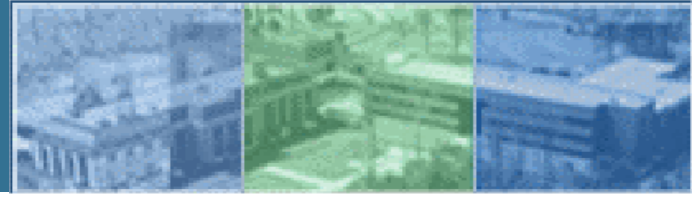
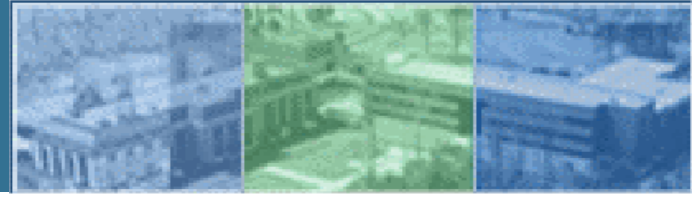


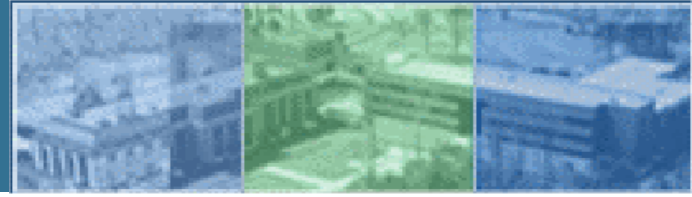
The Challenge of Assuring ACM Performance for Highway Concrete

Richard Meininger, PE
Federal Highway Administration (FHWA)
Turner-Fairbank Highway Research Center (TFHRC)



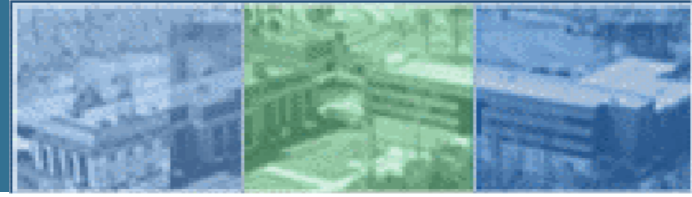
ACI Hot Topic Session

- Alternative Cementitious Materials (ACM) in construction is a developing technology.
- Current specifications and design codes are based on ordinary portland cement (OPC) as primary binder
- Need to address specifying, testing, and performance of ACMs, and the state-of-the-art of quality construction with ACMs;
- What properties are used to evaluate ACM Performance?
- Challenges of using ACMs and special testing requirements



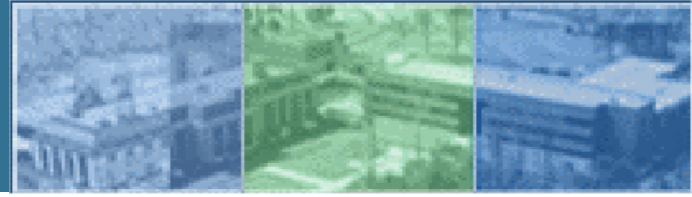
Objectives – Key Factors

- Sustainability in transportation – pavements & structures
- Carbon dioxide footprint coupled with long-term durability and performance in all types of weather and climates.
- Performance specifications and test methods for both
  - The range of new cements; cement QC & acceptance QA
  - Concrete made with the ACMs; both material & structural capabilities
- Must be seen as an advancement or viable alternative by highway engineers and the construction industry alike



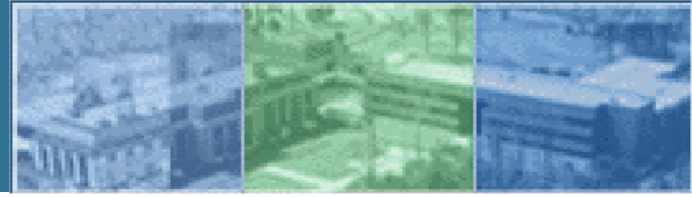
Do we?

- Modify existing tests and specifications, or
- Is a whole new paradigm for qualifying materials needed?
- How do we verify that we are building with quality?
- Many questions will be asked
  - compatibility with ordinary portland cement (OPC)
  - constraints on aggregates; casting and setting properties
  - as well as volume change, cracking tendencies
  - structural & corrosion properties with reinforcement.



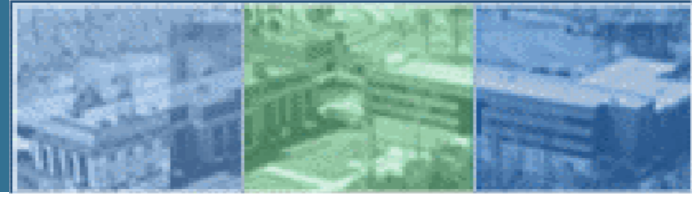
Projects, partnership with industry, agencies, universities

- EAR – FHWA Exploratory Advanced Research Projects
  - GaTech on ACMs, includes OK State U., Corps of Engineers, TCG
  - UCLA, NIST on SCMs and ACMs
  - OPC Hydration Micro/Nano Chemistry & Models – Princeton & NIST
- Workshop ACM-ASR held last month at TFHRC, McLean, VA
- Cooperative Agreements – CRADAs … more later.
  - CeraTech
  - Solidia



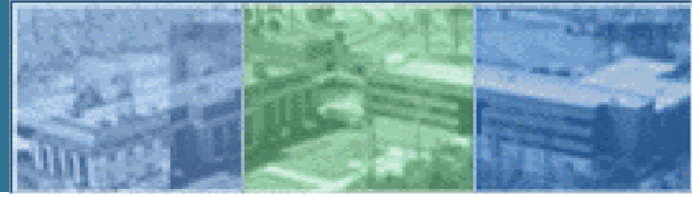
Cement Quality

- Demonstrate Strength with Project Binder Ratios & Conditions
- Chemistry or Consistency in Chemistry Batch to Batch
- Fineness (Mixture Rheology, Calorimetry)
- Do We Measure on Cement or Concrete?
  - Time of Set or Workability Period
  - Volume Change and Durability
  - Resistance to Aggressive Solutions and Actions in Service
  - Sulfates, De-icers, Acids, Alkalis, Temp. Extremes, Abrasion, Other?



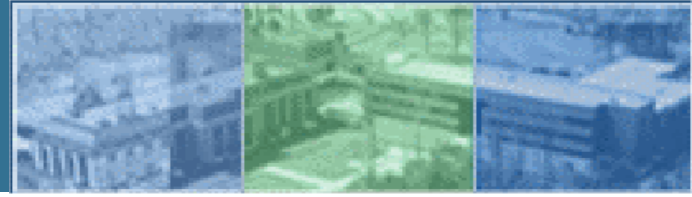
Concrete Quality

- Demonstrate Strength with Project Mixture and Conditions
- Placeability, Slump, Workability Period
- Air-Void Properties, if A/E is Needed
- Measure on Cement or Concrete?
  - Time of Set or Workability Period
  - Volume Change and Durability, Temp. Extremes, Abrasion, Other?
  - Resistance to Aggressive Solutions and Actions in Service
  - Sulfates, De-icers, Acids, Alkalis, Abrasion, Other?



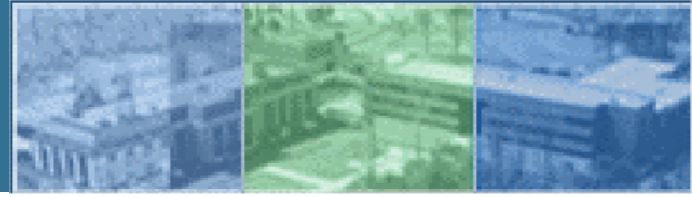
US Concrete Infrastructure Mixtures

- Mostly Contain Portland Cement, Type I, II (OPC)
  - With Added or Blended Supplementary Cementitious Material (SCM)
    - Fly Ash: Class C (Hi Ca) or Class F (Lo Ca); 10 – 40 %
    - Slag Cement (Ground Granulated Blast Furnace Slag); 35 – 60%
    - Silica Fume; 5 – 15%
    - Natural Pozzolans are of More Interest Now – *AASHTO Fly Ash Report*
- Ternary Blends of Cementitious Materials Used by Some



AASHTO & ASTM Cements & Harmonization

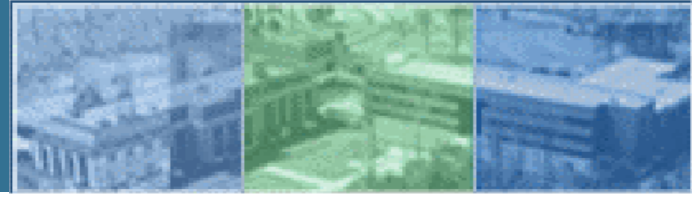
Cement	AASHTO	ASTM
Portland Cement (OPC)	M 85	C 150
Blended (Prescriptive)	M 240	C 595
Blended (Performance)	–	C 1157
Slag Cement (GGBFS)	M 302	C 989
Expansive Cement	–	C 845
Rapid Hardening (Performance)	–	C 1600



AASHTO & ASTM
Supplementary Cementitious Materials (SCMs)

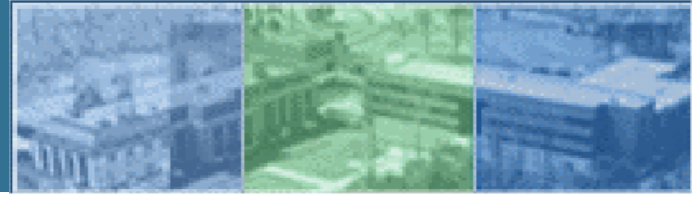
SCM	AASHTO	ASTM
Fly Ash / Natural Pozzolans	M 295	C 618
Silica Fume	M 307	C 1240
Blended SCMs	–	C 1697
High Reactivity Pozzolan*	M 321	–

*Amorphous silica such as metakaolin, rice hull ash, ultra-fine fly ash, and fume from ferrosilicon



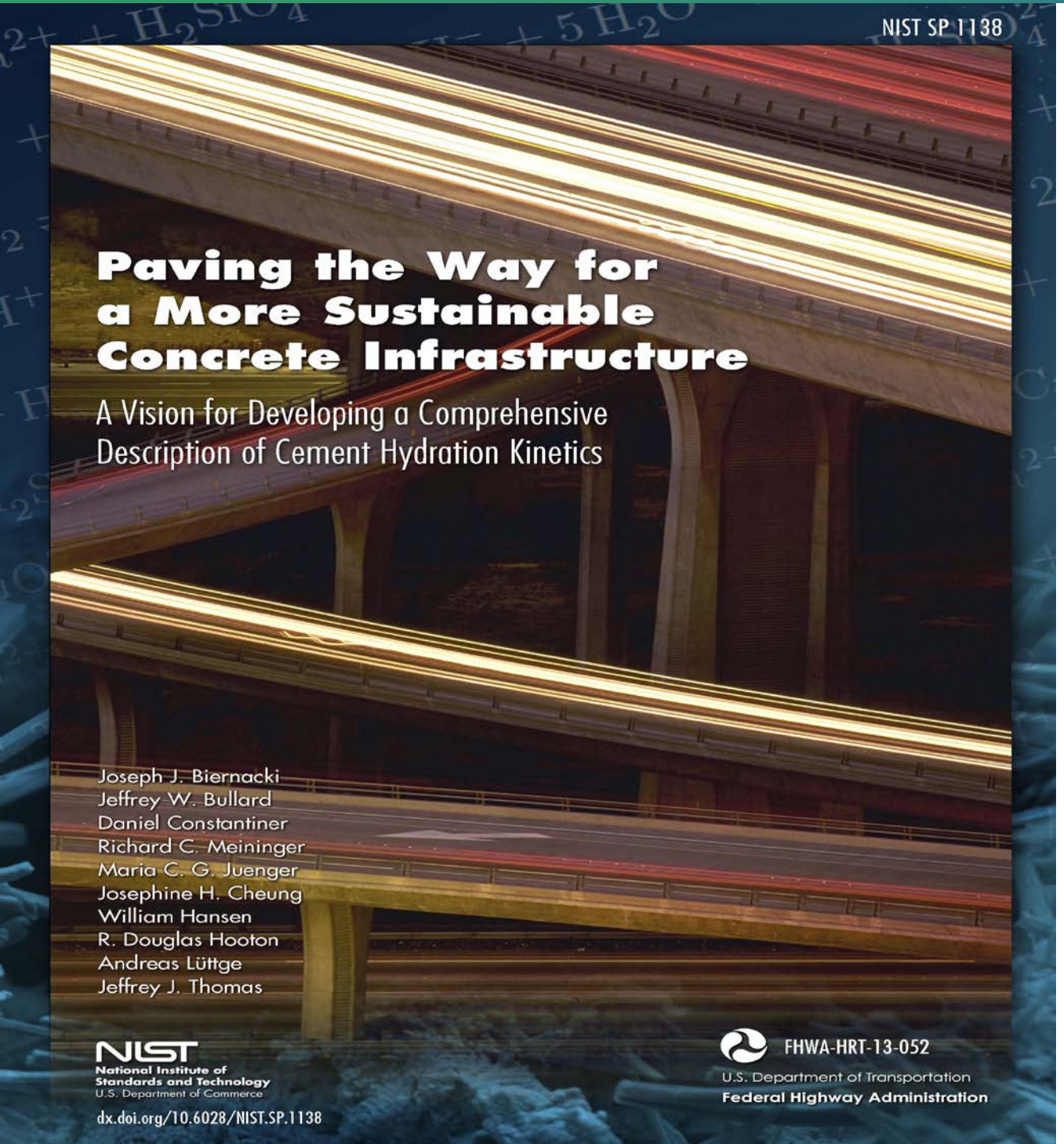
SCM Research in TFHRC Labs

- High Fly Ash Content / Ground Limestone (NIST)
- Rheology of Pastes & Mortars with SCMs
- Characterization / Optimization of Fly Ash
- Hydration Kinetics of Mixtures / Calorimetry
- Compatibility of Cementitious Materials & Admixtures
  - Incompatible Combinations of Concrete Materials; FHWA-HRT-06-080; Tech Brief FHWA-HRT-06-082



EAR Research Cementitious Projects

- High Volume Fly Ash (HVFA) Concrete
  - Purdue & Auburn Universities
  - NIST & National Ready Mixed Concrete Association
- Cementitious Composites with Carbon Tubes
  - Texas A&M University
- Hydration Modeling
  - NIST's Virtual Cement and Concrete Lab (VCCTL)
  - Princeton University, et al; Hydration Mechanisms
  - Hydration Research Roadmap *(NIST SP 1138) – One Chapter on ACMs – http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1138.pdf–*



NIST Special Publication 1138

Paving the Way for a More Sustainable Concrete Infrastructure

A Vision for Developing a Comprehensive Description of Cement Hydration Kinetics

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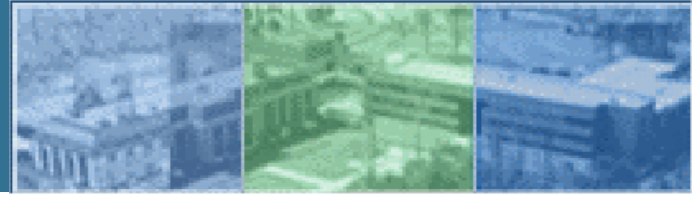
Patrick D. Gallagher, Under Secretary of Commerce for Standards and Technology and Director

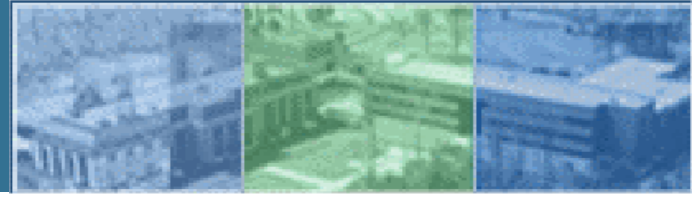


Transportation Pooled-Fund (TPF) Study

Properties of Ternary Mixtures – Lab & Field Structures

TPF-5(117) Materials Used in Combinations

- Cements – Type I, Type I/II, Type IS(20), Type IP
- Slag Cement – GGBFS 100, GGBFS 120
- Blended – Limestone
- Fly Ash – Class C, Class F
- Silica Fume
- Metakaolin



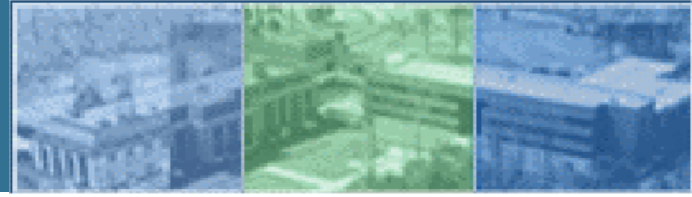
Alternative Cementitious Materials (ACMs)

- TFHRC Bi-Annual SCM/ACM Workshops
- Federal Agency Steering Committee on ACMs
- American Ceramic Society Cements Division
- Cooperative Research & Development Agreements (CRADAs)
  - Solidia Cement – Carbonation Process
  - CeraTech Cement – Class C Fly Ash Based
- EAR Research on ACMs with GaTech, et al Team

Federal Labs can do ***CRADAs*** with Industry
Cooperative Research And Development Agreements

The Conditions Include:

TFHRC does not directly or indirectly endorse any product or service … This is an evaluation by FHWA-TFHRC of new technologies for possible use in highway infrastructure. The collaborating party shall not in any way imply that this CRADA is an endorsement by TFHRC …



- Solidia Technologies® – http://solidiatech.com/ – "is a cement and concrete technology company with patented processes that sequester CO2 to produce sustainable cement and concrete products …"
  - Cement that Carbonates (Complete OPC replacement)
- CeraTech – http://www.ceratechinc.com/ – "… High Performance, Carbon Neutral Cement System that Replaces Portland Cement in the Production Of Concrete"
  - Hydraulic Class C Cement (Complete OPC replacement)

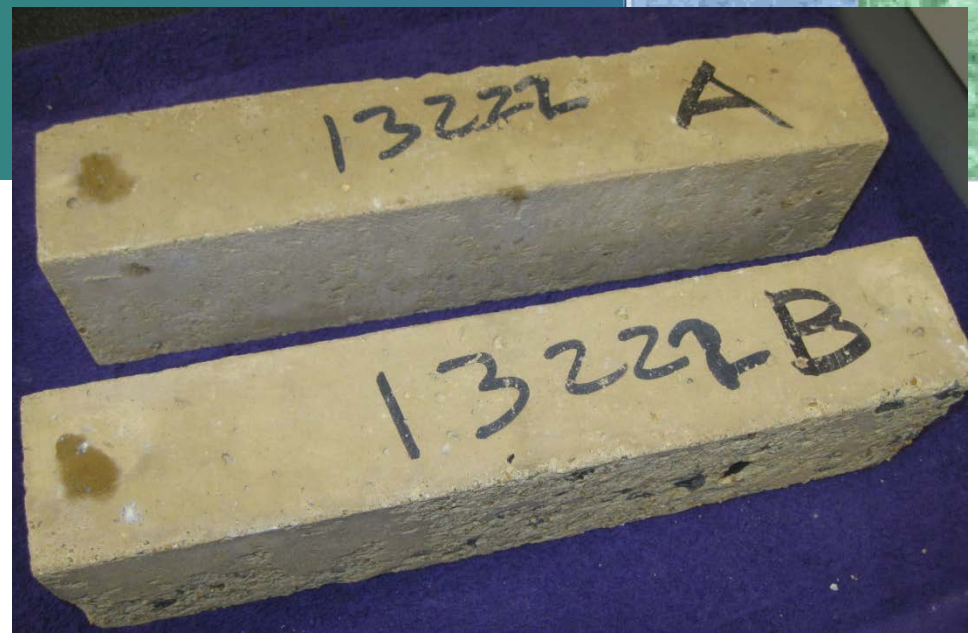
Solidia
Freezing & Thawing
3/4 in. MSA, A/E Concrete

Solidia Specimens for Evaluation

CeraTech Freezing & Thawing

Sample ID: 13222A Eirich Mixer	Air content (%)	Spacing factor (mm)	Specific Surface (mm-1)
LT	4.72	0.073	63.0
MP	5.05	0.072	61.4

Sample ID: 13221A Drum Mixer	Air content (%)	Spacing factor (mm)	Specific Surface (mm-1)
LT	5.08	0.137	34.3
MP	5.65	0.137	32.7



FYI – CeraTech Paving, Port of Savannah

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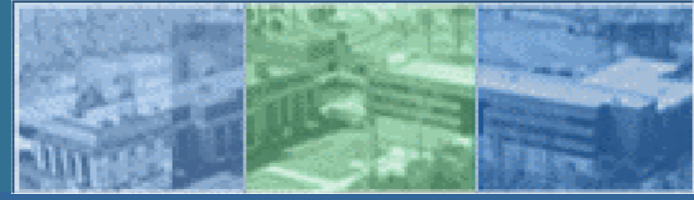
CeraTech Concrete Placement by Pump
Galveston Molten Sulfur Storage Facility

CeraTech Concrete Placement by Pump
Galveston Molten Sulfur Storage Facility

CeraTech Concrete Placement by Pump
Galveston Molten Sulfur Storage Facility

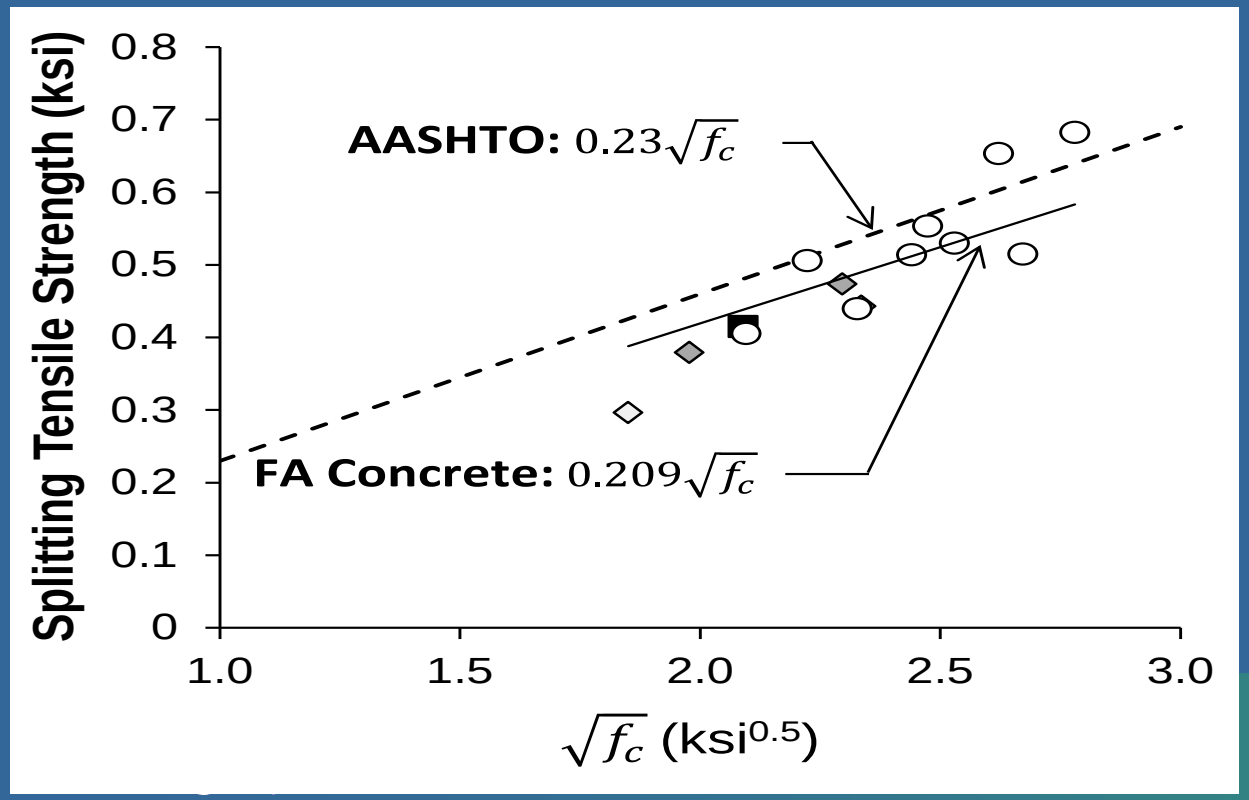


ACMs – Structural Concrete Research

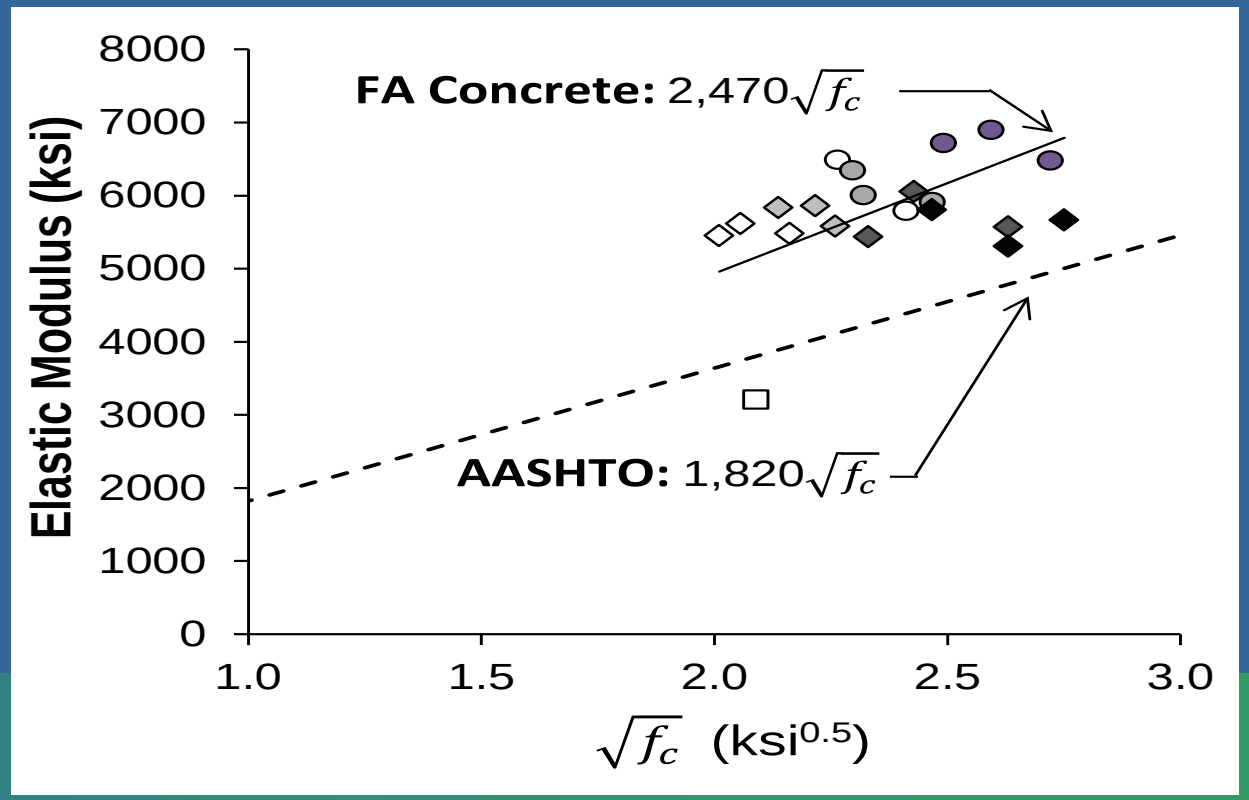
- Question: *What information is critical for structural design?*
- Multi-Part Test Plan Developed:
  - Mix Proportions & Basic Properties
  - Bond to Reinforcement and Stress Block Parameters
  - Creep & Shrinkage Testing
  - Full-Scale Testing of Structural Elements

Preliminary Results: $\sqrt{f'_c}$ - Relationships

Tensile Strength

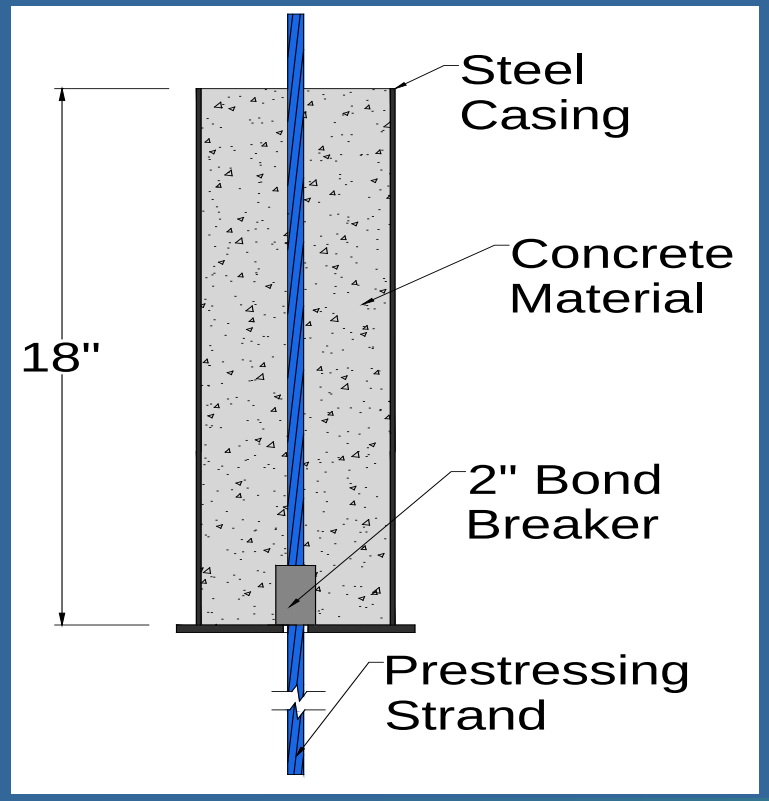


Elastic Modulus



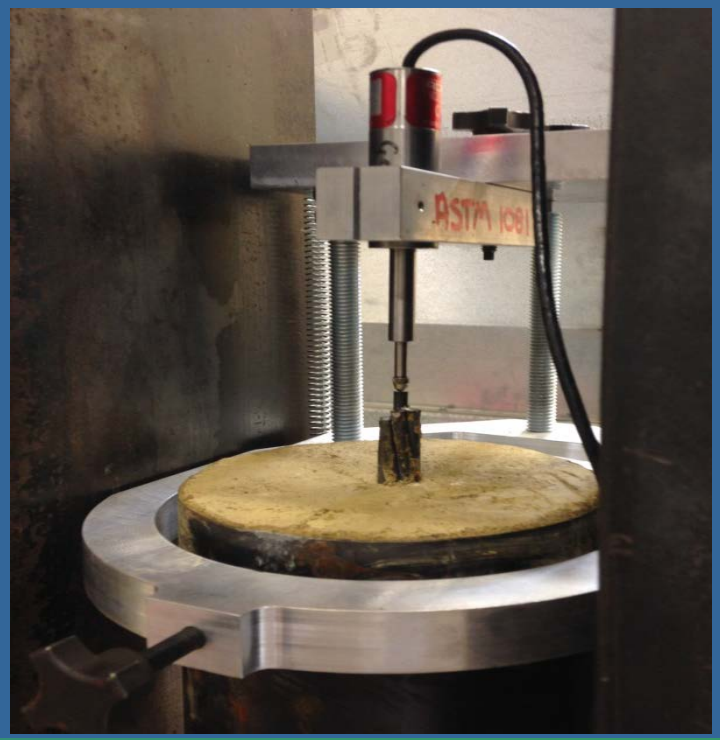
Prelim. Results: Bond to PS Strand (Mod. ASTM C1081)

Specimen



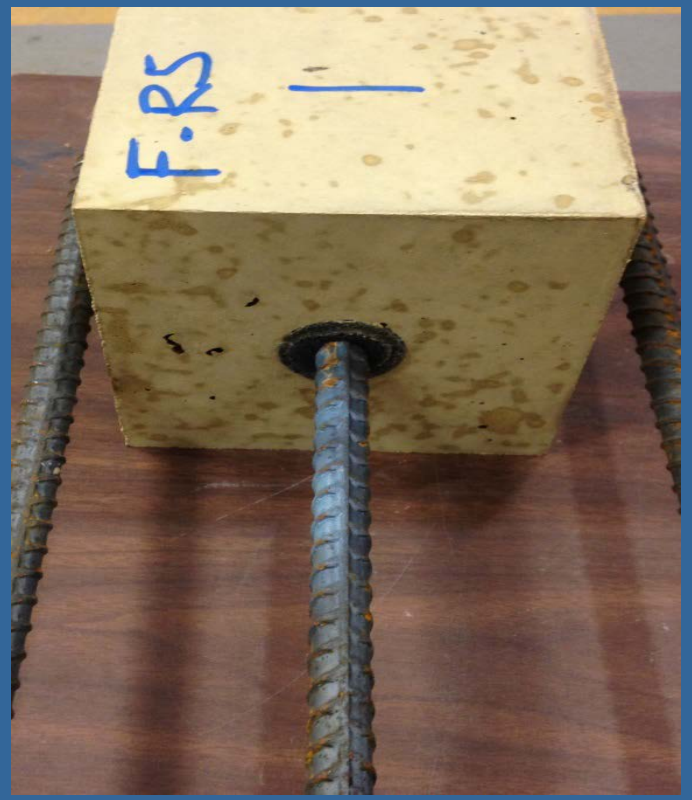
Test Config.

Slip Measurement

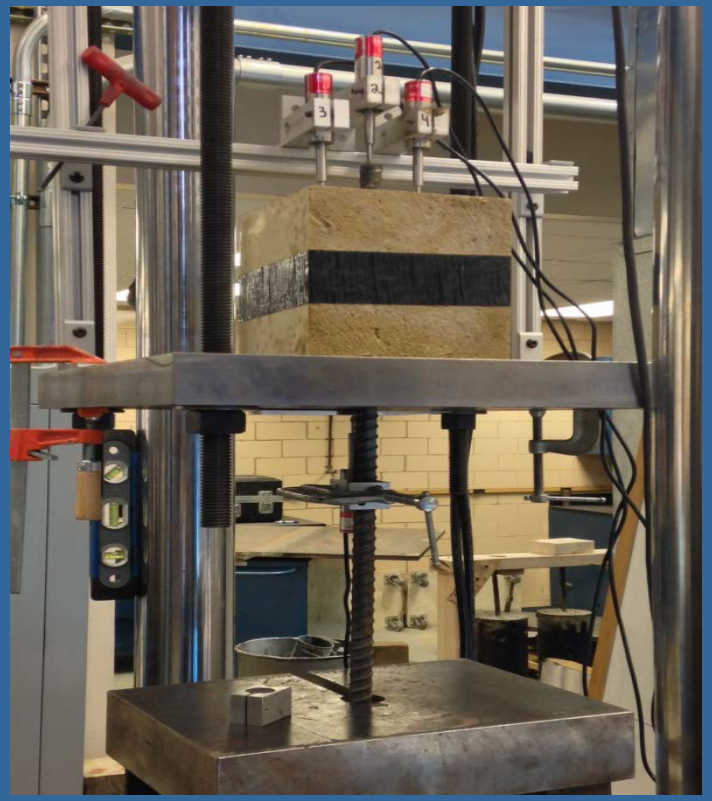


Prelim. Results: Bond to Rebar (RILEM)

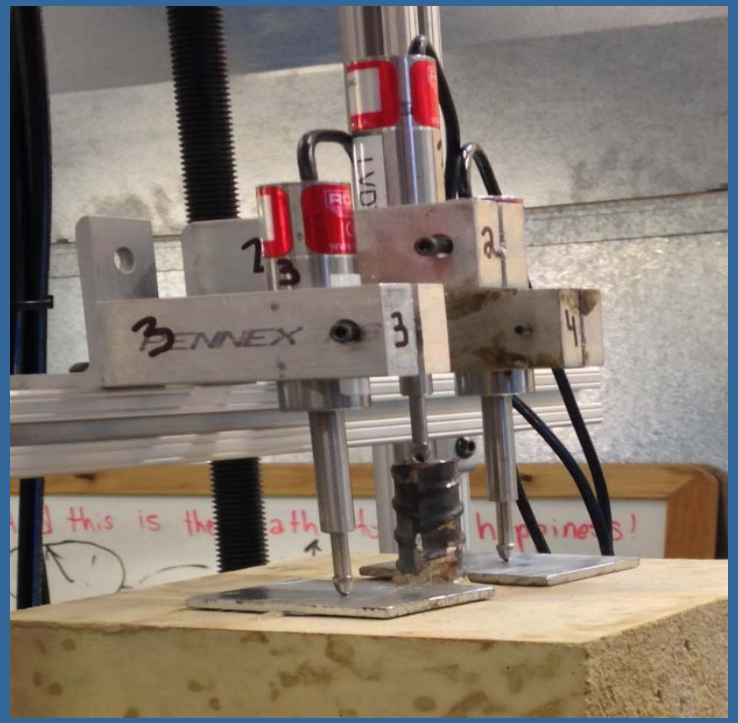
Specimen



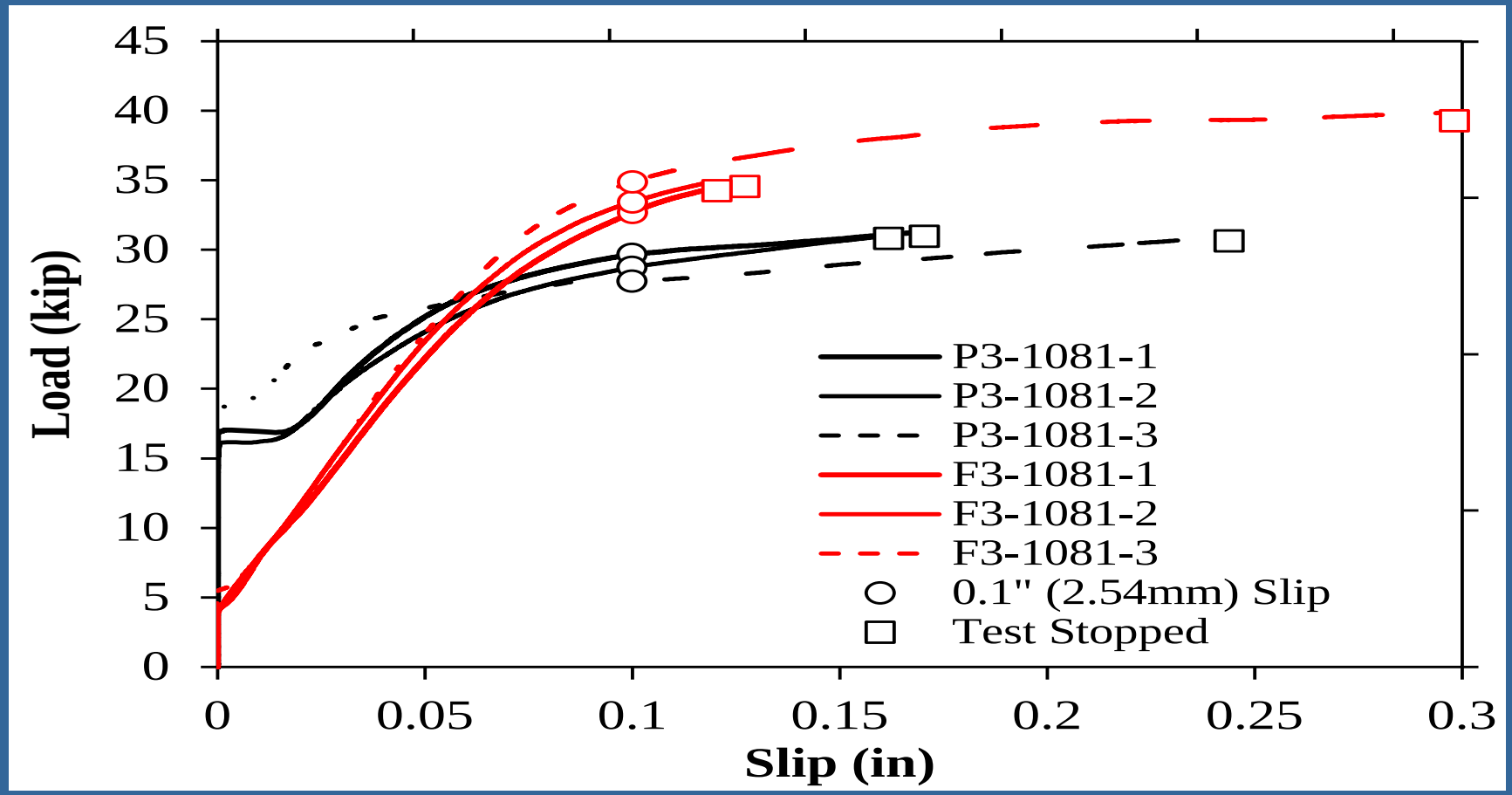
Test Config.



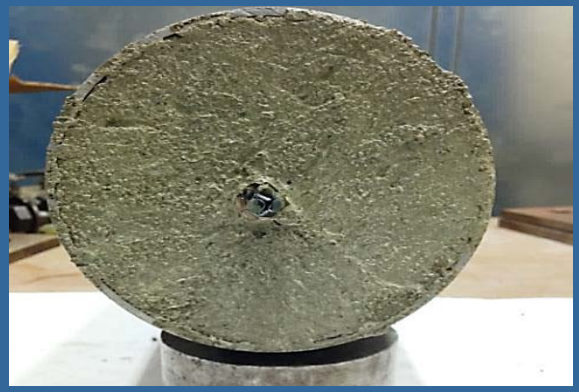
Slip Measurement



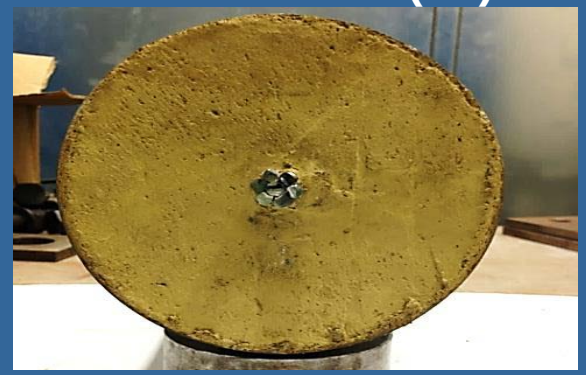
Prelim. Results: Bond to PS Strand (Mod. ASTM C1081)



OPC Concrete (P3)



FA Concrete (F3)



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Materials Team

Questions?

Discussion Topics – Some issues for a panel discussion:

- ACMs have been used for repairs
- Pros/cons of repair performance?
- Can they be scaled up for use as pavements and structures?
- Compatibility with PCC
- Constraints on aggregates?
- Durability
- Admixtures required
- Batching and mixing procedures
- Setting time, finishing
- Precast vs. cast-in-place

- Prestress and post-tension
- Availability
- Cost Projections if Used More?
- Specifications –toward performance
- Volume change and cracking; is it different from PCC?
- Structural properties
- Creep
- Corrosion of embedded steel
- Authoritative reference documents?
- How should ACI address ACMs?

TFHRC SCM/ACM/AAR Workshops

- Objectives: Collaborate/Exchange Information
  - Increased SCM/ACM Research on Performance
  - Sessions: Fly Ash & Alternative Cementitious Materials
  - Mitigate ASR
  - Is ACR really ASR?

- *Summary Available*