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

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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.

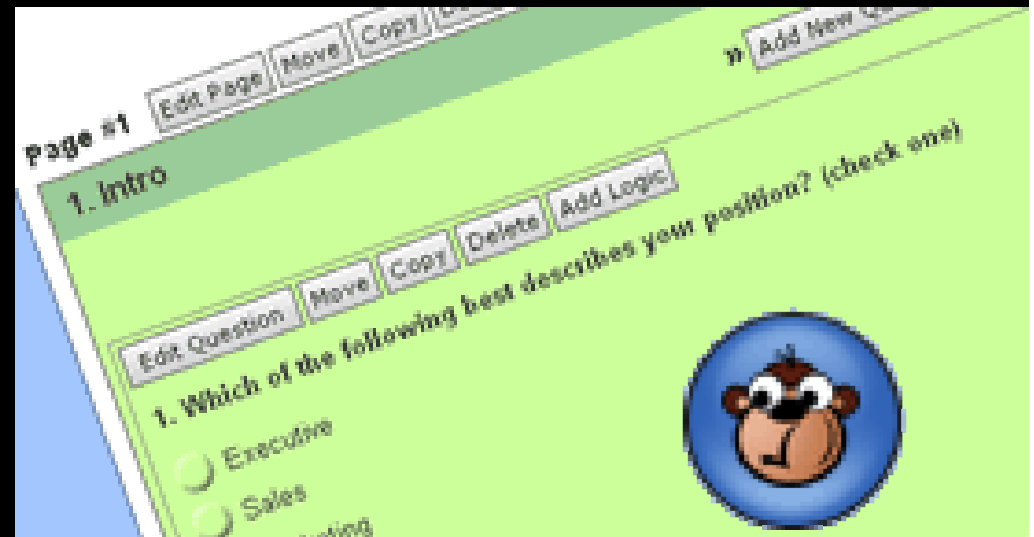
- Evaluation of existing transport test procedures
- Development of new, or improvement test procedures
- Correlation between transport properties and existing 'durability' tests.
- Develop guidelines to relate permeability, exposure conditions, and field performance for use in specifications and quality control



Phase I - The Survey



- Review of tests used by numerous agencies
- Substantial information obtained
- Mining data and a summary will be reported
- Cost with some tests is a concern
- Time involved with some tests is a concern
- RCPT 45%; Ponding 15%; Absorption, Conductivity 10%; Percent of States Using

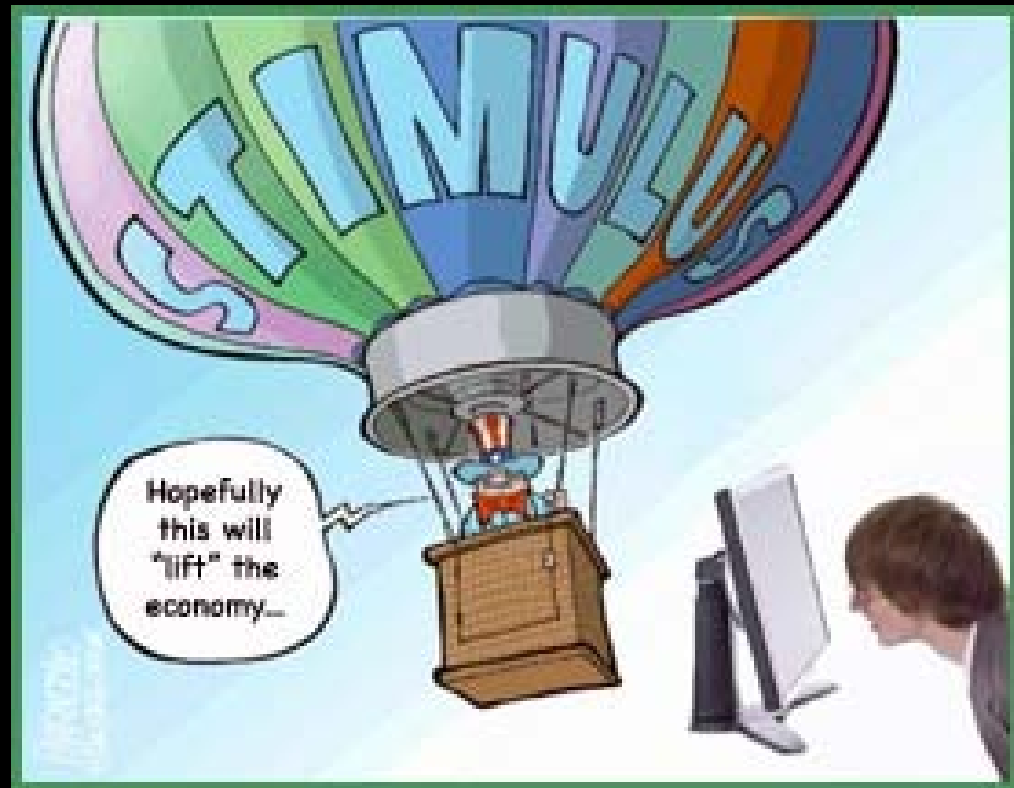




Phase I – Review Tests Available, First Principles, Cost, Data



- For Each Test – Review Stimulus-Response
- Scientific principle
- Cost
- Time
- Conditioning Samples
- Accuracy
- Data Obtained
- Advantages and Disadvantages





Phase I – Define the Various Types of Transport



- Diffusion
 - Diffusion of Species
- Absorption/Sorptivity
 - Filling of a Dry Material/Capillarity
- Permeation
 - Pressure Gradient
- Wicking
 - Drawn in by One Side Drying



Stars of the Literature Review



- Hundreds of papers, some very good reviews exist and are being used as background documents
- RILEM 189NEC Non Destructive Evaluation of the Penetrability and Thickness of the Concrete Cover
- Brite Euram III Duracrete Reports
- Current RILEM committee on Performance Related Specifications

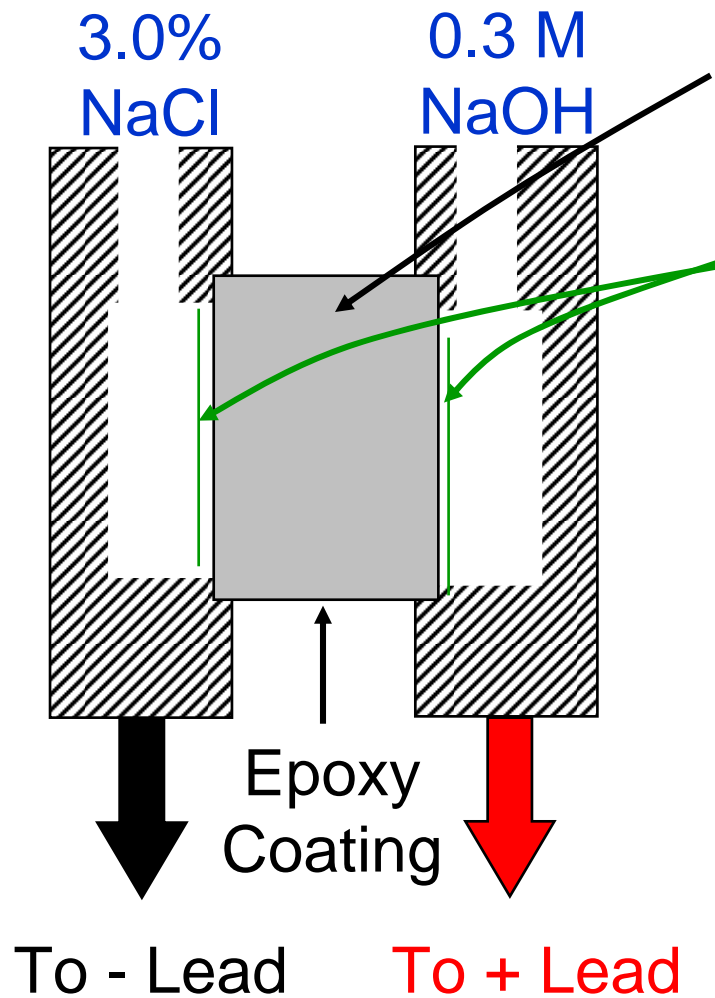


Phase II – Evaluate Tests

- Review Different Test Methods Using Reference Materials
- Summarizing By Category
 - Electrical Analog (RCPT to Wenner to 30 sec)
 - Water Absorption (various standards + others)
 - Air Permeability (not covered today)
 - Fluid Permeability (not covered today)
- A Short Summary of a Few Methods is Presented



Rapid Chloride Permeability Test



Chloride Permeability	Total Charge	Typical Concrete
High	>4000	w/c>0.6
Moderate	2000-4000	w/c` 0.4-0.5
Low	1000-2000	w/c<0.3
Very Low	100-1000	HSC w/SF LMC
Negligible	<100	Polymer Conc.



Mechanism of Electrical Conduction in Concrete



Concrete is a composite:

- Solid phase (unhyd Cement, CSH, CH,...); $\sigma_{sol} \approx 10^{-9} \text{ S/m}$

(Rajabipour 2006 based on results of Hammond and Robson 1955)

- Liquid phase (pore solution);

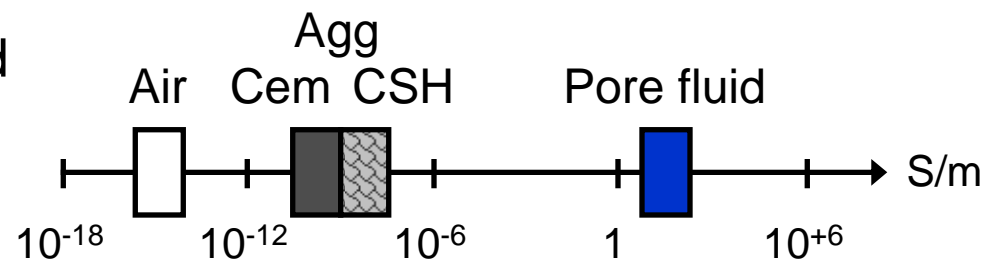
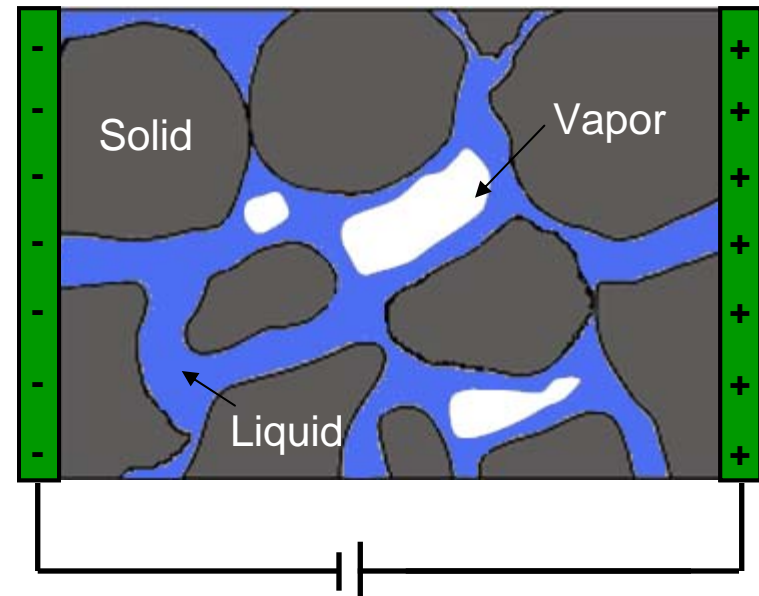
➔ $\sigma_{liq} \approx 1 \text{ S/m to } 20 \text{ S/m}$

(Christensen 1993)

- Vapor phase (air voids, emptied pores);

$\sigma_{vap} \approx 10^{-15} \text{ S/m}$

(Aplin 2005)



Flow of electricity is essentially ionic and through material's liquid phase



Modified Parallel Law to Model Concrete Conductivity



- Considers pore fluid as the only conductive phase in concrete
- Pore fluid can be in capillary or gel pores or in aggregate pores

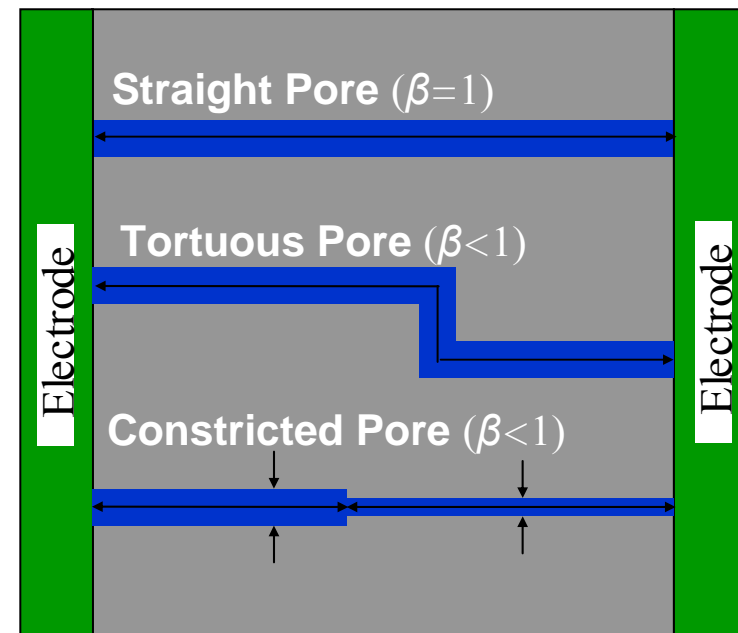
$$\sigma_t = \sigma_o \phi \beta$$

σ_t : concrete conductivity (S/m)

σ_o : pore solution conductivity (S/m)

ϕ : liquid volume fraction

β : avg. liquid connectivity
(describes liquid tortuosity and constrictedness)

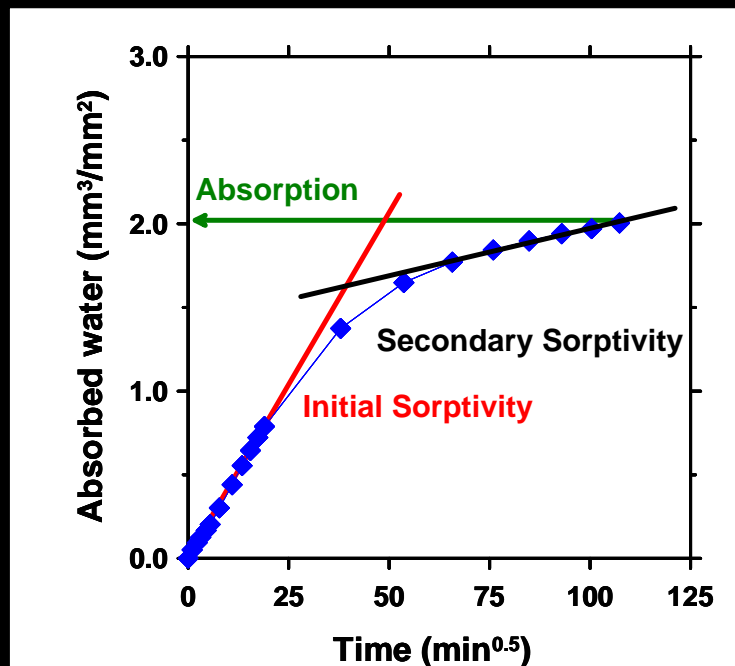


(Garboczi 1990, Christensen et al. 1994, Rajabipour 2006)



Sorption Test

- Determine the rate of absorption (sorptivity) of water by measuring the increase in the mass of a specimen as a function of time when only one surface of the specimen is immersed in water

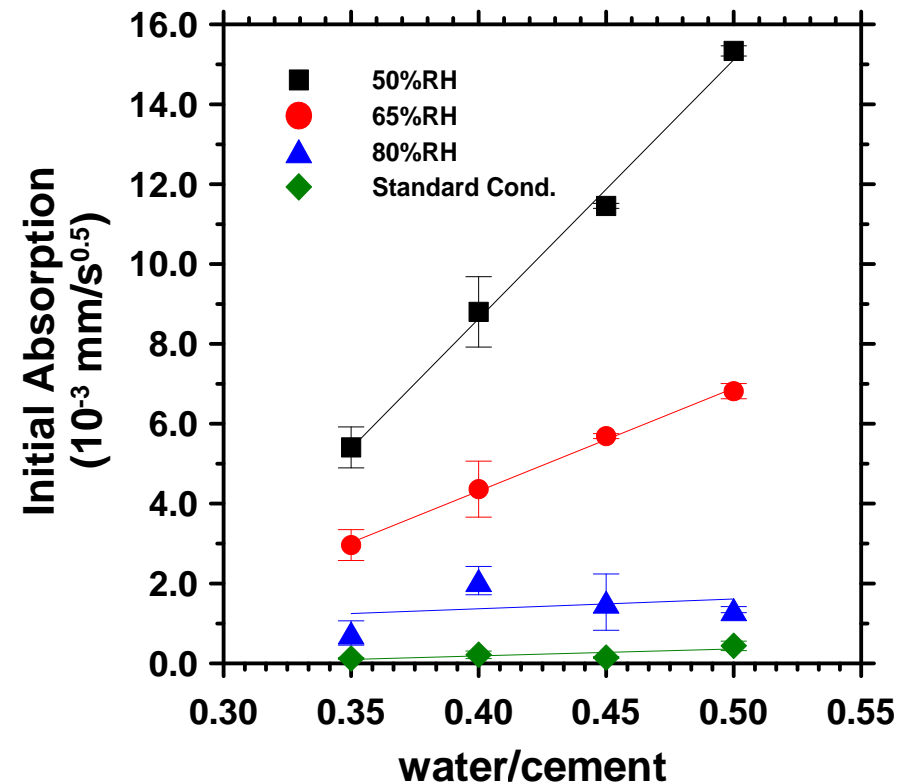
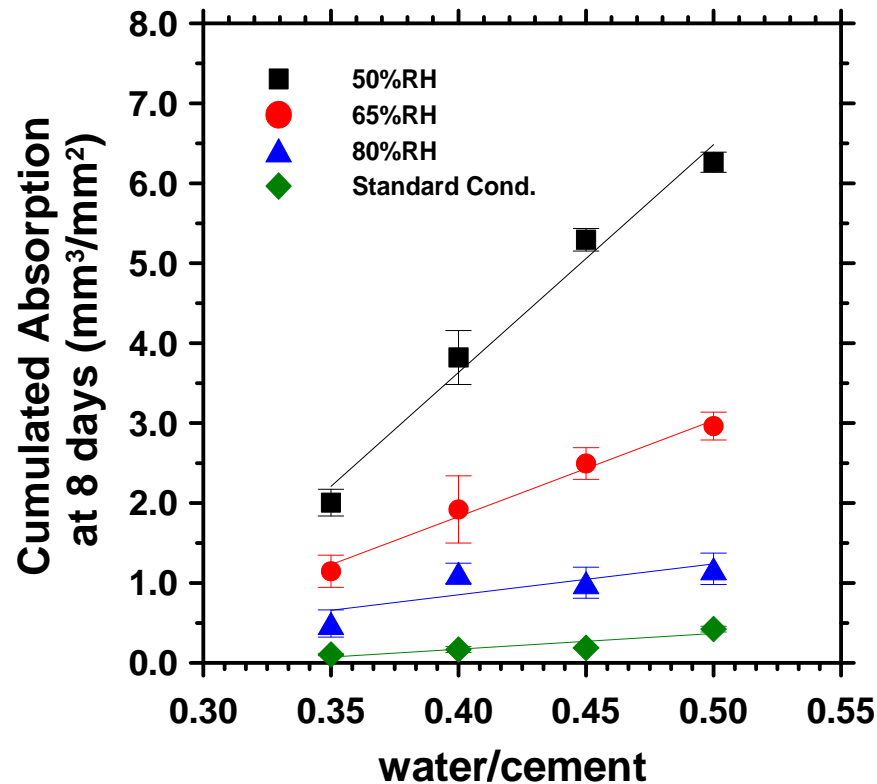




Effect on Initial Moisture Content



- Effect of the RH on absorbed water and initial sorptivity

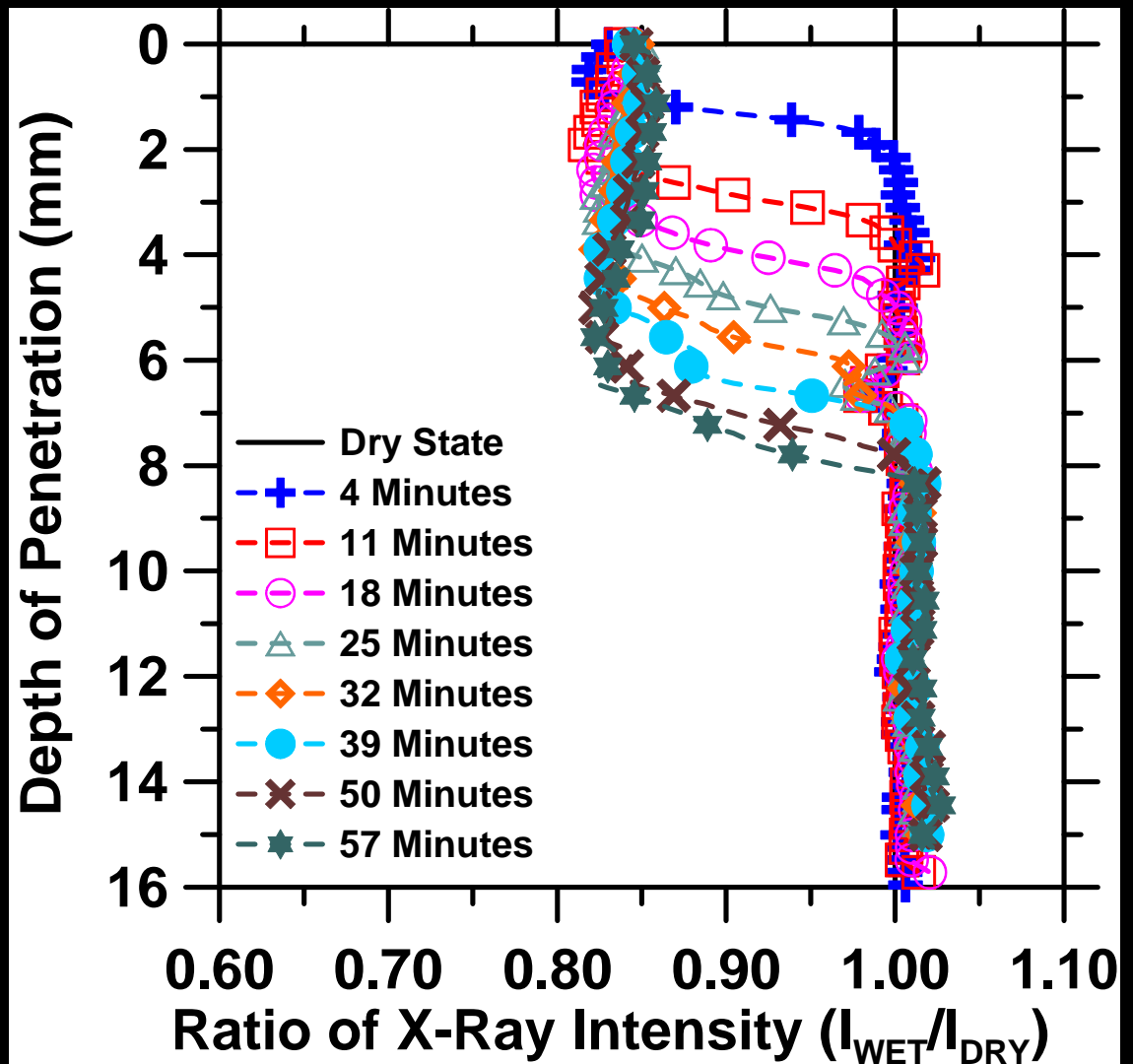
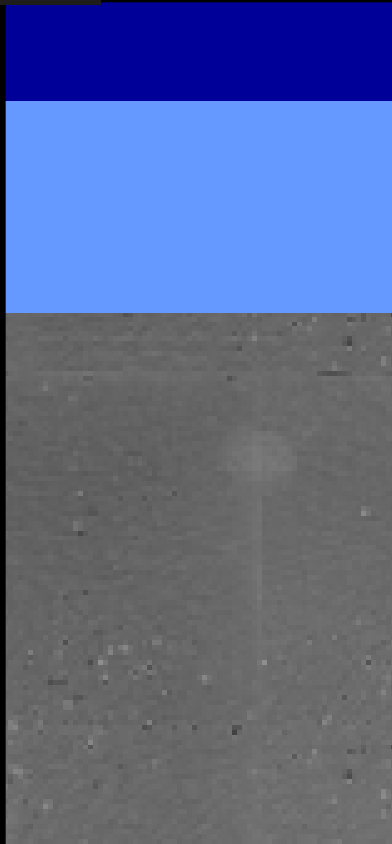


Note: Standard conditioning from saturation

Castro, in preparation



Typical Absorption Measurements



Sant et al. 2008



Summary



- Work is On Time and On Budget
- Survey - Insight into concerns and tests used
- Lit. Review Highlighted Numerous Tests
- The Research Team is Reviewing Each Test to Determine – Cost, Time, Basic Principles, Conditioning, Data Obtained
- Multiple Modes of Transport Separated
- Some Test Evals. Already Being Conducted
- Open House In 10 Months on Tests