EVALUATION OF TEST METHODS FOR PERMEABILITY (TRANSPORT) AND DEVELOPMENT OF PERFORMANCE GUIDELINES FOR DURABILITY

Prepared by:

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Karthik Obla, NRMCA, and
Jason Weiss Purdue

Presented at NCC September, 2008

Motivation for the Study

- Historically concrete has been specified and placed using prescriptive specifications
- States and agencies have begun the shift from prescriptive specifications to end result or performance based specifications.
- Though several states have experimented with performance specifications, this has been slowed by a lack of testing procedures, especially as they relate to transport

Project Objectives

- Develop a test procedure that directly evaluates the transport properties of concrete and relates these to anticipated performance with the use of exposure conditions.
- Evaluation of existing transport test procedures
- Development of new, or improvement test procedures
- Correlation between transport properties and existing 'durability' tests.
- Develop guidelines to relate permeability, exposure conditions, and field performance for use in specifications and quality control

Project Timing and Budget

- $883,000 Pooled Fund
- $335,100 Matching Dollars from Industry
- $135,515 In Kind Matching

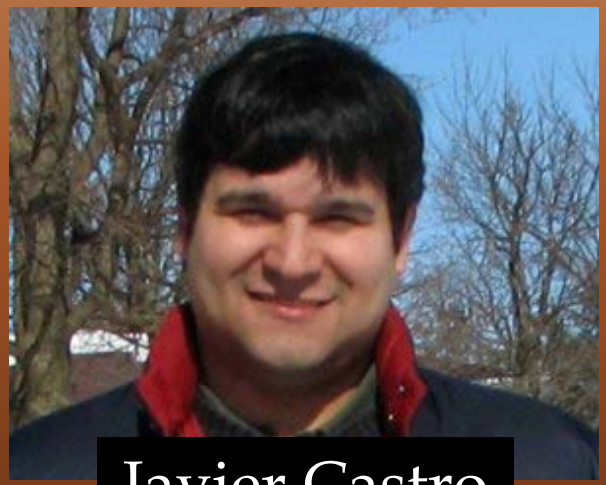
- 4 year Project
- $100,000 FHWA
- $25,000 each year for the first three years and $12,000 for the fourth year.

Project Team

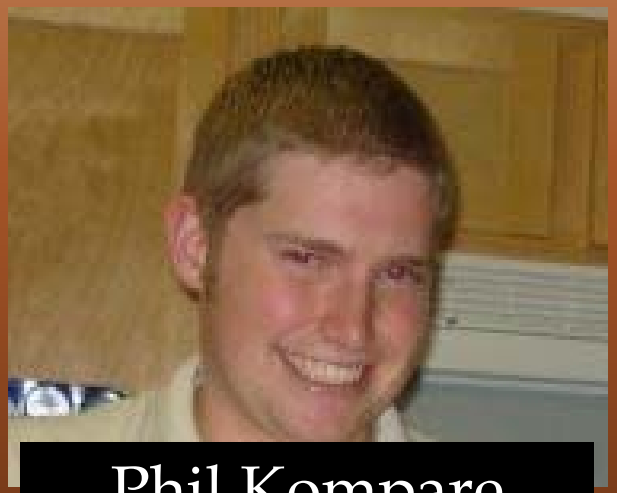
- INDOT
  - Tommy E. Nantung, Principal Investigator
- Purdue University
  - Jason Weiss, Ph.D., Professor and Associate Head
  - Jan Olek, Ph.D., P.E., Professor
  - Mark Baker is the Laboratory Manager
  - Post Doctoral Assistants, Graduate Assistants and Hourly Labor
- NRMCA
  - Karthik Obla, Ph.D., P.E. Senior Director of Research and Materials Engineering,
  - Haejin Kim, Laboratory Manager/Materials Engineer
  - Soliman Ben Barka, Senior Laboratory Technician
  - Colin Lobo, Ph.D., P.E. Vice President of Engineering
  - Gary Mullings Senior Director of Operations and Compliance.

Post-Doc and Students working on the Permeability Project

- Amir Pourasee – Post Doc – Instrumentation
- Javier Castro – PhD Student – Sorption, Sample Conditioning Effects, ACIS
- Phil Kompare – MS Student – Exposure, Field Sampling



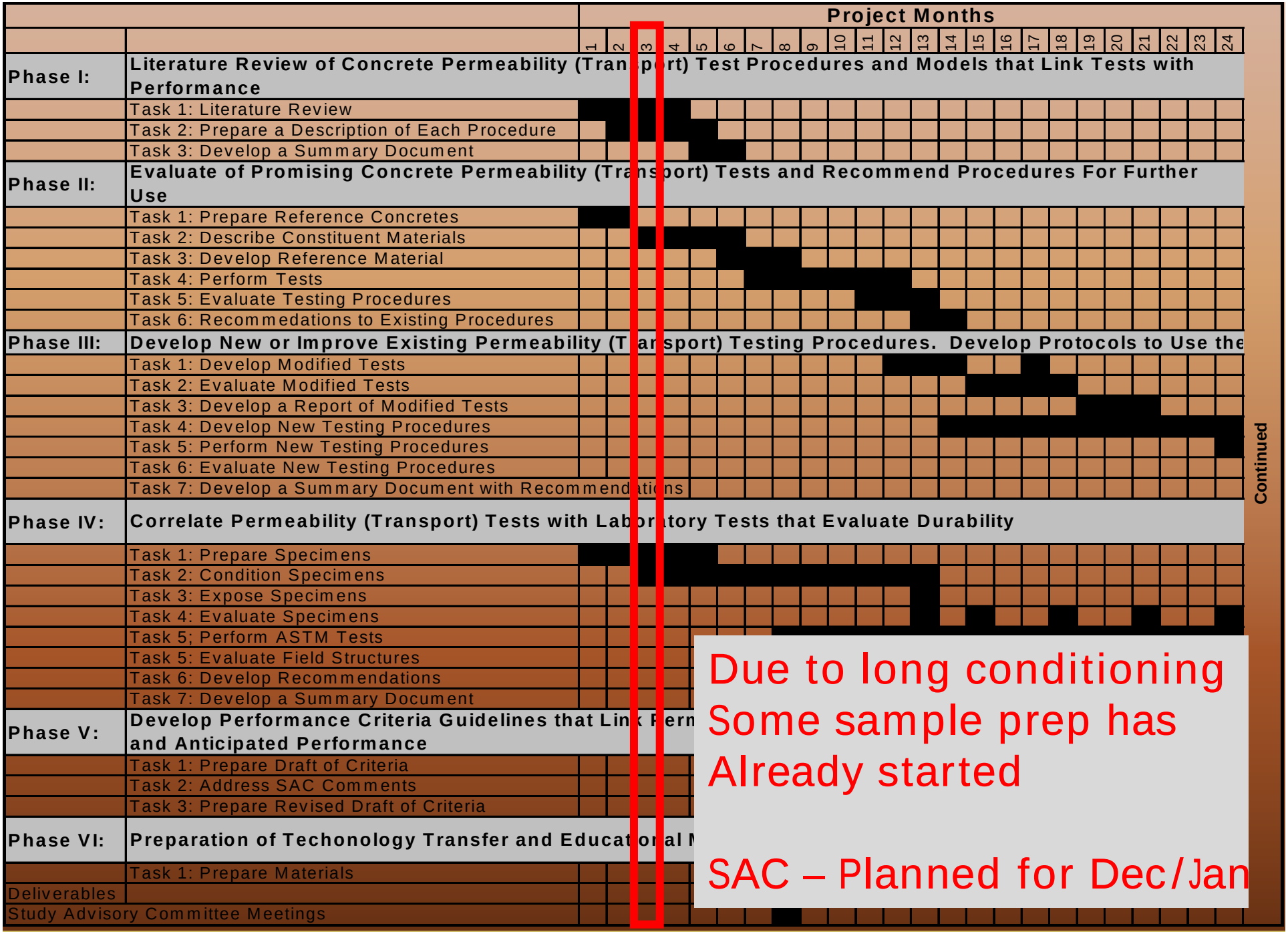
Javier Castro



Phil Kompare

Current Project Status

- The project received final approval in July 2008 and a contract was established with Purdue in early July
- The subcontract to NRMCA was established shortly thereafter
- Actively engaged in
  - Phase I the literature and practice review
  - Sample preparation stages of subsequent Phases


Project Months
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Phase I: Literature Review of Concrete Permeability (Transport) Test Procedures and Models that Link Tests with Performance
Task 1: Literature Review
Task 2: Prepare a Description of Each Procedure
Task 3: Develop a Summary Document
Phase II: Evaluate of Promising Concrete Permeability (Transport) Tests and Recommend Procedures For Further Use
Task 1: Prepare Reference Concretes
Task 2: Describe Constituent Materials
Task 3: Develop Reference Material
Task 4: Perform Tests
Task 5: Evaluate Testing Procedures
Task 6: Recommedations to Existing Procedures
Phase III: Develop New or Improve Existing Permeability (Transport) Testing Procedures. Develop Protocols to Use the
Task 1: Develop Modified Tests
Task 2: Evaluate Modified Tests
Task 3: Develop a Report of Modified Tests
Task 4: Develop New Testing Procedures
Task 5: Perform New Testing Procedures
Task 6: Evaluate New Testing Procedures
Task 7: Develop a Summary Document with Recommendations
Continued
Phase IV: Correlate Permeability (Transport) Tests with Laboratory Tests that Evaluate Durability
Task 1: Prepare Specimens
Task 2: Condition Specimens
Task 3: Expose Specimens
Task 4: Evaluate Specimens
Task 5; Perform ASTM Tests
Task 5: Evaluate Field Structures
Task 6: Develop Recommendations
Task 7: Develop a Summary Document
Phase V: Develop Performance Criteria Guidelines that Link Perm and Anticipated Performance
Task 1: Prepare Draft of Criteria
Task 2: Address SAC Comments
Task 3: Prepare Revised Draft of Criteria
Phase VI: Preparation of Techonology Transfer and Educational M
Task 1: Prepare Materials
Deliverables
Study Advisory Committee Meetings
Due to long conditioning
Some sample prep has
Already started
SAC – Planned for Dec/Jan

Phase I: Literature Review of Concrete Permeability (Transport) Test Procedures

- Literature review was developed using indexes:
  - Cement and concrete research, CCR
  - Cement and concrete composites, CCC
  - Materials and structures, MS
  - Journal of materials in civil engineering, ASCE
  - Database of TRB, TRIS
  - ACI materials, ACI structural, ACI procedures, Concrete International
- Several Large Reviews of Test Methods and Durability Design Frameworks

Phase I: Literature Review of Concrete Permeability (Transport) Test Procedures

A few state of the art reports have been acquired on durability based compliance tests and concrete penetrability, these are very valuable sources

	Keywords						
Indexes	Permeability	Absorption	Sorption	Desorption	Diffusion	Wicking	**Total**
CCR	87	15	12	5	83	1	**203**
CCC	12	11	1	1	11	0	**36**
MS	24	13	1	2	19	0	**59**
ASCE	6	5	9	1	15	0	**36**
TRIS	1	1	3	1	1	0	**7**
ACI Mat.	31	41	8	2	0	2	**84**
ACI Struct.	0	0	1	0	1	0	**2**
ACI Proc.	4	0	7	0	1	0	**12**
CI	26	0	6	0	2	0	**34**
Total	**191**	**86**	**48**	**12**	**133**	**3**	**473**

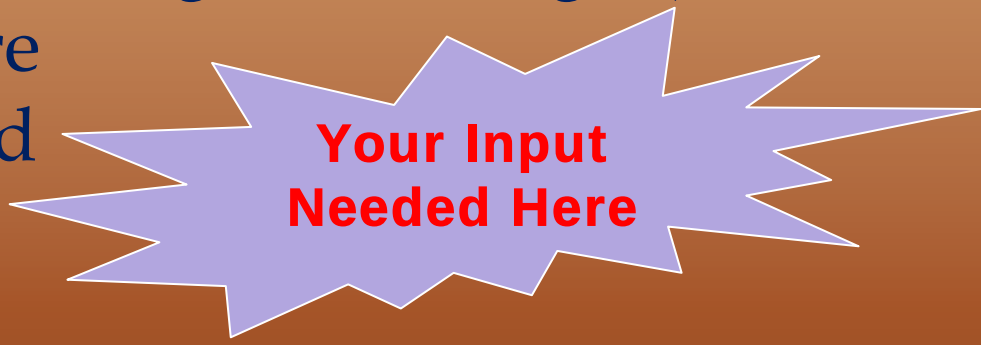
This information is currently being critically reviewed and summarized in a state of the art report

Phase I: Literature Review of Concrete Permeability (Transport) Test Procedures

- Develop a summary of each existing test:
  - description of the scientific principle behind a particular test,
  - application of the test,
  - size and conditioning of the specimens,
  - testing procedure,
  - methods used to evaluate the test,
  - advantages and disadvantages of a particular test,
  - length of time that a test takes to perform,
  - commercial availability, and
  - an approximate cost

Task 1 – Request

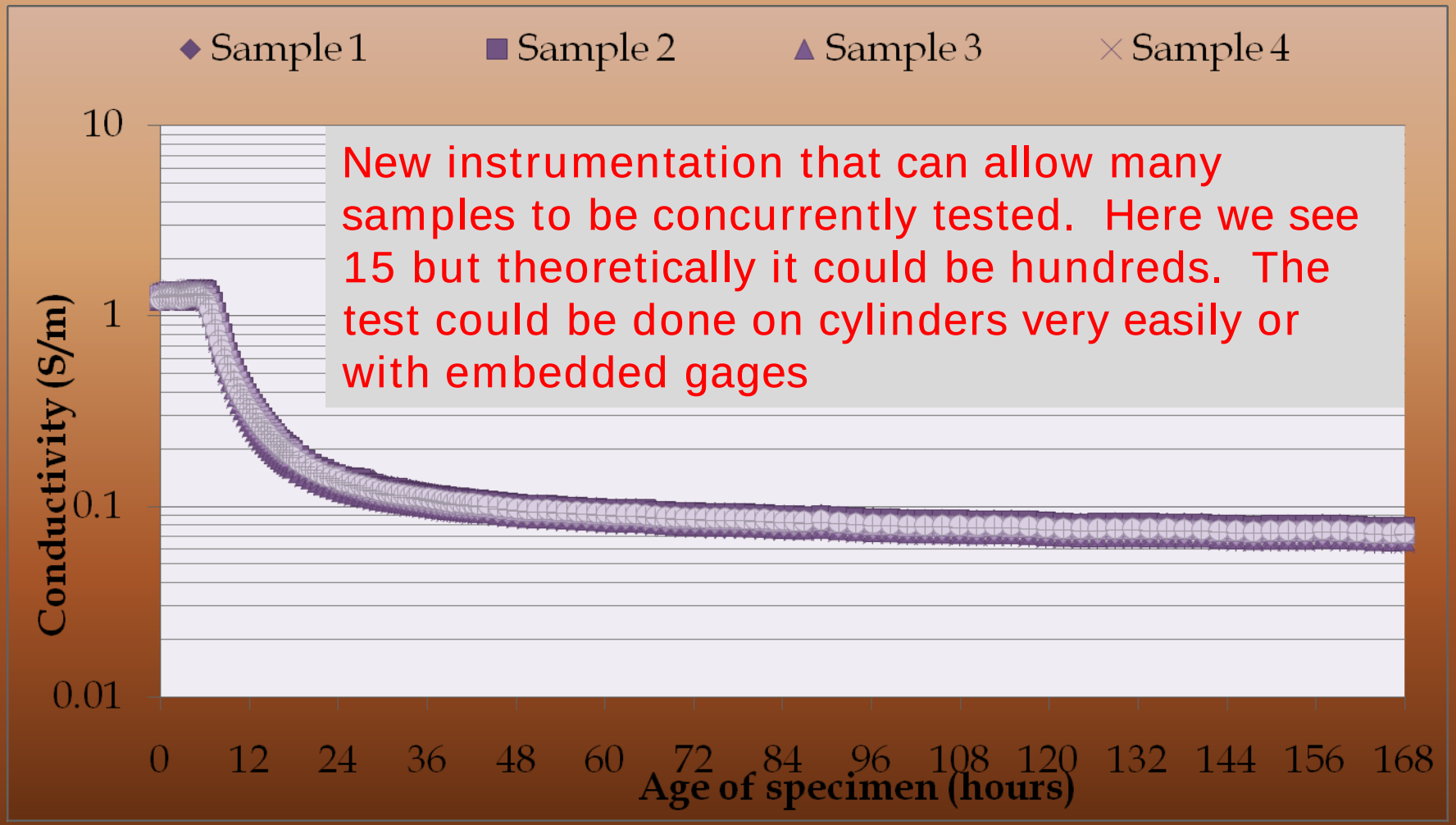
- If you have a particular 'transport related test' or a specific conditioning procedure that you would like included please feel free to contact Tommy Nantung (tnantung@indot.in.gov) and we will make sure that it will be included in the review and evaluated as a part of the process if it is at all possible.



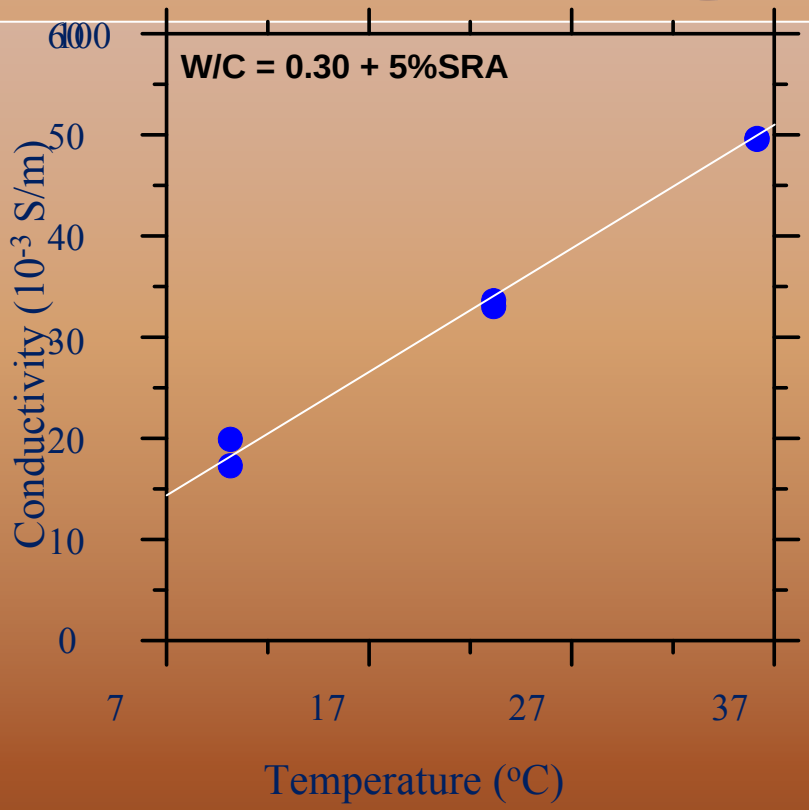
Phase II: Evaluation of Promising Concrete Permeability (Transport) Tests

- Conduct these tests on a smaller, yet comprehensive, subset of materials
- Calibration on a known material (ceramic similar to an OPC paste, repeatable and known)
- Specimen curing, conditioning, sample size, air content, specimen maturity, and variations in mixture proportions
- The resolution, repeatability, and robustness of these test procedures will be evaluated
- Will build on ongoing work at Purdue

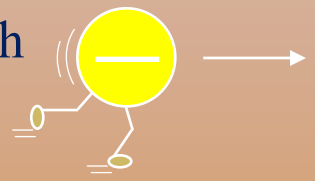
Typical Example of Automated Conductivity Based Data Collection



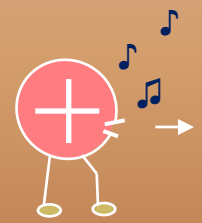
Before Applying Maturity Transforms to Conductivity Measures Correct for Temperature



- High Temperature: High mobility, fast ions High conductivity



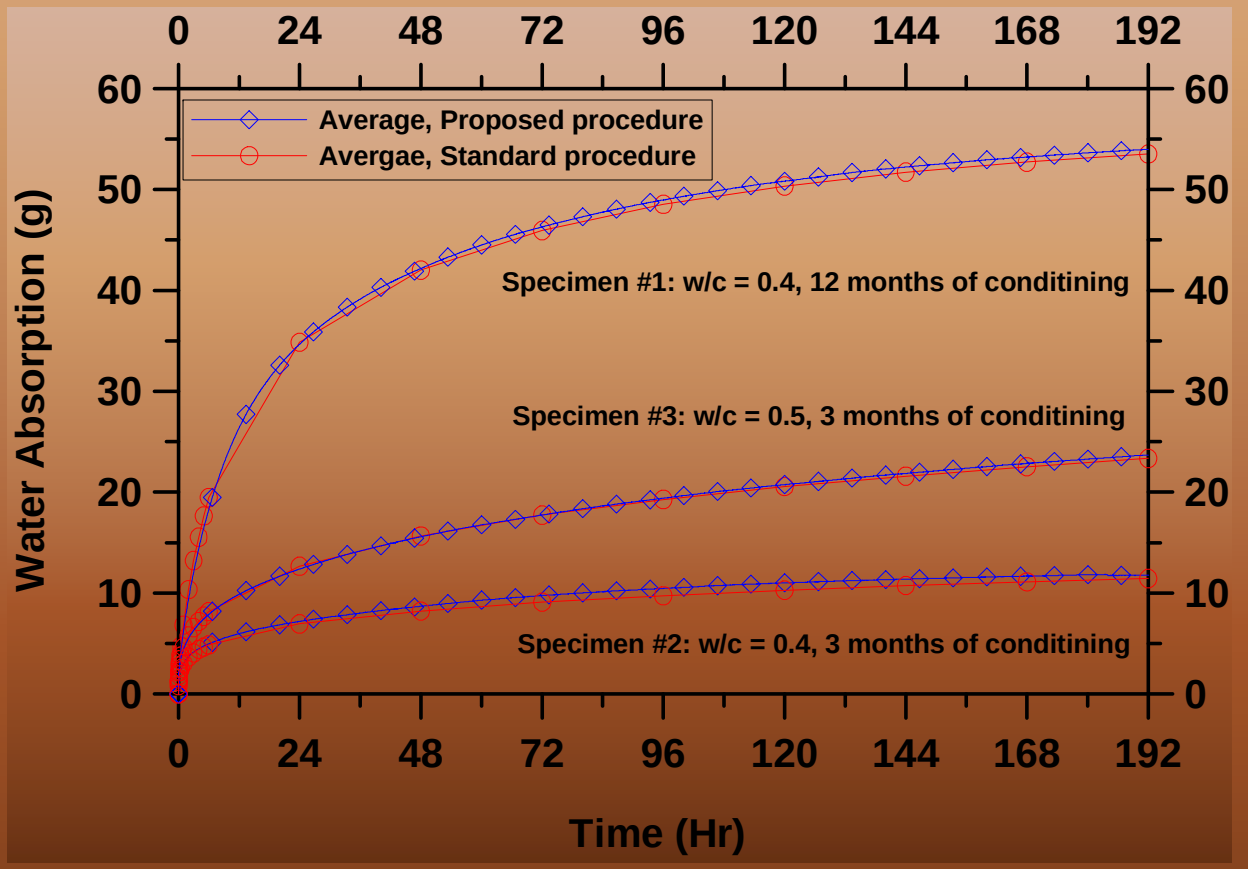
- Low Temperature: Low mobility, slow ions Low conductivity



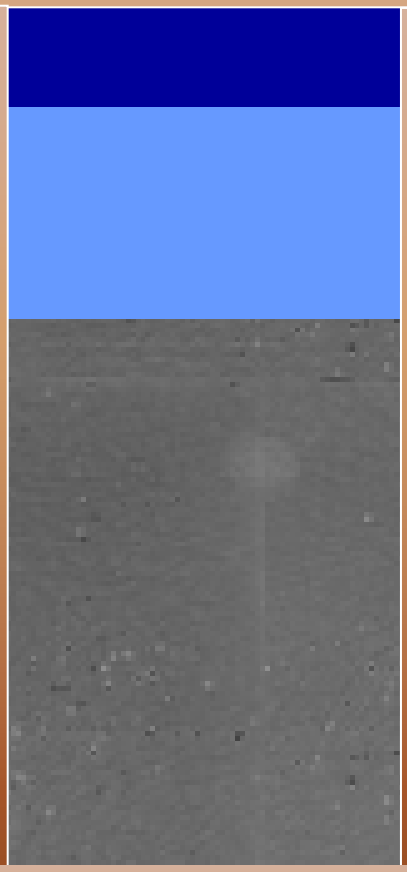
$$\sigma(T) = Ae^{\left(\frac{-E_a}{RT}\right)}$$

- Higher temperature → higher conductivity
- First correct for temperature then for maturity

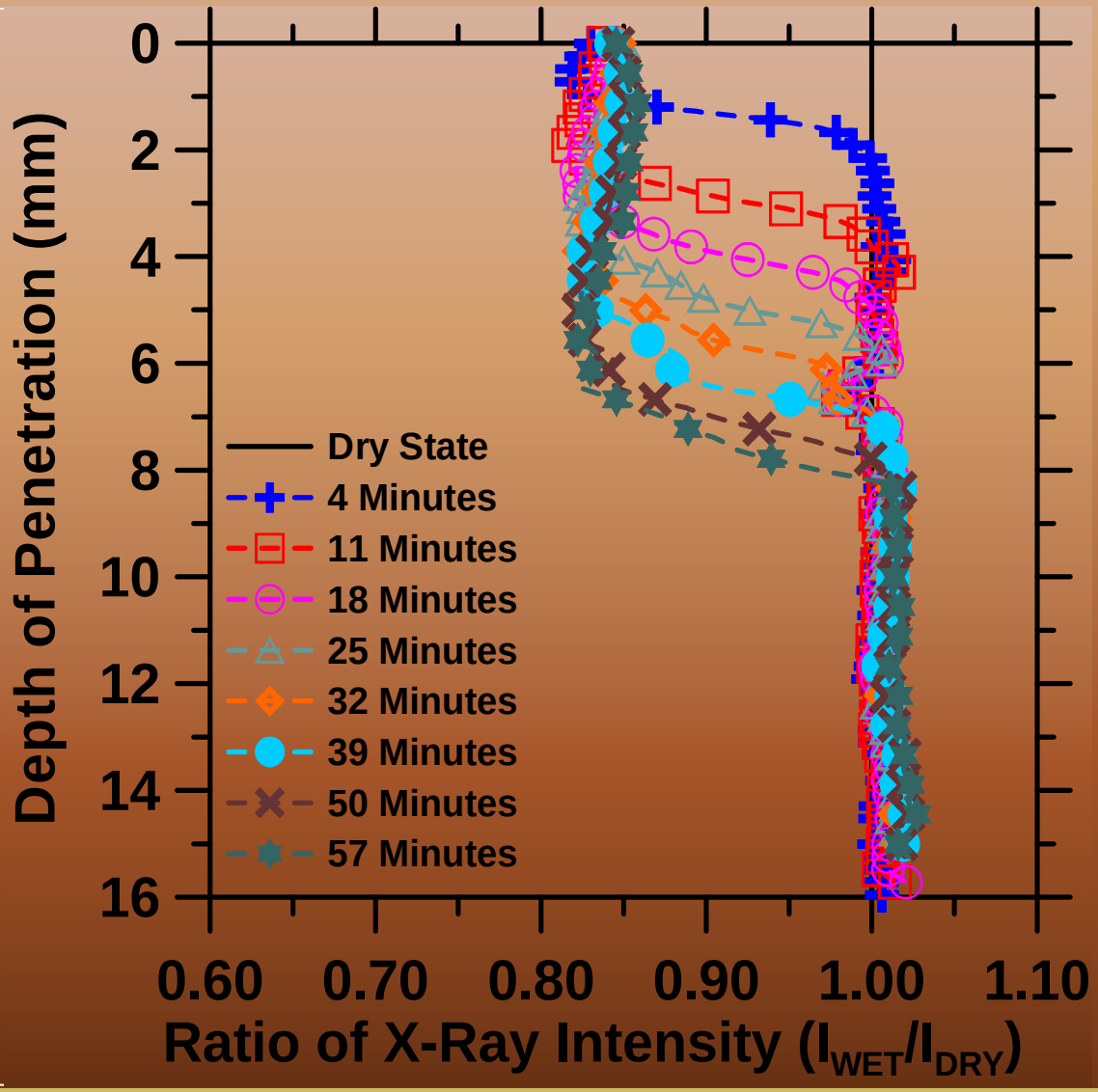
Examples of Automated Water Absorption Testing



Example of Other Tests



Change in normalized intensity with ingress



Concurrent Study

- Currently INDOT is conducting work that is examining the role of sample conditioning on fluid absorption
- Samples are being collected from pavements and bridge decks and conditioned to arrive at equilibrium
- These samples are being compared with rapid conditioning test procedures