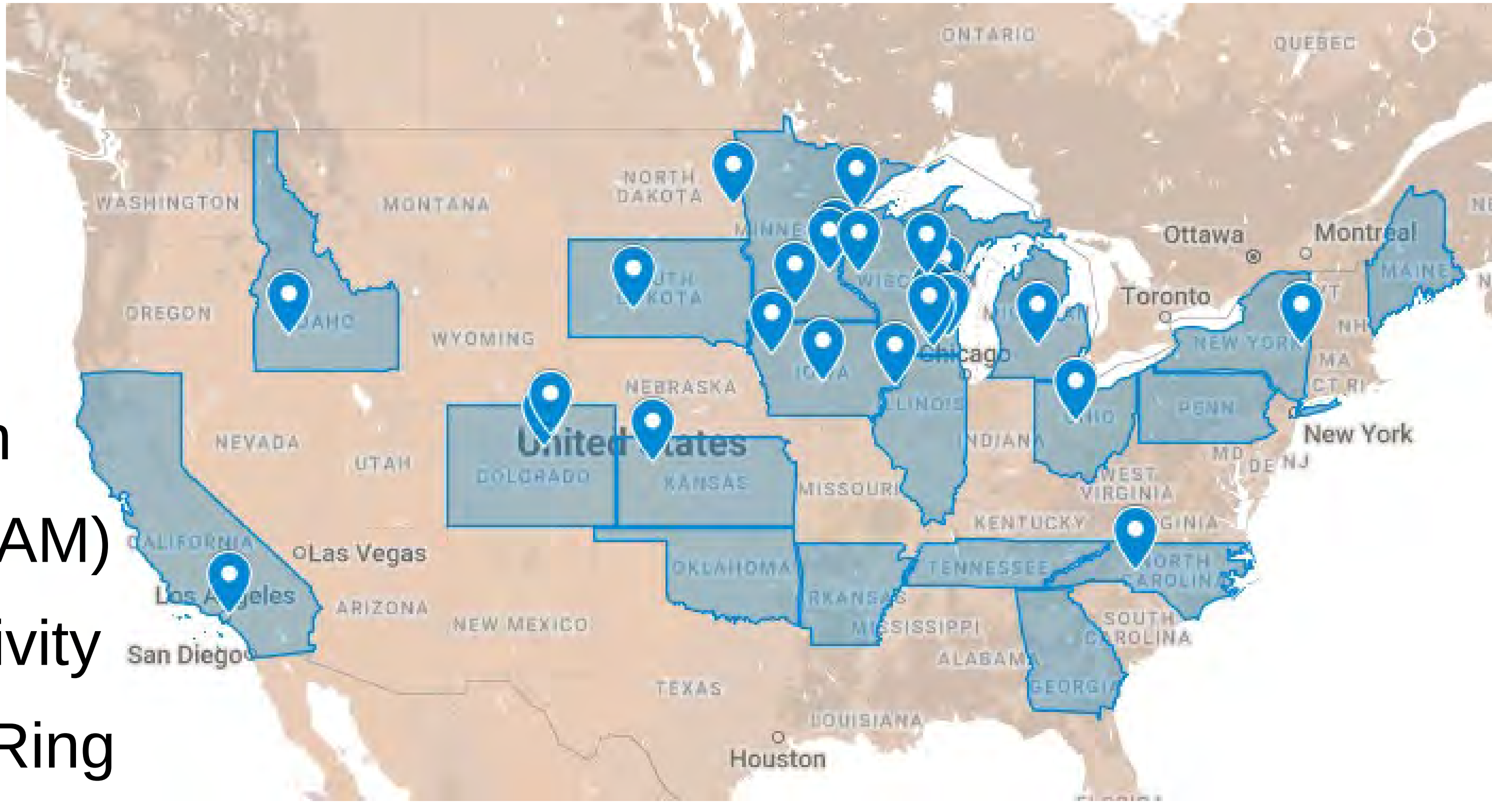
Concrete Quality

- A large part of good concreting is doing what we already know
- We can control the capillary pores by controlling the w/c (SCM and WRA good)
- Excess water leads to pores and increased transport
- ‘Low Hanging Fruit’ all can reach
- Lower w/c general move in right direction



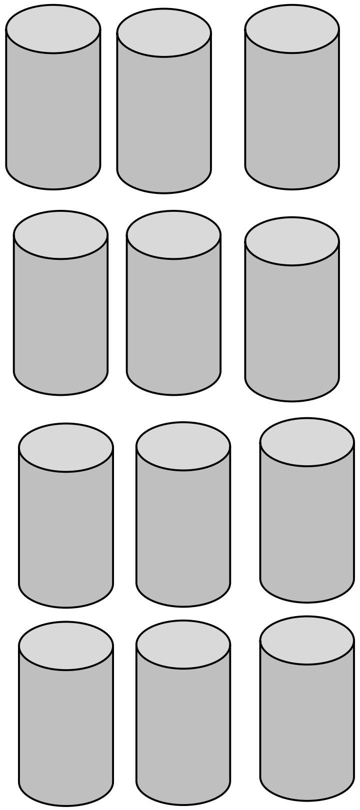
Concrete Durability FHWA – PEM Effort

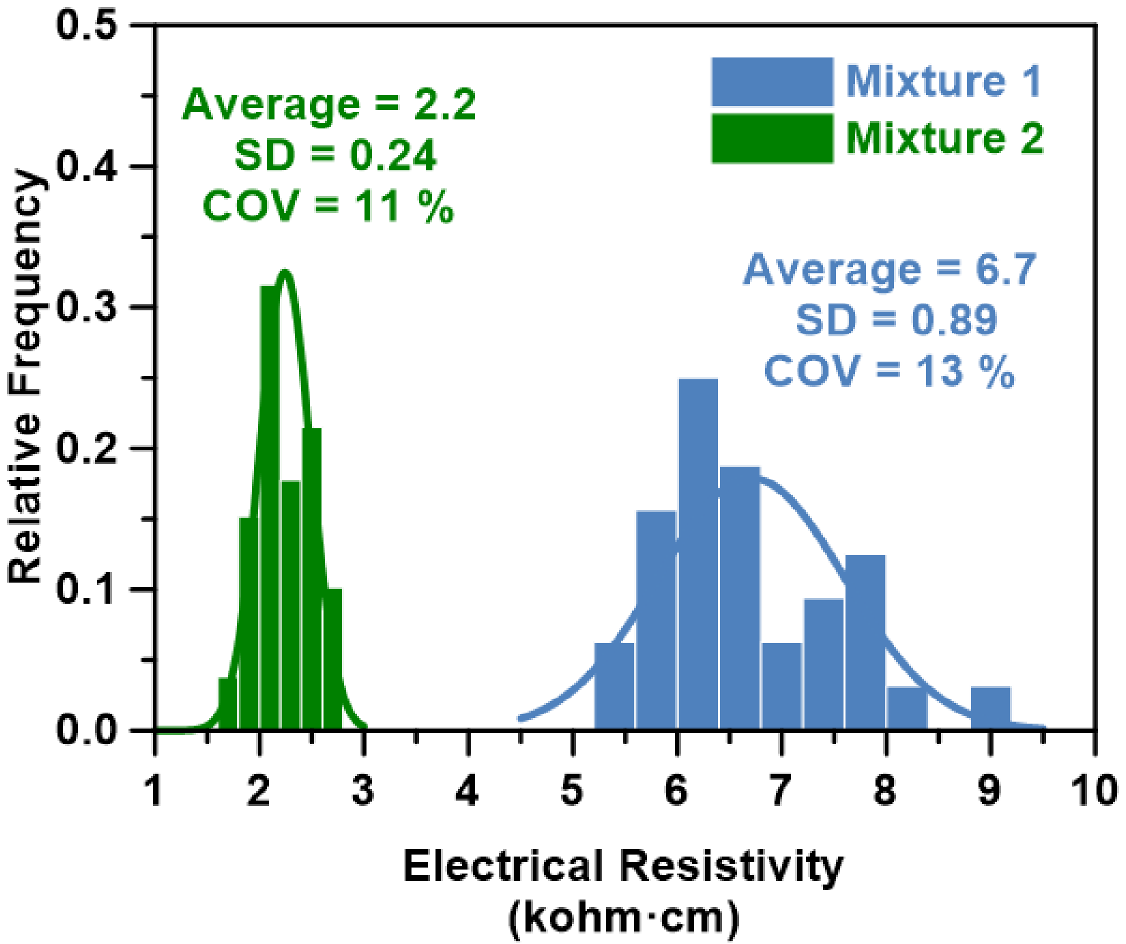
- AASHTO R101
  - Transport (and Corrosion): Resistivity/F Factor
  - Freeze-Thaw Durability: Critical Saturation Approach
  - Freeze-Thaw Durabilitiy: (SAM)
  - Calcium Oxychloride Reactivity
  - Shrinkage Cracking - Dual Ring
  - Workability – V Kelly
  - Workability – Box



Quality Assurance and Quality Control

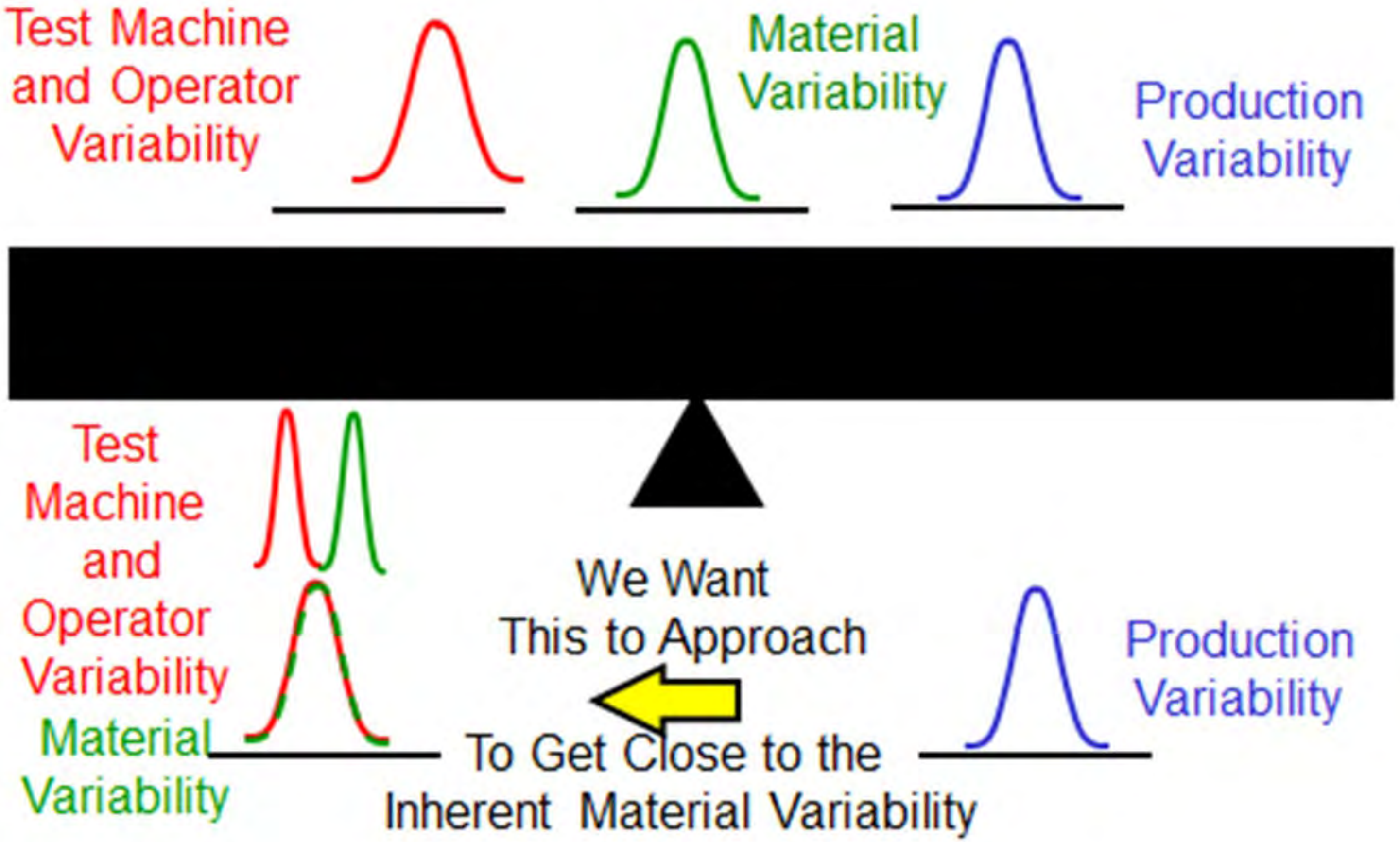
- Measurements during construction
- Owner: Is this the same mixture we qualified?
- Producer: Is this the mixture we want to produce?
- Test with good repeatability
- Easy tests allow for large sample size, statistical information as well





Concrete Quality

Oregon State University
College of Engineering



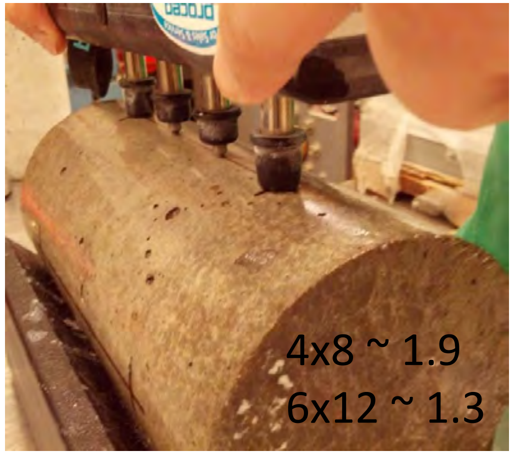
A Few Issues (Fixable)

Oregon State University
College of Engineering

- Improper correction for geometry
- Not accounting for temperature
- Drift, cable damage, or improper size
- Importance and implication of sample
  - curing – allowing microstructure in the sample to fully form/hydrate
  - conditioning – allowing the pore solution to be well known
- Standards need to be followed for
  - accurate results
  - correct data interpretation

$$\rho = R_{\text{cylinder}}\left(\frac{A}{L}\right)$$

$$\rho = \frac{R}{2\pi a} * (f_{\text{confinement}})$$



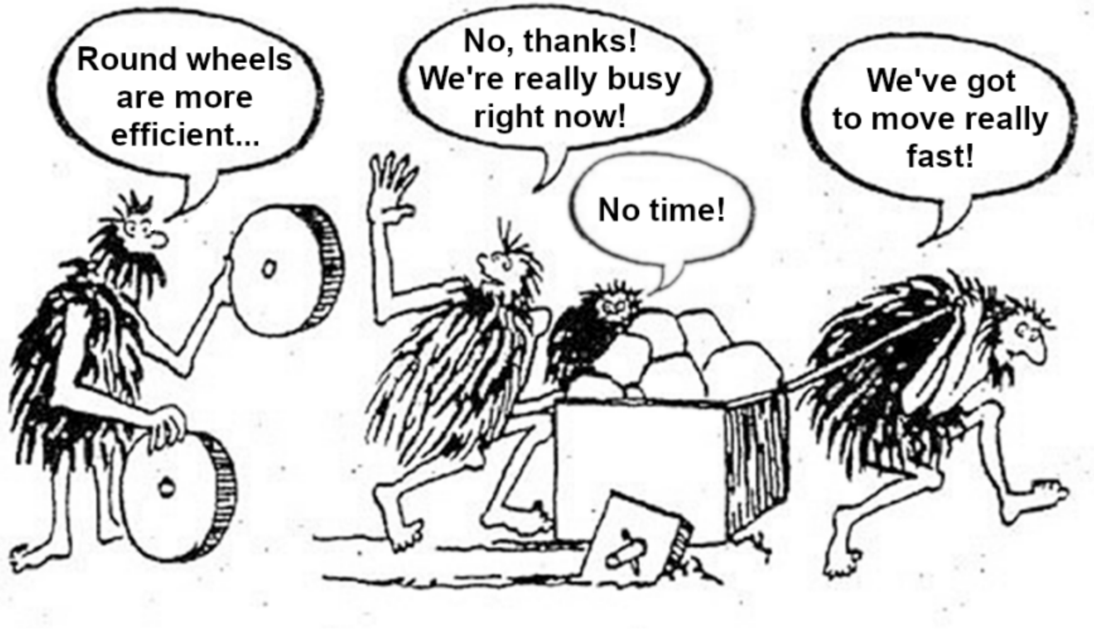
Frank was not a specification follower

Oregon State University
College of Engineering

A lot done on resistivity over the last century

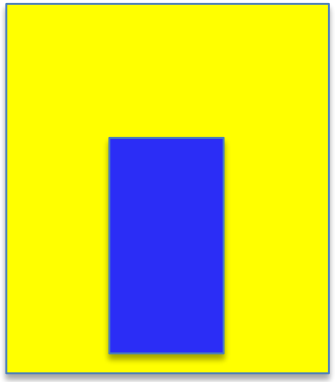
- A lot is known about concrete and a lot is known about the electrical properties of concrete
- However, in many ways we are not considering what is known

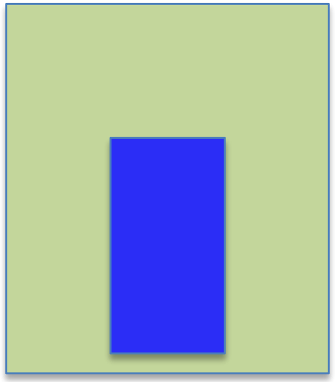
- Are we too busy as this comic suggests
- Do we need to learn it for ourselves
- We are missing some basics
  that will hinder us in the long run
- Example - reports and calls



A Few Issues (Fixable)

- Improper correction for geometry
- Not accounting for temperature
- Drift, cable damage, or improper size
- Importance and implication of sample
  - curing – allowing microstructure in the sample to fully form/hydrate
  - conditioning – allowing the pore solution to be well known
- Standards need to be followed for
  - accurate results
  - correct data interpretation





Keep Encouraging Training

P&B study

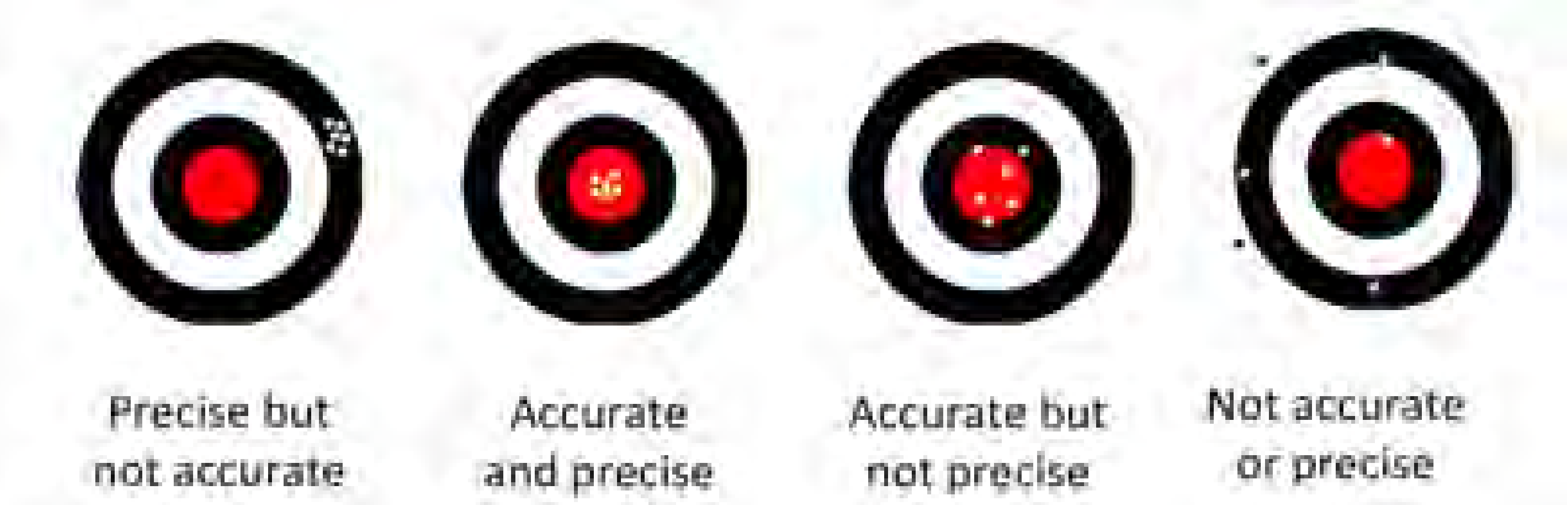
- Several round robin tests have been conducted (Spragg et al.2012)
  - Single-operator COV = 4.4 % (Bulk), 4.3% (Surface)
  - Multi laboratory COV = 13.2 % (Bulk), 11.5% (Surface)
  - Curing/conditioning a key issue

- Current AASHTO standards need precision and bias statements that follow the standards and are conditioned per standard

Precision and Bias

Oregon State University
College of Engineering

- Bias "the difference between a population mean of the measurements or test results and an accepted reference or true value" (Bainbridge 1985).
- Precision is the "spread of the data … attributable to the statistical variability present in the sample" (Debanne 2000).



- Bias and precision combine to define the performance of an estimator.

Overall Study Approach

Oregon State University College of Engineering

- To provide **precision** and **bias** data for AASHTO TP119 and AASTHO T358
- **Phase A:** Identify participating labs and sample preparation for Phase C (1 month)
- **Phase B:** Develop and deliver training tools (2 months)
- **Phase C:** Controlled Curing to Isolate Testing Operator and Testing Equipment Variation (4 months)
- **Phase D:** Curing in Participating Laboratories to Include Curing Variation (5 Months)

Resistivity Testing

Oregon State University College of Engineering

Will be done at your home labs

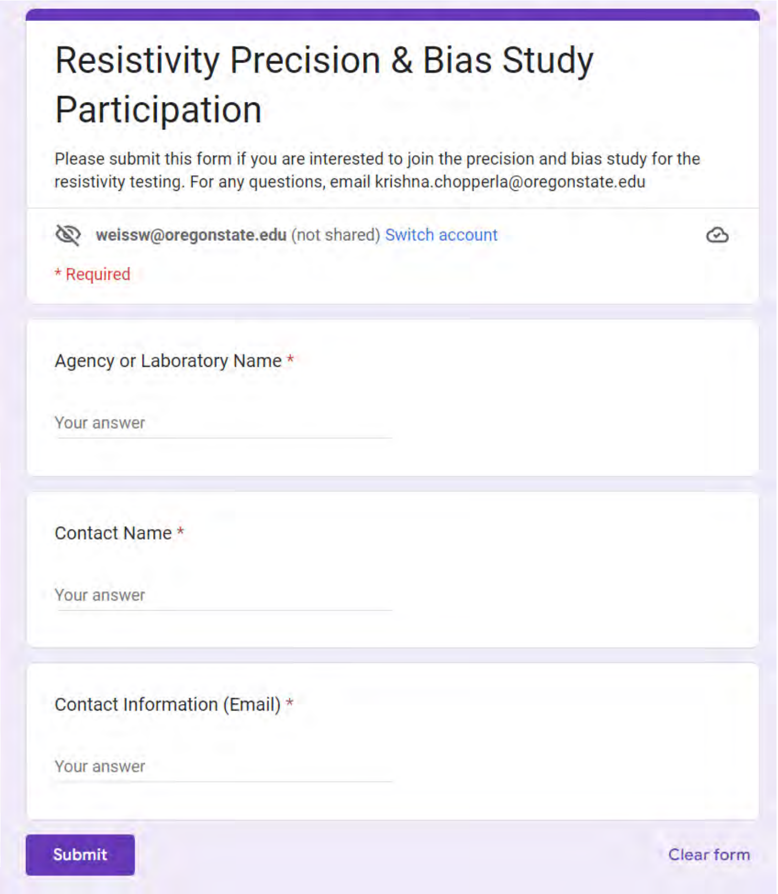
Goal is to have trainings and then evaluations

Special physical testing tools

Phase A Participating Labs and Sample Prep

- Link to fill in the participation form https://forms.gle/qTUHR8cgZuFhfKu17

- We need to know the labs that will be involved in testing
- 10 resistivity calibration devices are ready, shipped in October. (More can be made if desired)
- Concrete samples need to be cast but we need to know how many samples are being made and where they are going


Resistivity Precision & Bias Study Participation

Please submit this form if you are interested to join the precision and bias study for the resistivity testing. For any questions, email krishna.chopperla@oregonstate.edu

weissw@oregonstate.edu (not shared) Switch account

* Required

Agency or Laboratory Name *

Your answer

Contact Name *

Your answer

Contact Information (Email) *

Your answer

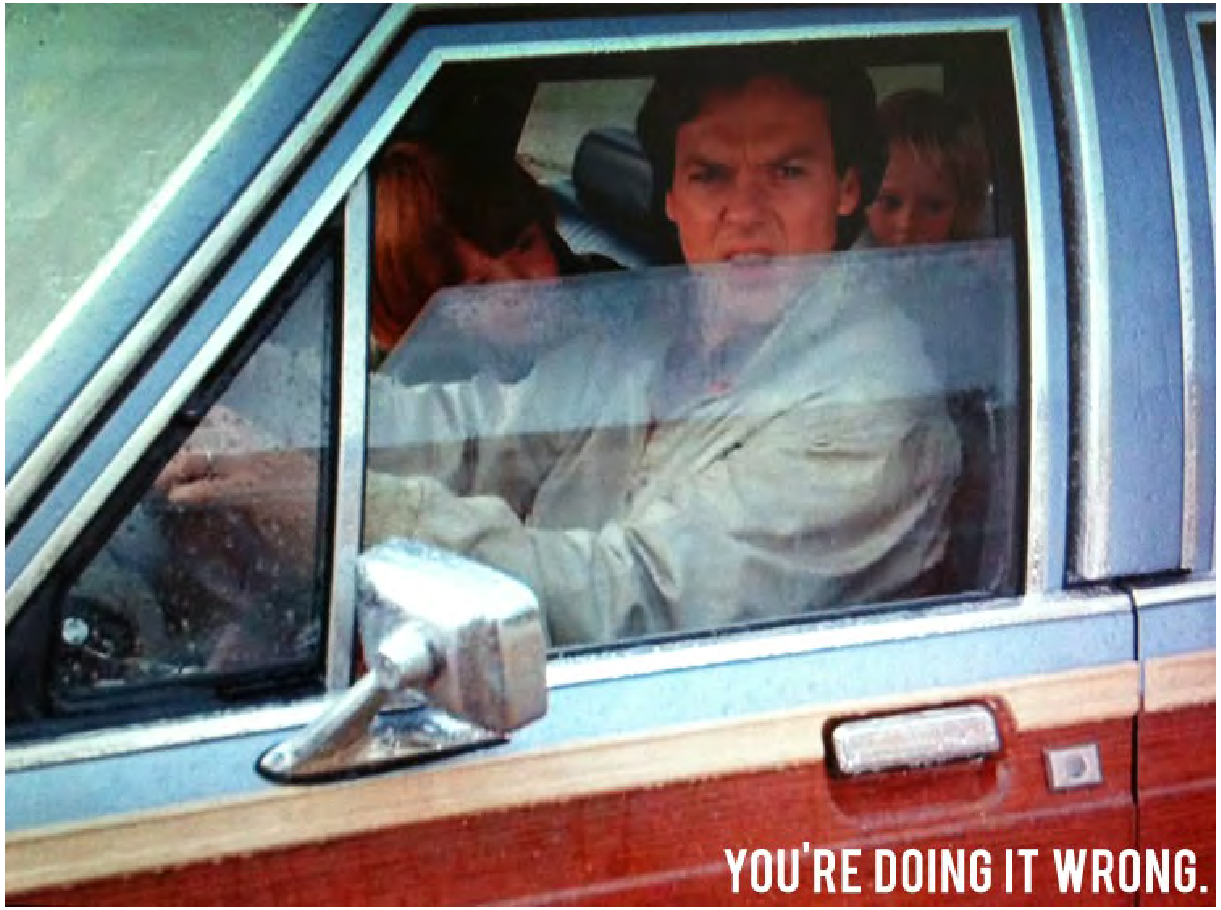
Submit

Clear form

Oregon State University College of Engineering

Phase B – Training Tools

Oregon State University
College of Engineering



Phase B – Training Tools

Develop and deliver training tools

- A video as the training tool for performing the test
- A video/webinar – factors that impact testing
- Calibration cell to make sure folks are doing this correctly
- Worksheet to enter the data will be shared with the participating laboratories
- Test of knowledge at the end

Phase C – Test Equipment, Operator, Well Cured Sample

- **After online webinar**
  - Review AASHTO TP119/358
  - Testing the calibration cell
  - Mature (56d) samples will be sent to the labs (to minimize curing variation)
  - 2 mixtures – bridge deck and pavement
  - Results from the labs will be compared to OSU results
  - Results will be compared with other testing labs

- **Determining**
  - identifies equipment variation
  - Identifies operator variation
  - Identifies pooled variation when curing is not varied

Phase D – Varied Sample Curing and Conditioning

Oregon State University
College of Engineering

Curing in Participating Laboratories to Include Curing Variation

- Prepared samples will be sent at an early age (36-72 hours)

- **Curing and conditioning (ask you to return solutions)**
  - Option A – 5-gal bucket with simulated pore solution

    7.6 g/L NaOH (0.19 M); 10.64 g/L KOH (0.19 M); 2 g/L $Ca(OH)_2$.
  - Option B – Seal cured
  - Option D – Lime water bath

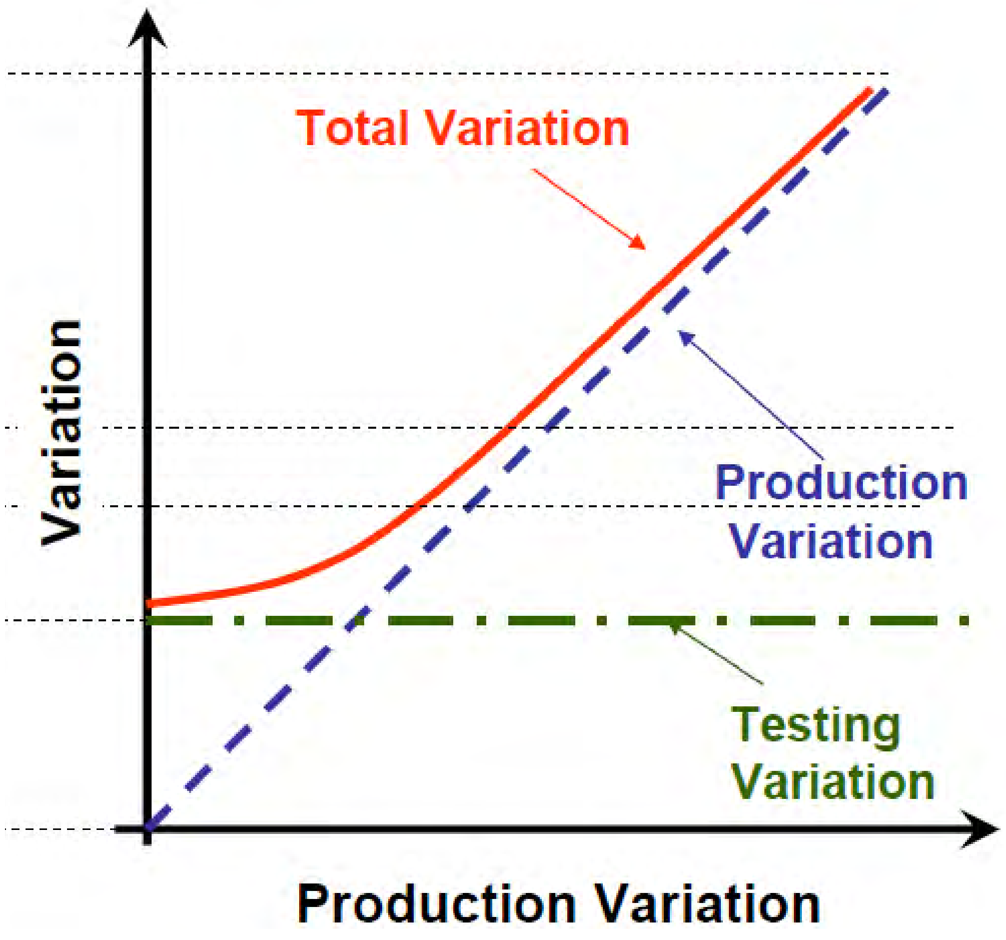
- **A precision statement**
  - for the testing equipment and operator
  - curing and conditioning

Output from the study

AASHTO TP 119 (T358)

- precision and bias statement
- help consideration as a full test standard
- any final modifications to the provisional standard

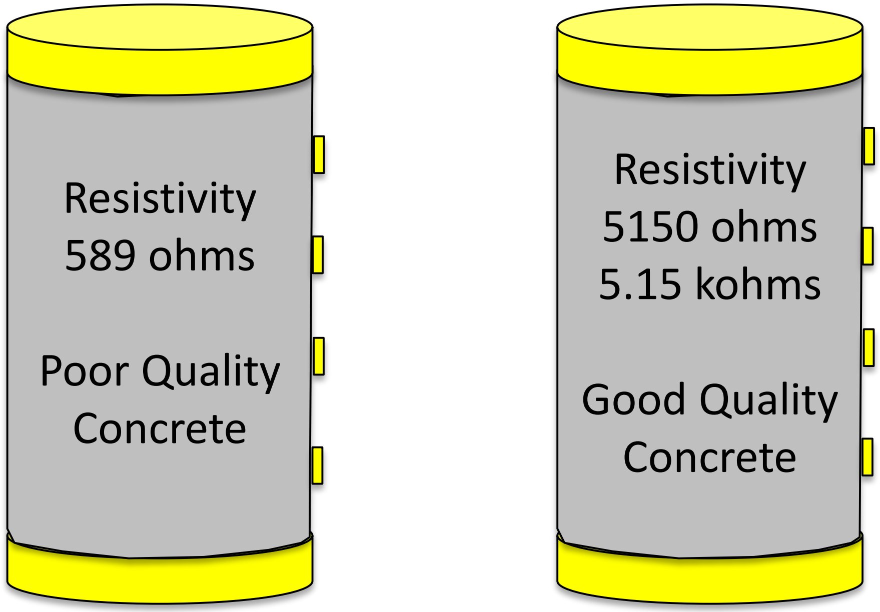
Helps to set specification limits that are realistic and capture production variation



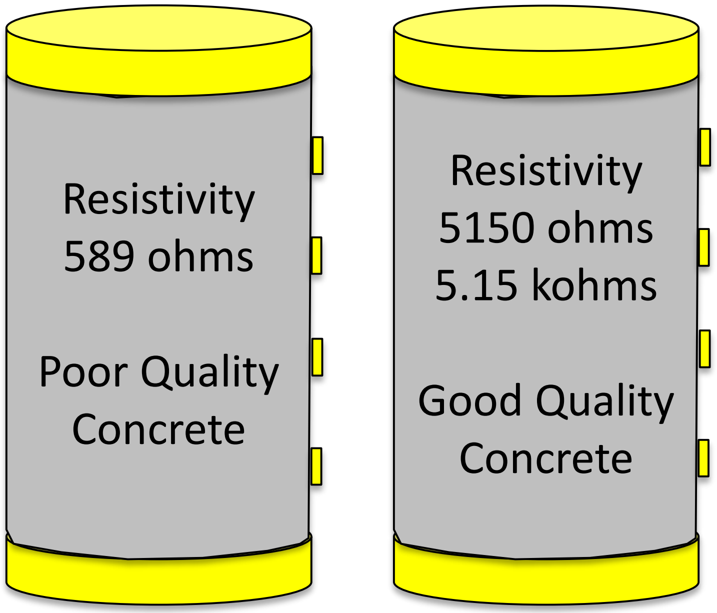
Pellinen et al., 2005

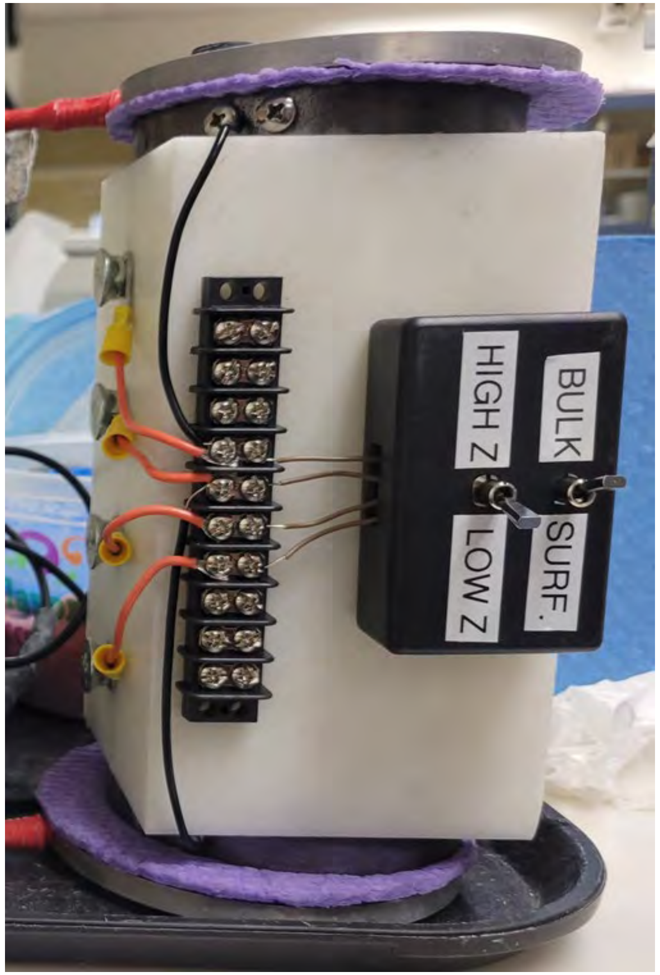
Calibration Samples

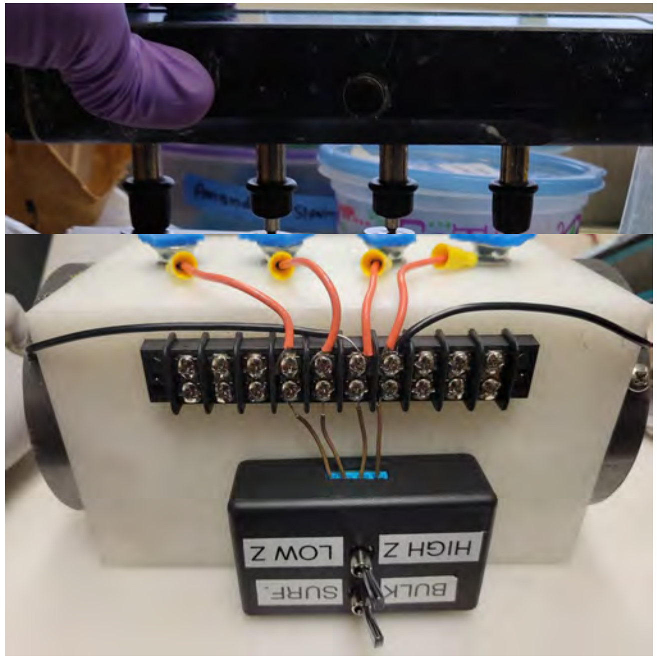
- In 2008 we stated that calibration/reference devices were needed
- Some suppliers have made some items but we needed to develop the calibration cell at OSU to verify the equipment is setup correctly
- Specifically:
  - Correct sponges and the solution used
  - Electrical connections are not faulty
- Real examples of issues



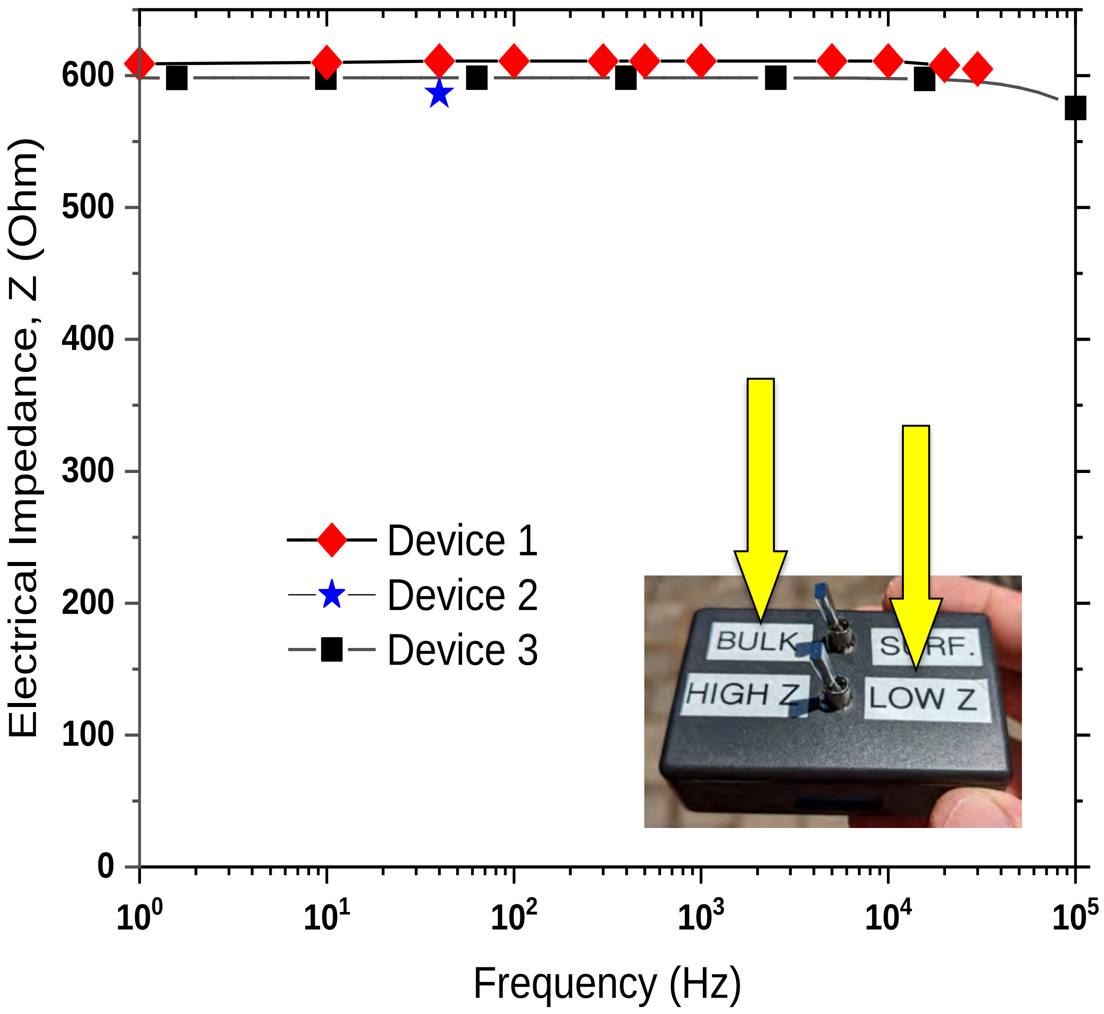
Calibration Samples



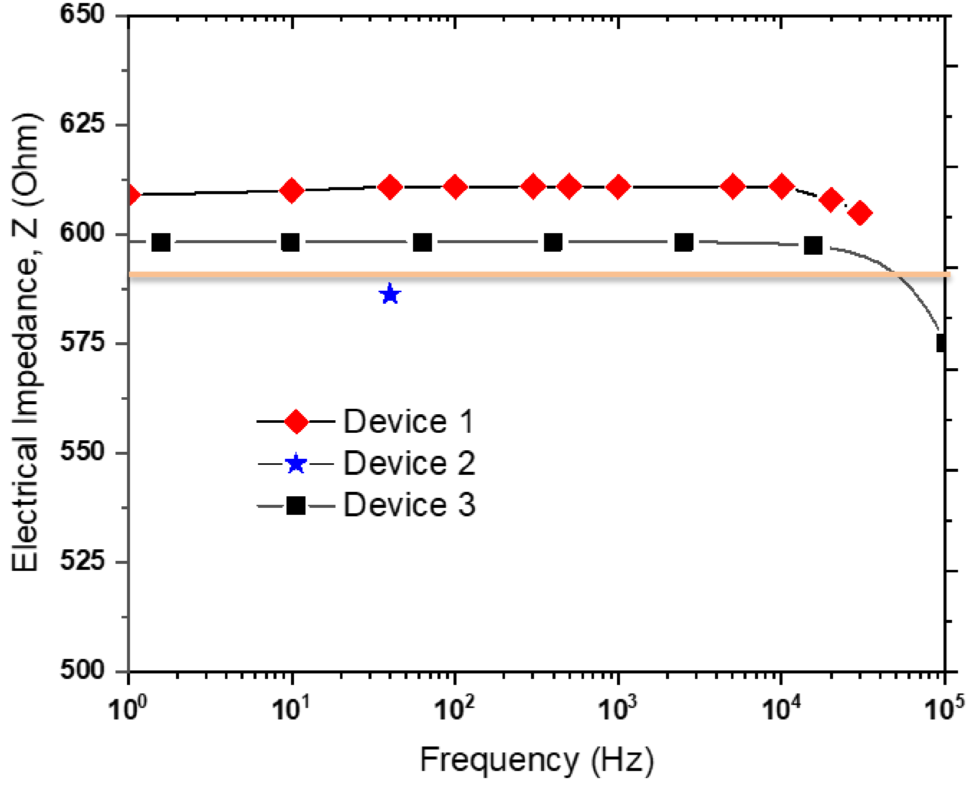




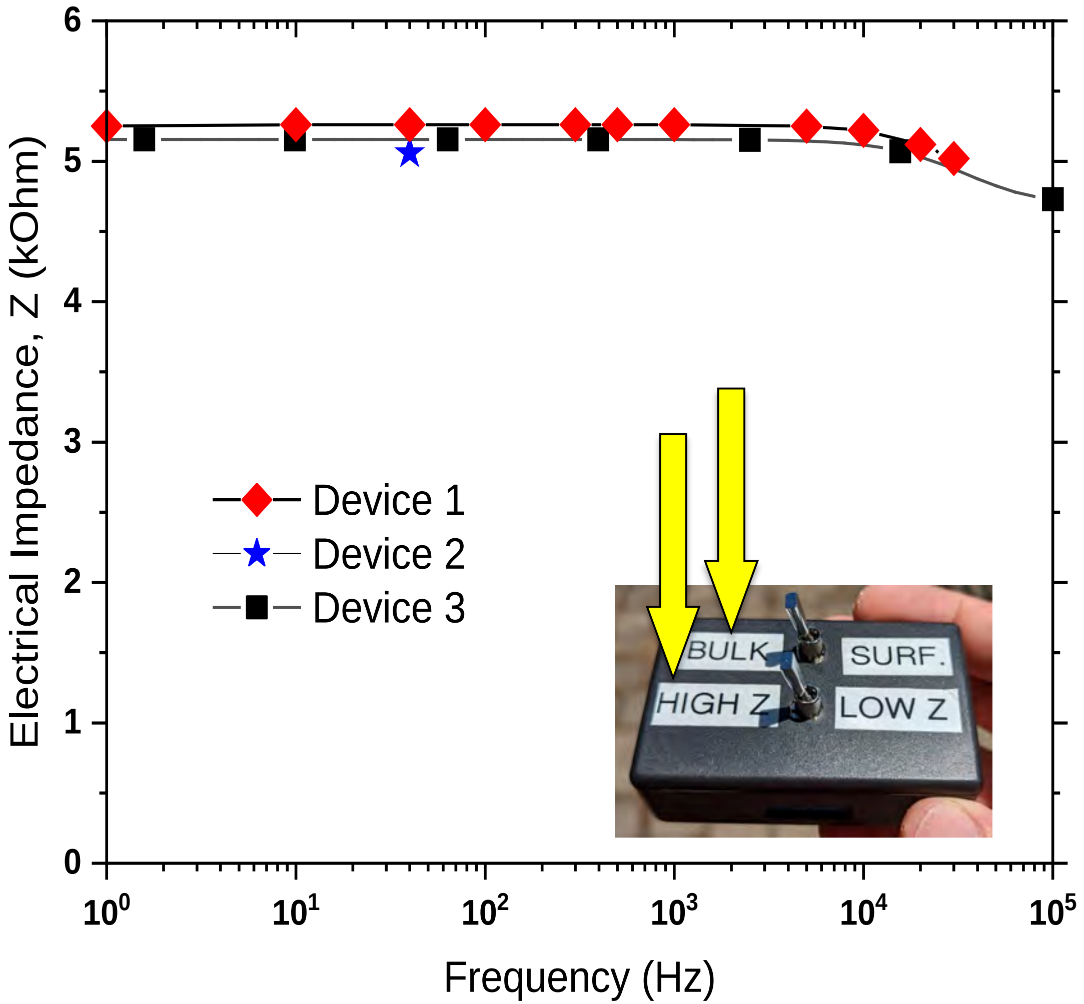
Known Materials (low)



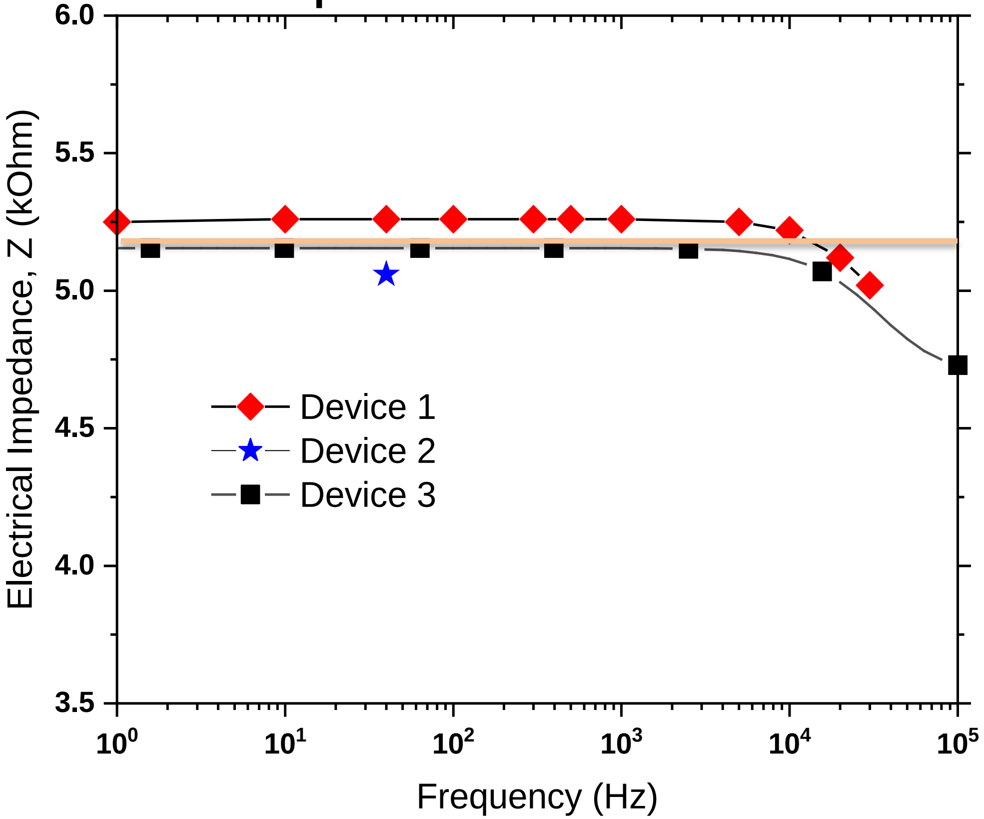
- Tested known sample
- Actual Impedance 589 ohms



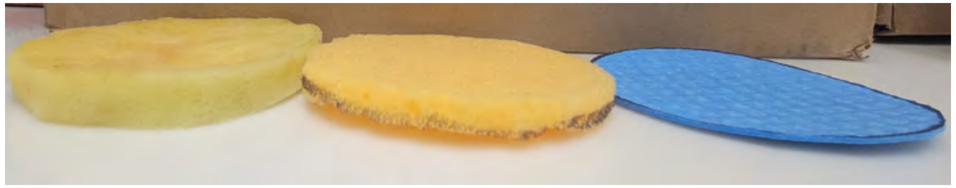
Known Materials (high)



- Tested known sample
- Actual Impedance 5.15 kohms

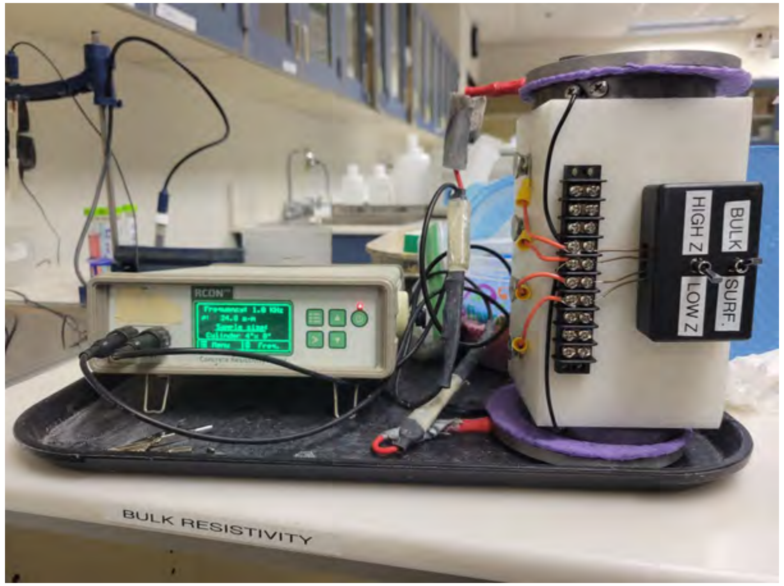


Resistivity calibration device



- Effect of using different sponges (Corrected)
  - Thickness: 0.55’’, 0.35’’, 0.04’’
  - Using sponges thicker than 0.35’’ can cause > 4% change in measured resistivity (typically 1%)

- Effect of conductive solution for sponges
  - Using DI water instead of conductive solution (simulated pore solution or lime water) can cause up to 8% increase in resistivity measurement



- Effect of using defective wires
  - Can cause fluctuations in measurements and effect the consistent measurements

Summary

- Concrete Quality – related to water content and connectivity of pores
- Resistivity (Formation Factor) – related to water content and connectivity of pores
- PEM – Enabled different groups to become familiar with resistivity
- Now that we are familiar there is an opportunity to tighten up how we are testing – education and verification
- Huge value in proper calibration cells
- We will conduct a precision and bias study – Looking for testing labs

Fresh Concrete Study

Oregon State University
College of Engineering

- Travel to Iowa
  - SAM testing
  - V- Kelly Testing
  - Box Testing

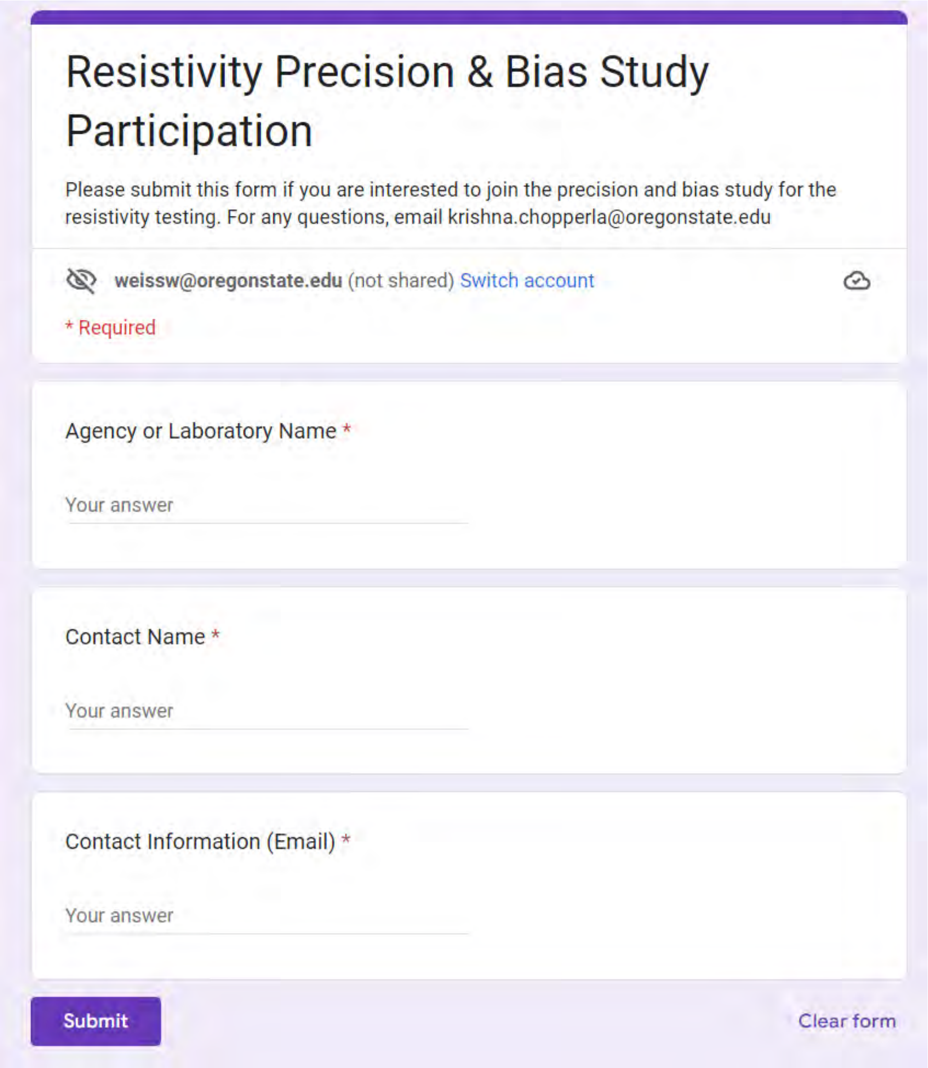
https://www.roadsbridges.com/concrete/article/10648919/stop-being-premature

Phase A Participating Labs and Sample Prep

Oregon State University College of Engineering

- Link to fill in the participation form https://forms.gle/qTUHR8cgZuFhfKu17

Jason.Weiss@oregonstate.edu
krishna.chopperla@oregonstate.edu



Resistivity Precision & Bias Study Participation

Please submit this form if you are interested to join the precision and bias study for the resistivity testing. For any questions, email krishna.chopperla@oregonstate.edu

weissw@oregonstate.edu (not shared) Switch account

* Required

Agency or Laboratory Name *

Your answer

Contact Name *

Your answer

Contact Information (Email) *

Your answer

Submit

Clear form