



PURDUE
UNIVERSITY



Evaluation of Test Methods for Permeability (Transport) and Development of Performance Guidelines for Durability

Tommy Nantung (INDOT), Jason Weiss (Purdue), Karthik Obla (NRMCA)

Midwest Concrete Consortium, Des Moines, September 25, 2007



Motivation for the Study

- Concrete specified and placed - prescriptive specifications
- Shift from prescriptive specifications to end result or performance based specifications.
- PRS
 - Slowed by a lack of testing procedures, especially relate to transport

Motivation for the Study

- Prescription
 - $w/cm = 0.40$
 - Cover (1.5 to 2.5 in.), chloride ion limits
 - 20% fly ash, 30% slag etc.
 - 705 lb/yd^3
 - ECR, Corrosion inhibitor
- Replace prescription with performance requirement for corrosion resistance

Example of Proposed Performance Tests

- Rapid Index Tests
 - RCP (ASTM C 1202)
 - RMT (AASHTO TP 64)
 - Sorptivity (ASTM C 1585)
 - Gas Permeability (RILEM-CEMBUREAU)
- Science-based Tests
 - Chloride Diffusion (ASTM C 1556)
 - Modified Chloride Diffusion (ASTM C 1556)



The Link Between Durability and Transport

- Each potential durability issue can be related in part to water penetration
 - Freeze-thaw, chloride penetration and corrosion, alkali aggregate attack, and sulfate attack.
- To specify more durable concrete, tests are needed:
 - Qualify the resistance of the concrete to water (or aggressive fluid) penetration.

Project Objectives

- Develop test procedure(s)
 - Directly evaluates the transport properties of concrete and relates these to anticipated performance with the use of exposure conditions
- Evaluate existing transport test procedures
- Develop new, or improvement test procedures
- Correlate transport properties and existing ‘durability’ tests.
- Develop guidelines to relate
 - Permeability, exposure conditions, and field performance for use in specifications and quality control

Project Scope

- Phase I
 - Literature Review of Concrete Permeability (Transport) Test Procedures and Models that Link Tests with Performance
- Phase II
 - Evaluate Promising Concrete Permeability (Transport) Tests and Recommend Procedures for Further Use
- Phase III
 - Develop New or Improve Existing Permeability (Transport) Testing Procedures.
 - Develop Protocols to Use these Tests, Evaluate the Precision and Bias of these Tests

Project Scope

- Phase IV
 - Correlate Permeability (Transport) Tests with Laboratory Tests that Evaluate Durability
- Phase V
 - Develop Performance Criteria Guidelines that Relate Permeability (Transport) Tests with Exposure Conditions and Performance
- Phase VI
 - Preparation of Technology Transfer and Educational Materials



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

- Develop a summary of each existing tests
 - 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



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



Phase III: Develop New or Improve Existing Permeability (Transport) Tests

- Develop Protocols to Use these Tests, Evaluate the Precision and Bias of these Tests
 - hydraulic permeability (flow of water in a saturated concrete),
 - gas permeability (flow of a gas in an partially saturated concrete),
 - water absorption (fluid ingress into a partially saturated concrete), and
 - ion diffusion (transport of ions in a saturated concrete under a concentration gradient).

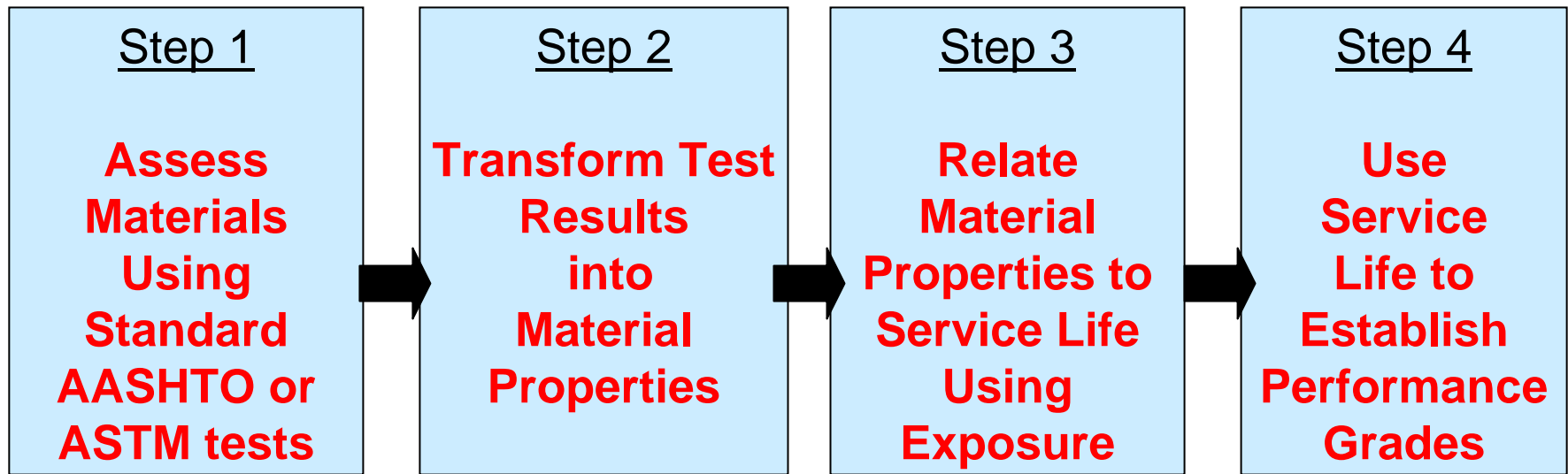


Phase IV: Correlate Permeability (Transport) Tests with Tests that Evaluate Durability

- Task 1
 - Performance Requirements for Corrosion Resistance
- Task 2
 - Performance Requirements for Freeze Thaw Resistance
- Task 3
 - Performance Requirements for Sulfate Resistance
- Task 4
 - Performance Requirements for Alkali Silica Reaction
- This work will tie into P2P initiatives

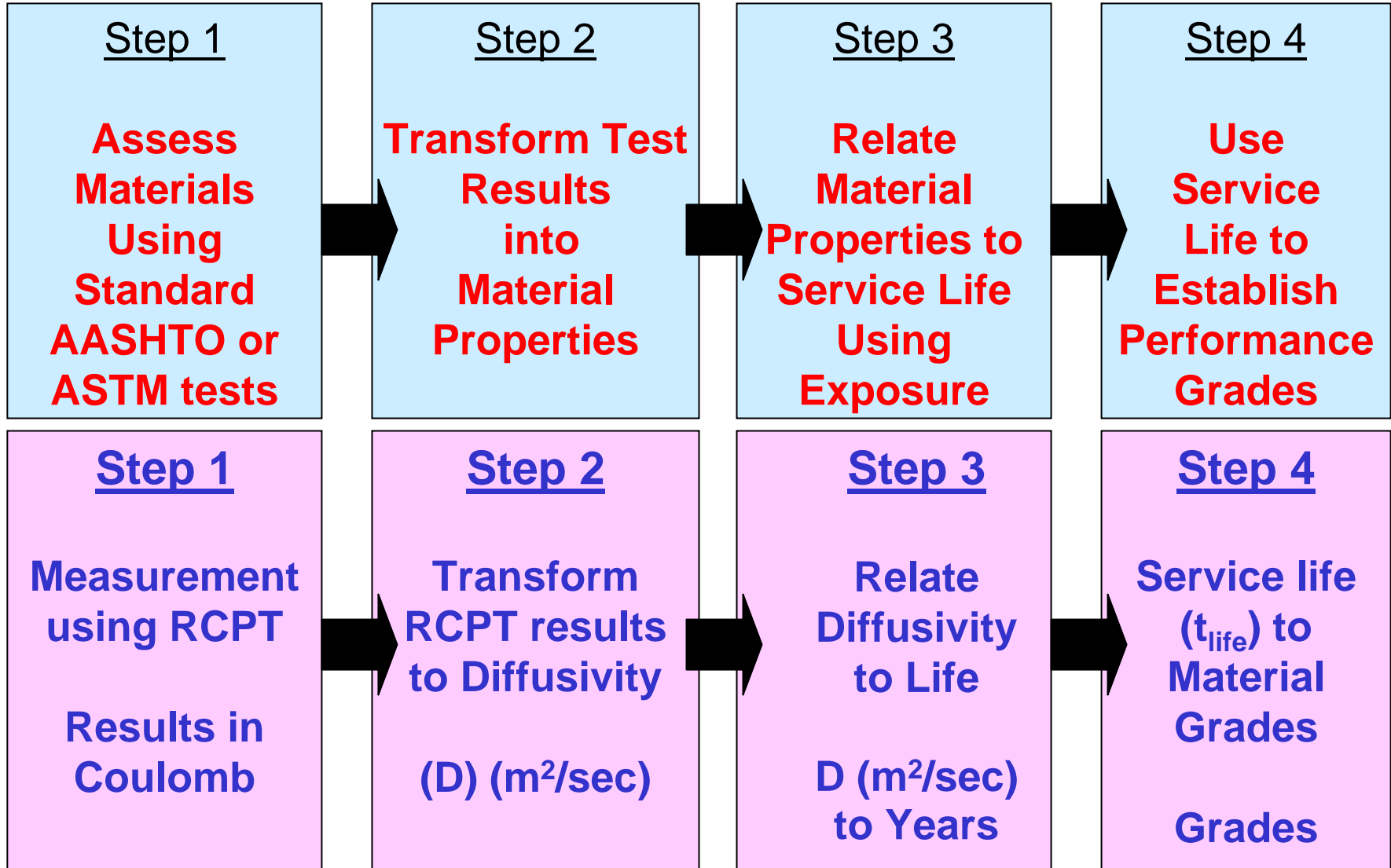
General Modeling Approach

For the main characteristics investigated in this work the following approach was used for modeling



- Chloride Permeability and Corrosion
- Freeze Thaw Durability

Corrosion Model Approach

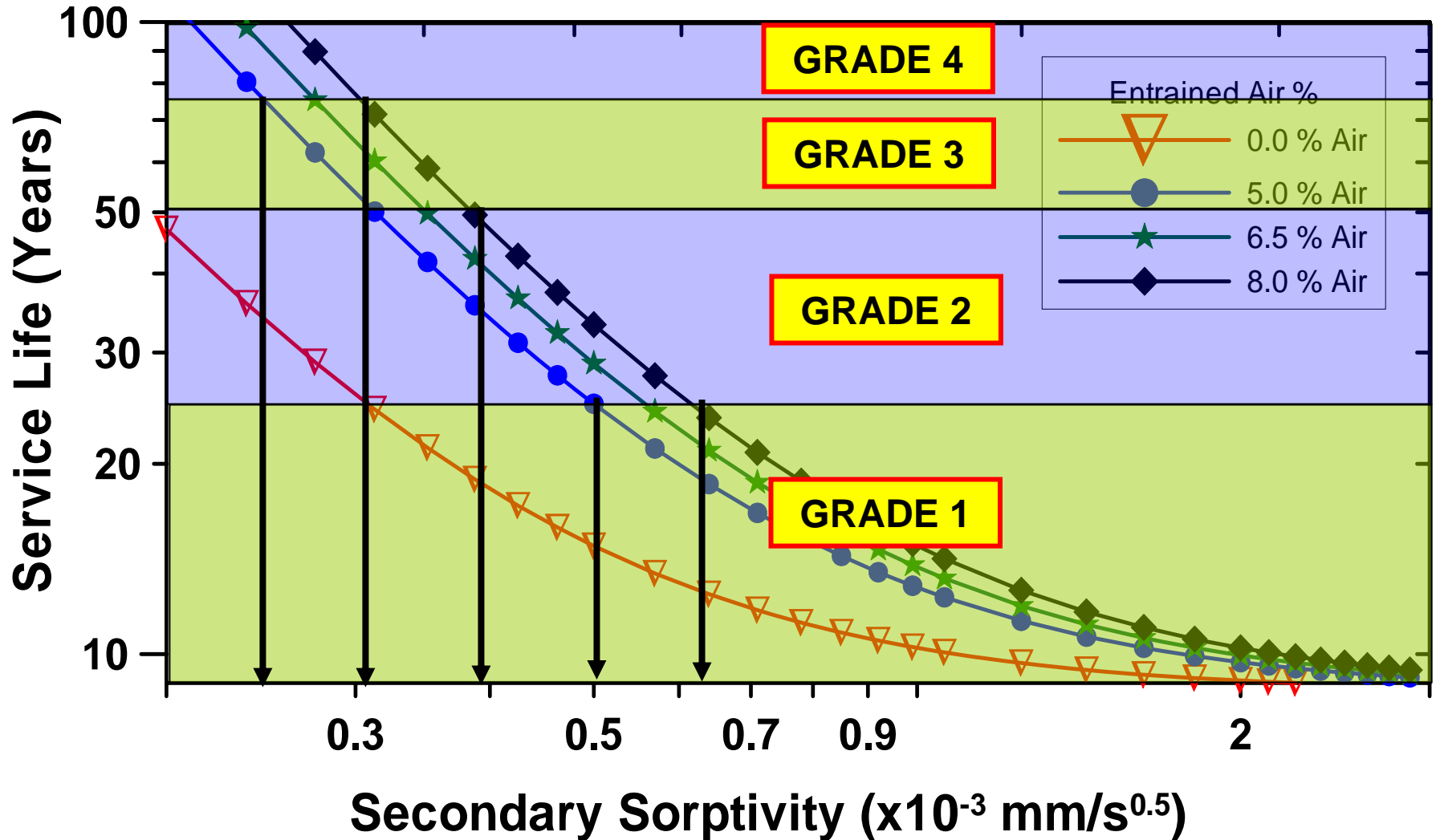




Phase V: Develop Performance Criteria Guidelines

- Develop Performance Criteria Guidelines
 - Link Permeability (Transport) Tests with Exposure Conditions and Anticipated Performance
- Preliminary project has been conducted at INDOT that shows promise in this area.
- Further work is needed
- Exposure classes can be developed
- Link to simulation will be considered

Performance Grades – Example





Phase VI: Preparation of Technology Transfer and Educational Materials

- Deliverables
 - One day seminars for practicing professionals from the DOTs, consultants, material suppliers, and contractors
 - Instructional information for training laboratory technicians.
 - Educational materials will be prepared for two one hour presentations that can be used in college classes



Project Team

INDOT

- Tommy E. Nantung, Ph.D., P.E., Section Manager

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.



Project Funding

- Funding
 - \$883,000 Pooled Fund
 - 4 year Project
 - \$25,000 each year for the first three years and \$12,000 for the fourth year.
 - \$100,000 FHWA
 - \$335,100 Matching Dollars from Industry
 - \$135,515 In Kind Matching



Project Schedule

		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: Recommendations 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																									
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 Permeability (Transport) Tests with Exposure Conditions 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 Materials																									
	Task 1: Prepare Materials																									
Deliverables																										
Study Advisory Committee Meetings																										

Continued



Summary

- Pooled Fund Study proposal has been out
 - Five states have joined
 - Four more states are needed
- Status of existing work and funding
 - This work will build on current work
 - This work leverages industry funding
 - This work will lead to a paradigm shift in how durability is thought about and tested