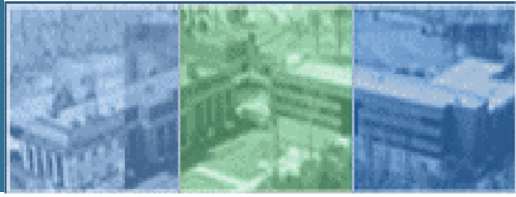

Federal Highway Administration

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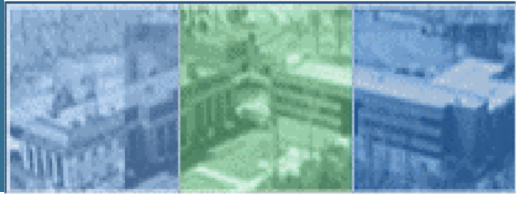
UNITED STATES OF AMERICA



FHWA Update –
Fly Ash in Highway Construction

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Office of Infrastructure R & D
Federal Highway Administration
US Department of Transportation

FHWA Concrete Research

In-House / Inter-Agency / Earmarks

Contracts / Cooperative Agreements

Turner-Fairbank
Highway Research
Center

- Pooled Fund Studies

Federal Highway
Administration

FHWA Organization Re: Concrete

- **Structures**
- FHWA HQ Washington, DC
- *Office of Bridge Technology*
- *FHWA Resource Center*
  - *High Performance Concrete*

- **Pavements**
- FHWA HQ Washington, DC
- *Office Pavement Technology*
- *FHWA Resource Center*
  - *Pavement / Materials*

- Structures – Research
- FHWA TFHRC McLean, VA
- *Office of Infrastructure R&D*
- -- Structures Lab
- -- NDE Lab
- -- GeoTech Lab
- -- Outdoor Labs
- -- Bridge
- -- Reinforced Earth

- Pavement – Research
- FHWA TFHRC McLean, VA
- *Office of Infrastructure R&D*
- -- Concrete Labs
- -- Mixing, Mech Prop, Creep
- -- CTE, Fz-Tw, Scaling
- -- Petrography
- -- Chemistry
- -- Outdoor ALF

Presently in Pavements and Structures SCMs Used & Often Required in Concrete

- Fly Ash Regulatory Situation
  - Comments to EPA by FHWA and AASHTO
- FHWA/FAA Research on Fly Ash/SCMs
- FHWA Workshop
  - Steps Research a New Fly Ash Specification
- FHWA Research at TFHRC and Outside
  - EAR - Exploratory Advanced Research Program
- FHWA Participation
  - NIST Virtual Cement and Concrete Lab (VCCTL)
  - Int'l Summit: Cement Hydration Kinetics & Modeling

Highway Concrete Challenges

- Less CO_2; Less Clinker; Sustainable
- Use Local Materials
- How Analyze / Approve Alt. Materials
- Mechanical / Strength Properties
- Resist Corrosion – Br. Decks, Pre-Stress
- Durability
  - Freeze-Thaw
  - Chemicals – Anti-Icing, Deicing, $MgCl_2$
  - ASR
  - Internal Sulfate Attack: Ettringite, DEF

Highway Concrete Challenges

- Getting New Materials on Projects
  - 50+ Agencies – How to Accelerate Adoption?
  - FHWA HQ, Div., Resource Center, Fed Lands
- Some Suggestions
  - Involve AASHTO Subcommittee on Materials
  - Promote ASTM / AASHTO Collaboration
  - NTPEP – National Transportation Product Evaluation Program – Involve State DOTs
  - SPEL – Special Products Evaluation List
    - Data from one State Shared with Others

FHWA Research and Deployment

Current

- ASR Mitigation and Gel Identification
- Freezing and Thawing, Air Distribution, AVA
- Coefficient of Thermal Expansion (CTE)
- Ultra High Performance Concrete Girders
- Reinforced Earth/Aggregate Bridge Abutments
- Permeability, Transport Properties, Corrosion
- Concrete Pavement – Texture, Friction, & Noise
- Fly Ash Properties and Specifications
- Ternary Cementitious Blend Mixtures (Pooled Fund)
- Mixture Optimization – Compass Software

Example of Cracking in San Antonio Bridge – Elements of this bridge structure showing signs of ASR include footings, columns, and bent caps. Cores have been taken from selected elements – ASR has been confirmed as a cause of distress, with future expansion still anticipated.

FHWA Research and Deployment

Future

- ASR Technology Implementation
- ASR Structure/Pavement Inventory
- ASR Research (Mechanism?, Expansion Remaining?)
- More Fly Ash Use in Concrete
- Lightweight Aggregate Bridges
- Internal Curing
- Link Mix Optimization with NIST VCCTL
- CP Mix Design, Proportioning, Analysis (Pavement)
- Pavement Surface (Abrasion, Texture)
- NDT Inspection, QC/QA, Internal Temp. & RH

Pavement / Structures Research Areas

- Pavement
  - Concrete Pavement – CP Road Map Res. Tracks
  - Asphalt Pavement
  - Aggregates for Pavement
  - ASR Research and Deployment
  - Coord. Earmarks & University Research Centers
  - Alternative Pavement Materials & Sustainability
  - Alternative Cementitious Materials
- Structures
  - Bridge of the Future
  - Ultra-High Performance Concrete
  - Lightweight Concrete
  - Other

Example Concrete - High Amounts of Class C Fly Ash

Activated Fly Ash Concrete with No Portland Cement in the Mixture

- Two Demo Lab Batches Baltimore
  - Rapid Set (30 Min)
  - Normal Set (90 Min)
- Concrete Pump Placement:
  - Molten Sulfur Flume Construction, Galveston, TX
- Mostly Class C Fly Ash (Cementitious Material)

Demo Lab Batches Baltimore

- Rapid Set (30 Min)
- Set Time 35 Min
- Slump 4.5 in.
- A/E 6.0% Total Air
- 4 x 8 in. Cylinders
  - 3, 4 Hours
  - 1,3,7,28 Days
  - 3 Months
  - Static Mod of E
  - Poissons Ratio
  - CTE

- Normal Set (90 Min)
- Set Time 85 Min.
- Slump 7.0 in.
- A/E 6.5% Total Air
- 4 x 8 in. Cylinders
  - 4 Hours
  - 1,3,7,28 Days
  - 3 Months
  - Static Mod of E
  - Poissons Ratio
  - CTE


Jackson



Jackson

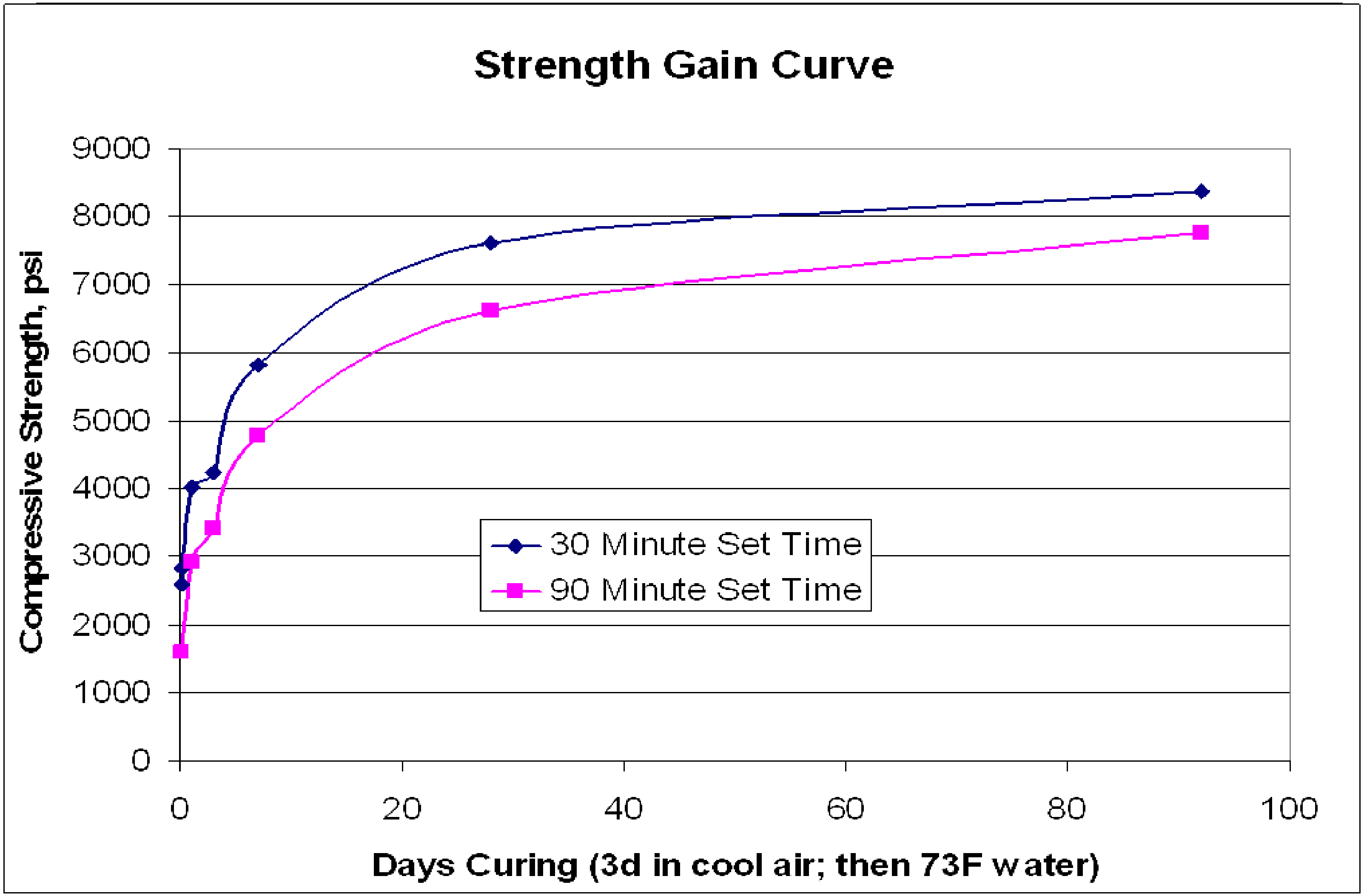



Demo Lab Batches Baltimore

- Rapid Set (30 Min)
- 3 Hr – 2600 psi
- 4 Hr – 2840 psi
- 1 Day – 4030 psi
- 3 Days – 4240 psi
- 7 Days – 5830 psi
- 28 Days – 7610 psi
- 1 Month – 8370 psi
- E – 5,740,000 psi
- CTE – 9.8 με/°C

- Normal Set (90 Min)
- 3 Hr – N/A
- 4 Hr – 1610 psi
- 1 Day – 2930 psi
- 3 Days – 3410 psi
- 7 Days – 4790 psi
- 28 Days – 6620 psi
- 1 Month – 7770 psi
- E – 5,400,000 psi
- CTE – 9.8 με/°C

Demo Lab Batches Baltimore



Redi Max Concrete Pump Placement: Molten Sulfur Flume Construction, Galveston, TX

- Normal Concrete “Dry Batch” Plant
- Class C Fly Ash in “Cement” Silo
- Granite Crushed Stone Coarse Aggregate
- Natural Sand Fine Aggregate
- Some bagged Class F Fly Ash
- Activation Chemicals: Used Admix Pump
- Thoroughly Mixed Concrete in Truck Mixer – Water Added Thru Truck System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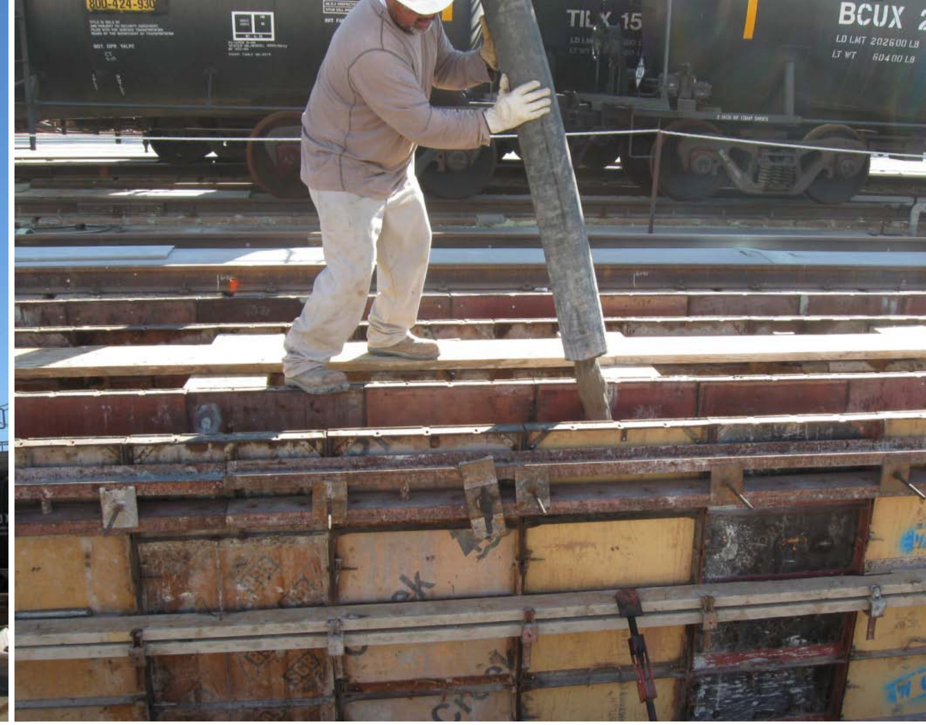
IBC REMANUFACTURED BY
NCG
FIREROK
High Temperature Concrete
Liquid Activator
KELSON CONCRETE
GALVESTON, TX



GOLDEN ARROW
SANY
318


TILX 15
LD LMT 202600 LB
LT WT 60400 LB






TFHRC Concrete Lab Example Trial Batches 50% Class F Fly Ash Concrete for PCCP

- All Portland Cement
- Slump 1.5 in.
- A/E 6% Total Air
- 7 Days – 3990 psi
- 28 Days – 5190 psi
- 3 Months – 5710 psi

- 50% Class F Fly Ash

  (Processed Fly Ash)
- Slump 1.5 in.
- A/E 6% Total Air
- 7 Days – 3900 psi
- 28 Days – 4550 psi
- 3 Months – 5400 psi

Example Fly Ash Beneficiation at Brandon Shores Power Plant Maryland

Fly Ash Feed Silo to Separation Equipment –

Brandon Shores Power Station – Maryland

Site Generation Information: Two stacks, each 700 ft high

- Brandon Shores produces 600,000 tons of fly ash/year.
- Most formerly used as structural fill (Brandon Woods Commercial Park)
- Unit 1 on line 1984; Unit 2 on line 1991
- Units 1 &2 are identical units, each 690 MW gross; **Capacity:**1,296 MW
- Selective Catalytic Reduction (SCR) added 1999 at cost of $100 million
- 90% reduction in NOx, May to Oct, at a cost of about 4% plant efficiency
- Plant also has overfire air and low NOx burners
- Hot side ES precipitator in front of SCR

Major Fuel Type:

- Coal, used at 250 tons per hour (5-6000 ton per typical day)
- All coal is received by 7000 ton capacity barges (shared with Wagner)
- There is normally a 300,000 ton storage pile (30 day backup)
- 0.7% Sulfur coal is used to avoid a need for scrubbers

Constellation Energy is installing wet scrubbers after fly ash removal

- Constellation Energy is installing flue gas desulfurization (FGD) emissions controls (also called "wet scrubbers") on Brandon Shores power plant. The scrubbers will reduce the plant's sulfur dioxide (SO_2) emissions by an estimated 95 percent and existing mercury emissions by 90 percent.

Separation Technology Equipment

Separation Technology QC Lab

Fly Ash – Hi Carbon : Feed : Product

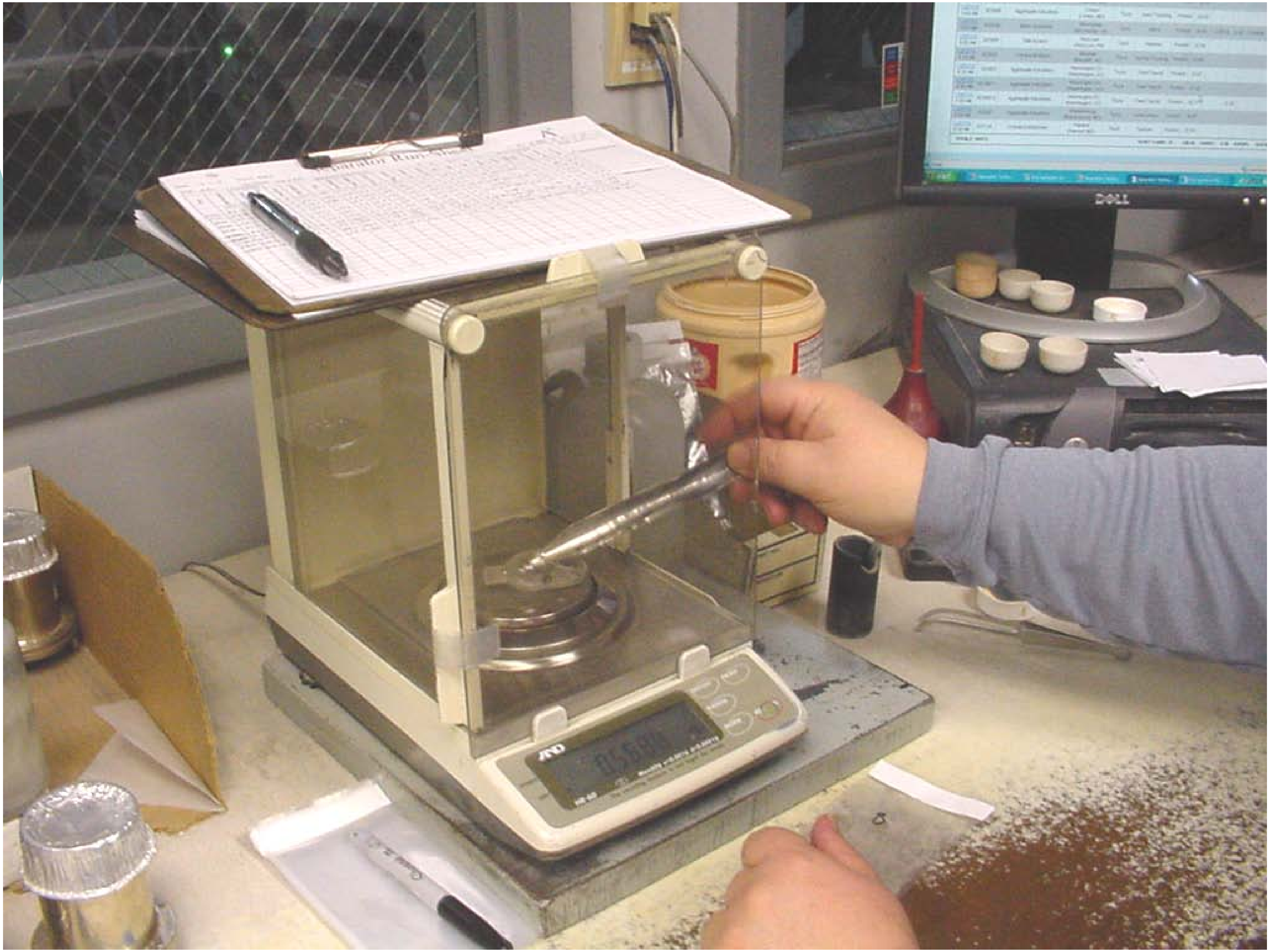
Fly Ash – Hi Carbon : Feed : Product

Fly Ash Product Storage Dome

Fly Ash Truck Scales Load Out

Loss On Ignition (LOI) – QC Furnace at 750 C

Foam Index Test – Steps



Foam Index Test – Steps

Foam Index Test – Steps

Foam Index Test – Steps

Fly Ash Samples Held for Troubleshooting

- Total Silica, Alumina, Iron – 92.3 %
  - Silicon Dioxide – 60.2 %
  - Aluminum Oxide – 29.0 %
  - Iron Oxide – 3.1 %
  - Calcium Oxide – 0.6 %
  - Sulfur Trioxide – 0.0 %
  - Moisture Content – 0.0 %
  - Loss on Ignition – 1.2 %
- Avail. Alkalis (as Na2O) – 0.4 %
  - Sodium Oxide – 0.06 %
  - Potassium Oxide – 0.56 %
- Retained on # 325 Sieve – 20.9%
- Density Mg / cu. m – 2.13 *(Specific Gravity)*

Class F Fly Ash Product

Strength Results: Concrete Paving Mixture (1.5 in. Slump and 6% Entrained Air)

	100 % Port. Cement		*50-50 Class F Fly Ash & Cem*		
Sample ID	9065C	9065D	9066C	9066D	
Diameter / In	4.00	3.99	4.03	4.03	
Length / In	7.89	7.86	7.89	7.94	
Load / lb	66550	63600	57460	58610	
Area, sq. in.	12.57	12.50	12.76	12.76	
Comp. Strength/PSI	5296	5087	4505	4595	% of 100% Cem
28-day Strength Avg.		*5191*		*4550*	*87.6*
Sample ID	9065A	9065B	9066A	9066B	
Diameter / In	4.00	4.02	4.02	4.02	
Length / In	7.86	7.85	7.86	7.88	
Load / lb	50540	50200	50380	48720	
Area, sq. in.	12.57	12.69	12.69	12.69	
Comp. Strength/PSI	4022	3955	3969	3839	% of 100% Cem
7-day Strength Avg.		*3988*		*3904*	*97.9*

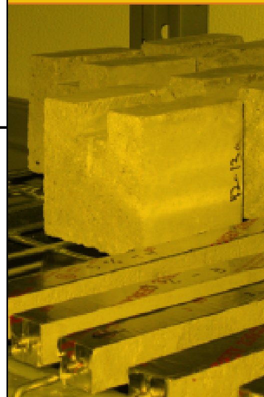
EAR Exploratory Advanced Research

- **Greatly Increased Use of Fly Ash in Hydraulic Cement Concrete (HCC) for Pavement Layers and Transportation Structures**
- **Research Partners:**
  - **Purdue University**
  - **Auburn University**
  - **NIST**
  - **NRMCA**
  - **FHWA**

Benefits of High Volume Fly Ash

New Concrete Mixtures Provide Financial, Environmental, and Performance Gains

Exploratory Advanced Research . . . Next Generation Transportation Solutions



High volume fly ash (HVFA) concrete mixtures offer many benefits, including reduced cost, reduced energy content, enhanced environmental sustainability, and improved long-term performance. The aim of "Greatly Increased Use of Fly Ash in Hydraulic Cement Concrete (HCC) for Pavement Layers and Transportation Structures," an Exploratory Advanced Research (EAR) Program project, is to identify innovative methods to overcome existing barriers to use, and work towards the increased use of HVFA in pavements and transportation structures. The 24-month project, part of a Federal Highway Administration (FHWA) initiative, is being conducted by Purdue University in partnership with Auburn University, the National Institute of Standards and Technology, and the National Ready Mixed Concrete Association.

Obstacles to HVFA Use

Many producers and transportation agencies aim to increase the use of fly ash in the transportation infrastructure—however, several barriers exist to implementing new mixtures. A particular concern of many practitioners is the difficulty of predicting strength gain in full-scale structures. The project addresses this problem through the use of temperature management software and the development of a database with analytical prediction tools. In addition, agencies and contractors worry about potential incompatibilities between the fly ash, admixtures, and cement. To overcome this, the project team is developing screening procedures to identify the influence and properties of residual carbon on the rate of admixture absorption. Once all challenges are overcome, innovative strategies such as fly ash treatment, timing and rate of admixture addition, and prescreening of components for optimal performance can be implemented to improve the response of the overall system.

Moving Forward

The conventional approach to using fly ash has relied on the establishment of strict limits on the maximum amount of fly ash and the times of year that fly ash can be used in construction. Conventional applications also have set limits on the composition of the fly ash to enable the fly-ash-cement system to be treated the same way conventional portland cement has been treated in concrete. This project moves in a new direction by proposing innovative solutions to the use of fly ash in mixture proportioning. Fly ash is not used on a prescription basis, but on a performance basis—so that more fly ash can be used in concrete, and less will go to a landfill. New design methodologies are needed to predict strength, and new strategies to overcome issues associated with HVFA use. One example of innovation is the team's work with new internal curing technologies, with the intention of efficiently supplying water for hydration directly inside the concrete after placement. Another area of innovation is the use of low temperature calorimetry to determine the length of curing needed to ensure that concrete can ultimately be exposed to stresses brought on by freezing and thawing.

Concrete Solutions

The project kicked off with a literature review and consideration of the commercial, specification, and quality assurance impacts associated with the use of HVFA. The research and innovation phase of

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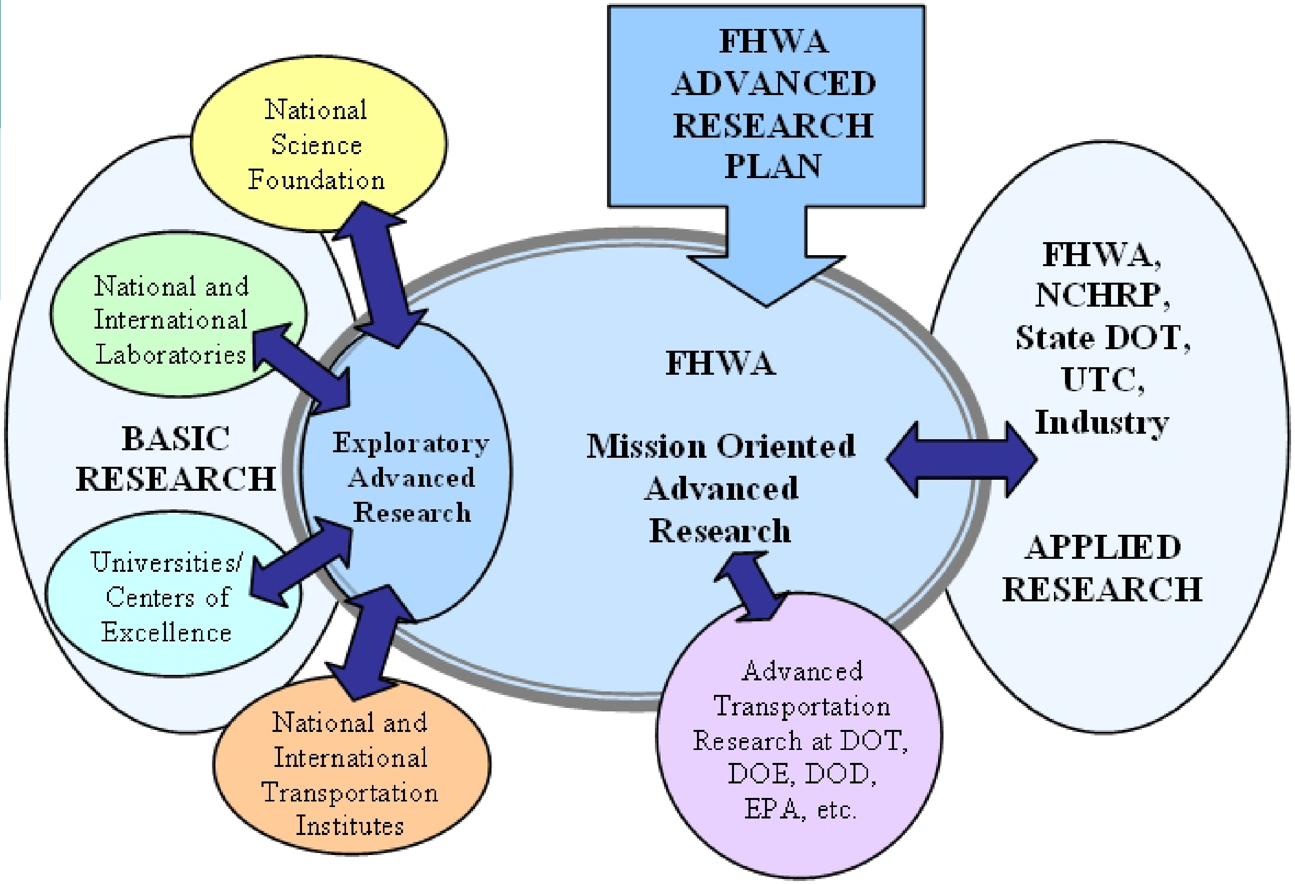
Research Ecology

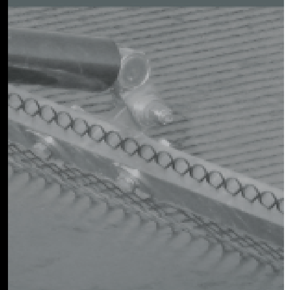


EAR Focus Areas

- Integrating highway system concepts
- Nanoscale research
- Human behavior and Travel Choices
- New technology and advanced policies for energy and resource conservation
- Information sciences
- Breakthrough concepts in material science
- Technology for assessing performance

EXPLORATORY ADVANCED RESEARCH

Breakthrough Ideas for Highway Research



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Exploring Cement Hydration Kinetics

International Summit on Cement Hydration Kinetics and Modeling

THE QUEST TO identify the underlying mechanisms that control cement hydration continues to be a challenge for modern materials science but has the potential to alter the fabric of constructed infrastructure for the global benefit of all. In 2009, a workshop supported by the Federal Highway Administration (FHWA), the National Science Foundation and other participating partners*, the International Summit on Cement Hydration Kinetics and Modeling, examined various aspects of cement hydration. The Summit was followed by an August 2010 Web conference to report on progress since the summit, and the drafting of an industry hydration roadmap.

Cement Hydration

Proportioning and placing portland cement concrete is performed thousands of times each day as the most-used building material on Earth. This process is unique in that the final product, a complex composite made from aggregate, water, other additives, and portland cement, is formulated on demand and batched and delivered in a plastic and unhardened state at the point of use. However, there are many common problems that can develop in the field, most associated with hydration, the chemical reaction that transforms the anhydrous cement into a hydrated binder that provides strength and durability to concrete.

Shrinkage and related cracking is one issue, resulting from autogenous volume change due to hydration and later-age drying after the curing period. Serious expansion and cracking can also take place in concrete when a secondary process causes an alkali silica reaction and expansive gel formation. Other problems can include adverse interactions between components, which can have unexpected effects on hydration and associated workability, setting time, and strength gain.

Industry Knowledge

A lack of knowledge about hydration processes makes improving, predicting, and controlling the performance of portland cement concrete a difficult task, accomplished today by trial-and-error experimentation combined with the experience of engineers, technologists, contractors, and producers. Developed under a program sponsored by FHWA, High Performance Concrete Paving (HIPERPAV) software is now used to analyze the early age behavior of concrete. However, with the exception of the efforts of the Virtual Cement and Concrete Testing Laboratory consortium, managed by National Institute of Standards and Technology, there has been a general lack of resource organization and dissemination of tools for modeling cement hydration in the United States. Although a number of isolated studies have looked at various aspects of hydration, until the 2009 International Summit there had been no industry-wide focal point and support for large-scale discussion.

Improving Capabilities

"We aim to facilitate interest in hydration modeling and discussion about the next steps in advanced cementitious systems research," says Richard Meininger at FHWA. "The recent Web conference was a valuable opportunity to continue discussions from the Summit. We were able to examine why ongoing research is important, how hydration modeling can be effective in improving cement and concrete products, and its performance in sustaining the transportation system through improved industrial, construction, and repair processes."

Advanced R & D – Modeling Innovation

- **NIST VCCTL – Members Include FHWA**
- **FHWA, NIST Rheology Research**
- **Hydration Summit (TN Tech; Laval U.)**
  - **Group Reports in *Cement & Concrete Research***
  - **Hydration Research Roadmap**
- **Collaboration**
  - **FHWA; Other DOT Agencies**
  - **NIST**
  - **TN Tech**
  - **MIT Sustainability Hub; NRMCA; PCA**

For more information:

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