MCTC

FHWA Mobile Concrete Technology Center

Semi-Adiabatic Calorimetry for Mixture Design and Quality Control

U.S. Department of Transportation
Federal Highway Administration

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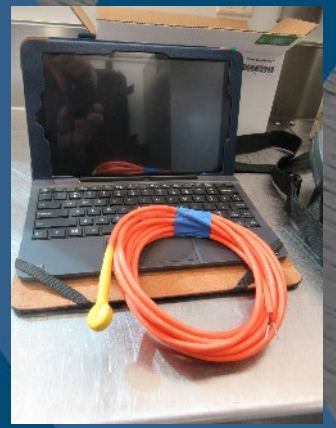
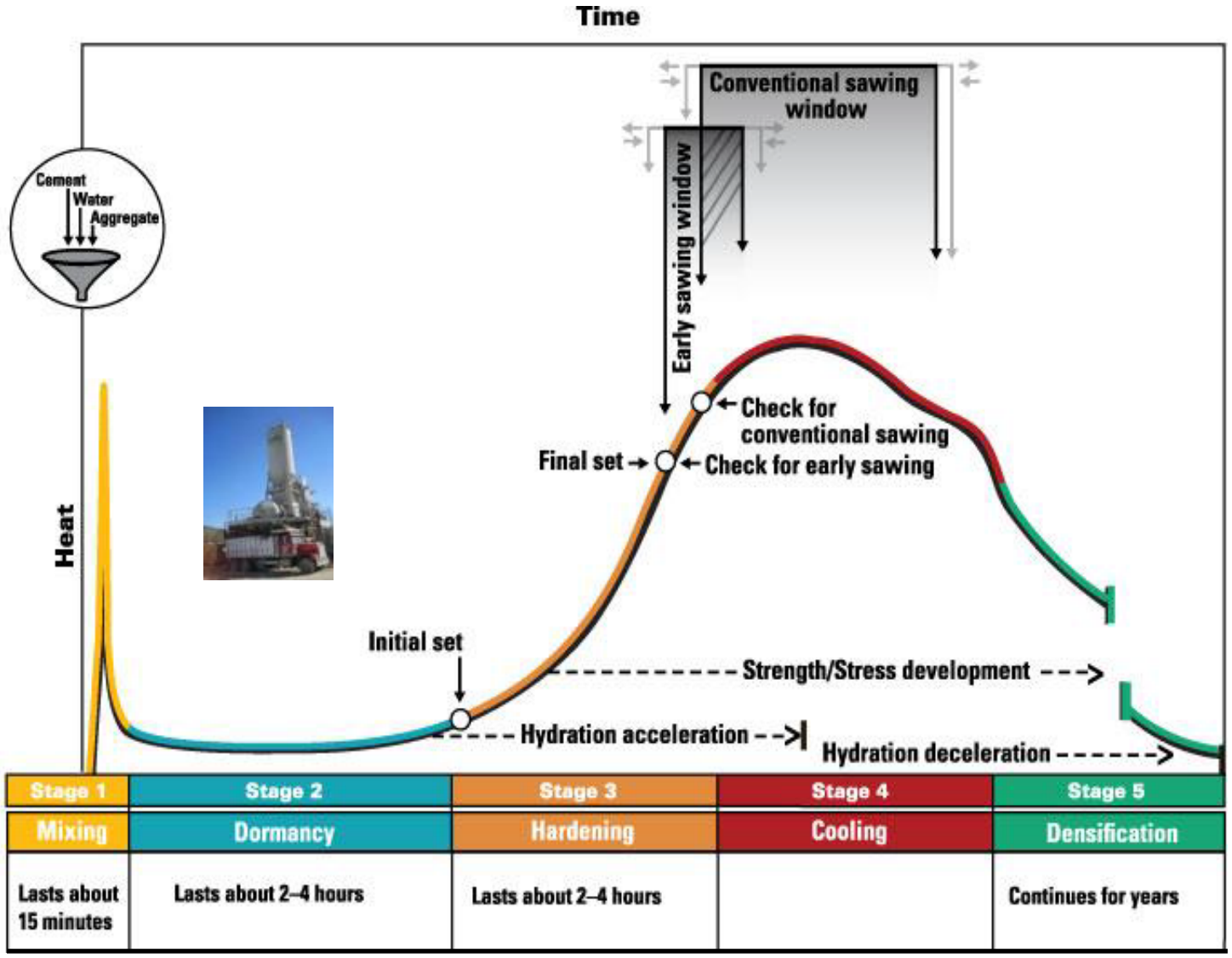
Innovative Technologies / Tests



Material Testing

Construction

Cement Chemistry



No simple REAL-TIME test

to capture heat of hydration during production

IMCP Manual

Heat of Hydration / Heat Signature – How to capture?

- **Isothermal Calorimeter**
  - Research oriented
  - More accurate
  - Expensive

Isothermal Calorimeter

- **Semi-Adiabatic Calorimeter**
  - Rugged and simple to use
  - Research and production use
  - Relatively inexpensive
  - Battery powered and portable

ASTM C1753: Standard Practice for Evaluating Early Hydration of Hydraulic Cementitious Mixtures Using Thermal Measurements

Semi-Adiabatic Calorimeter – Heat Signature

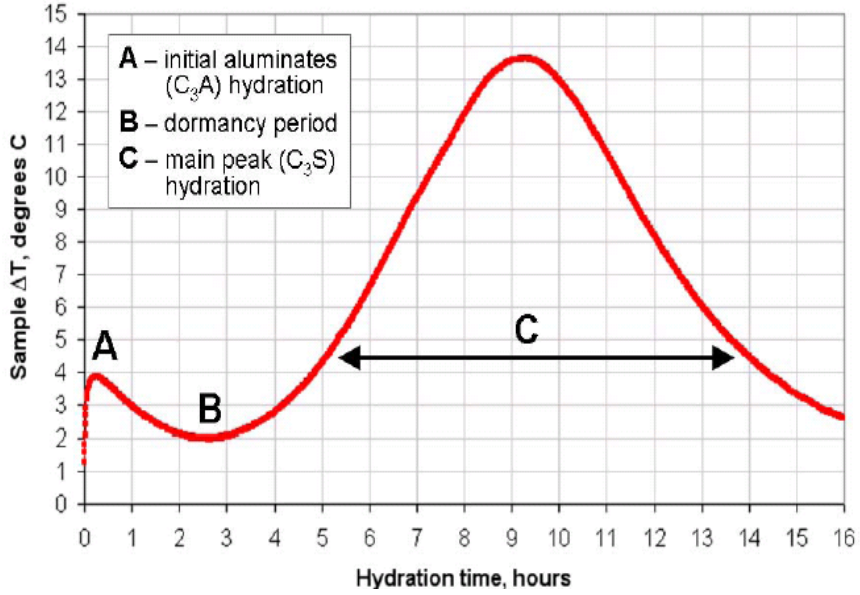
➢ **Procedure is simple:**

1. Cast a standard cylinder
2. Place it in the calorimeter
3. Shut the lid

Heat Signature (Calorimetry)

Indicator / Monitor

- Cementitious system
- Strength development
- Time of set
- Sawing window
- Uniformity



Uses – During Mixture Design

- Optimize mixture materials and proportions
- Identify adverse interactions (Incompatibilities)
- Compare competitive materials
- Troubleshoot field problems

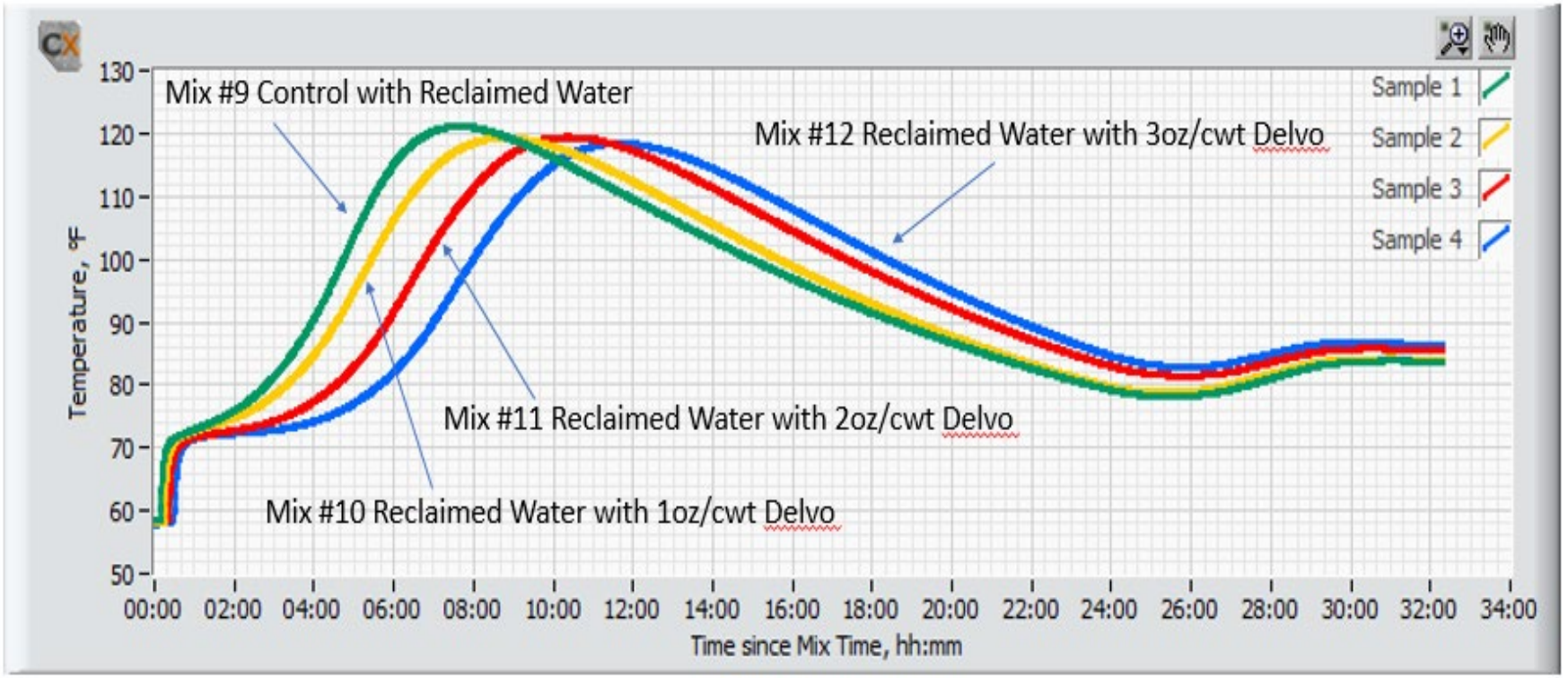
Standard 4 X 8 or 3 X 6 cylinders

Semi-Adiabatic Calorimeter

➢Mixture Design Example

➢Mixture with Varying Dosage of Same Admixture

Easy to see the linear response to increase in retarder dosage



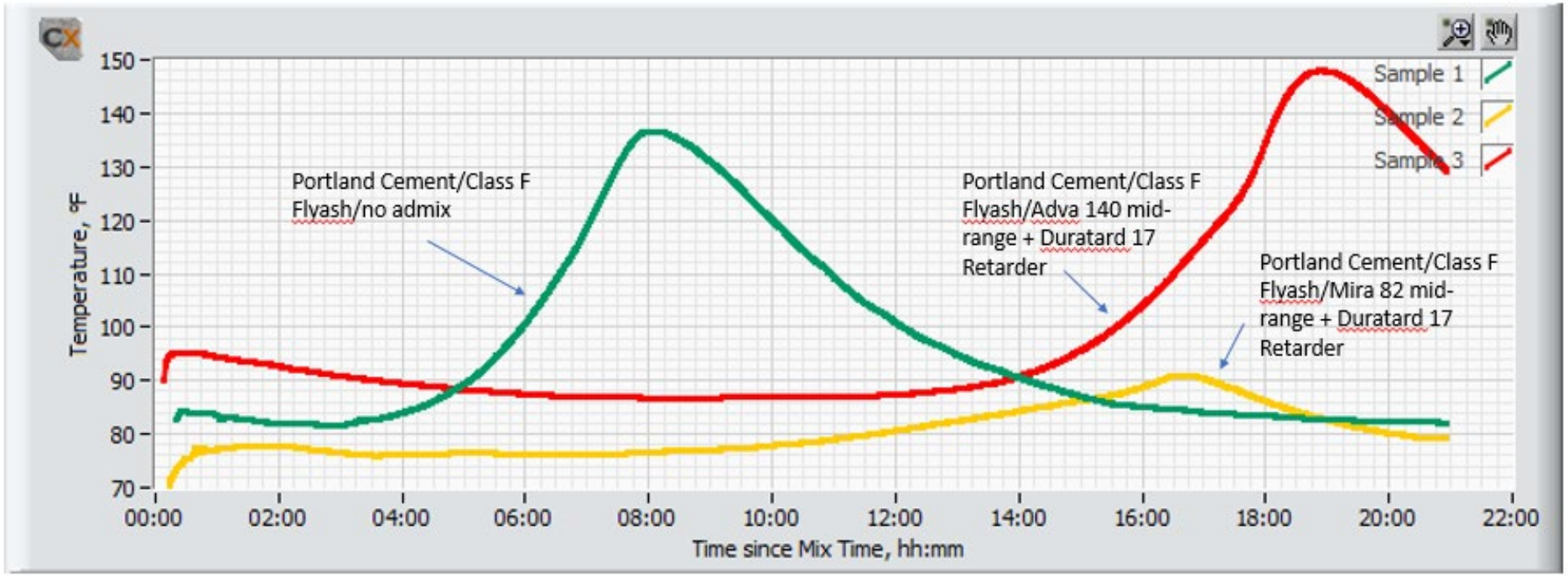
Data Source: Calmetrix

Semi-Adiabatic Calorimeter

➢Mixture Design Example

➢Cement-Admix Incompatibility

Fly ash without admixtures: OK. Flys ash with admixtures => Excess retardation with Adva MRWR
Total incompatibility with Mira 82 MRWR – kills the reaction



Data Source: Calmetrix

Semi-Adiabatic Calorimeter

- **Mixture Design Example**
  - SCM dosage based on initial set time

Data Source: Calmetrix

Mixture Consistency

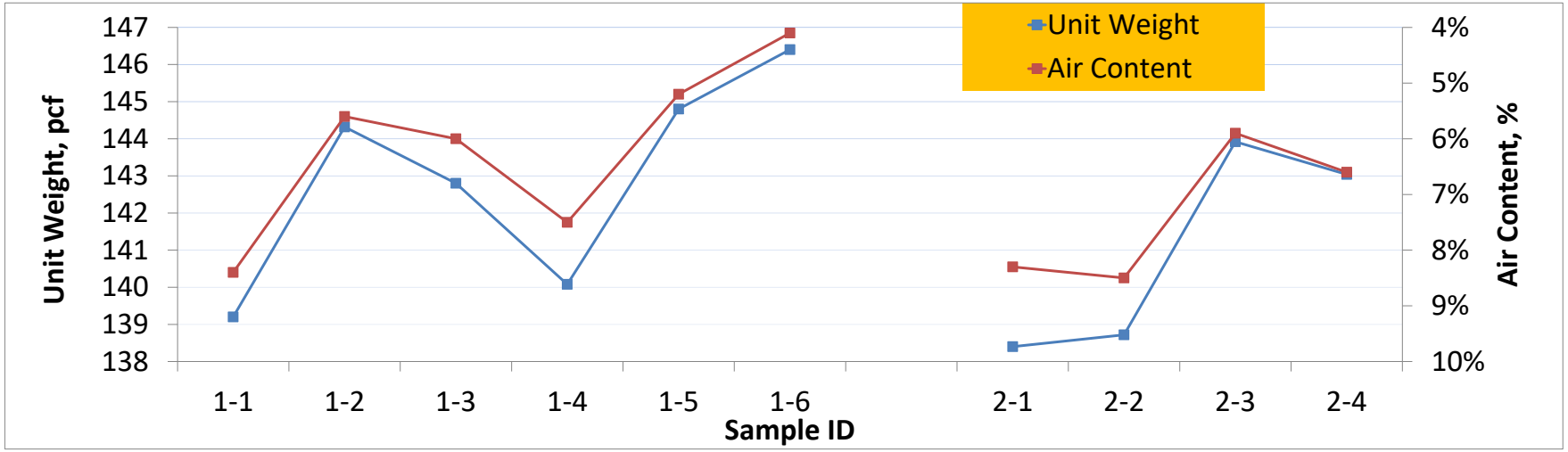
- **Modern Definition of Quality**
  - **Quality is inversely proportional to variability**

- **Traditional Test**
  - **Unit Weight**
    - Weight / Volumetric Changes

- **New Test**
  - **Semi-Adiabatic Calorimeter**
    - Chemical Changes

Mixture Consistency

- **Unit Weight**
  - **Uniformity (Weight and Volumetric Changes)**
    - Batching tolerances
  - **Air Content, Water**
  - **Sample and easy to run**
  - **AASHTO T121**



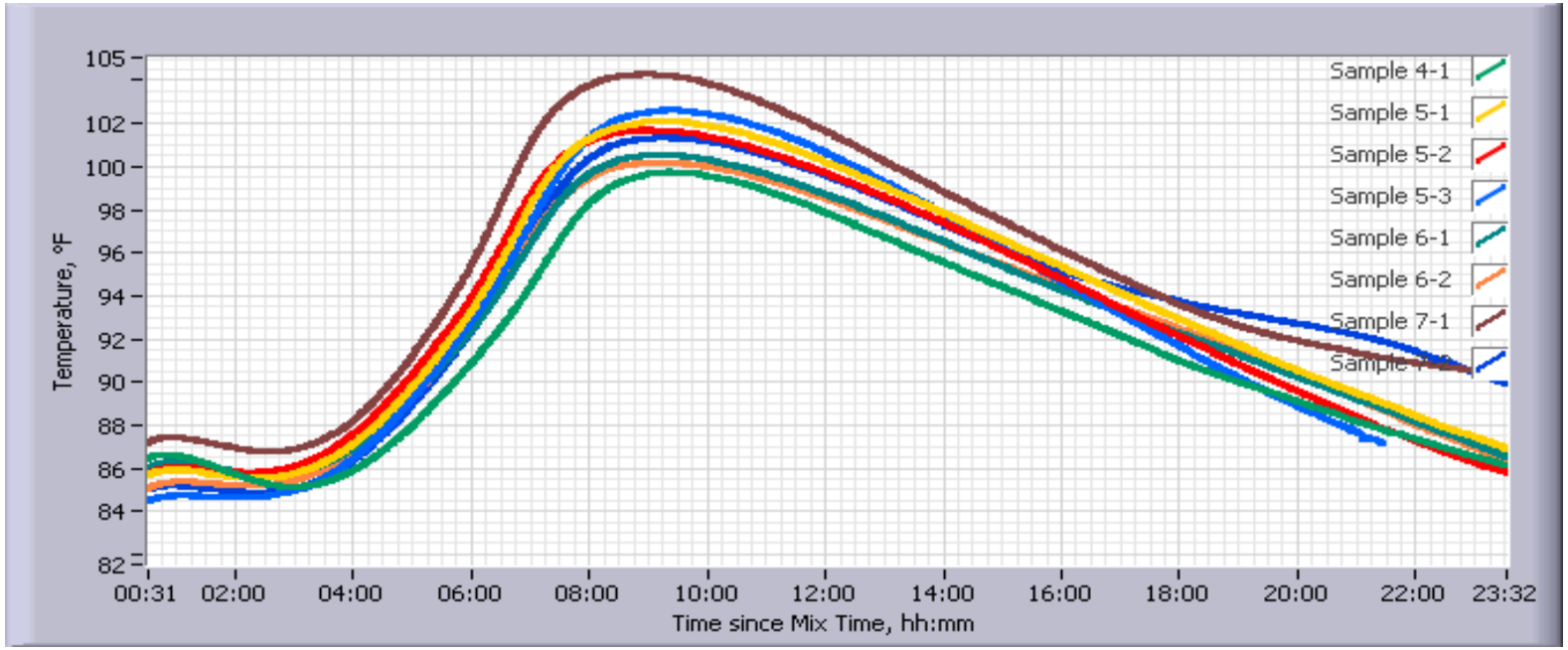
Data Source: MCTC

Mixture Consistency

Production

Consistent Heat Signature Curves

- Same overall shape
- Similar upward slope in the ramp up to main peak
- Paek temperature within a few degrees at most



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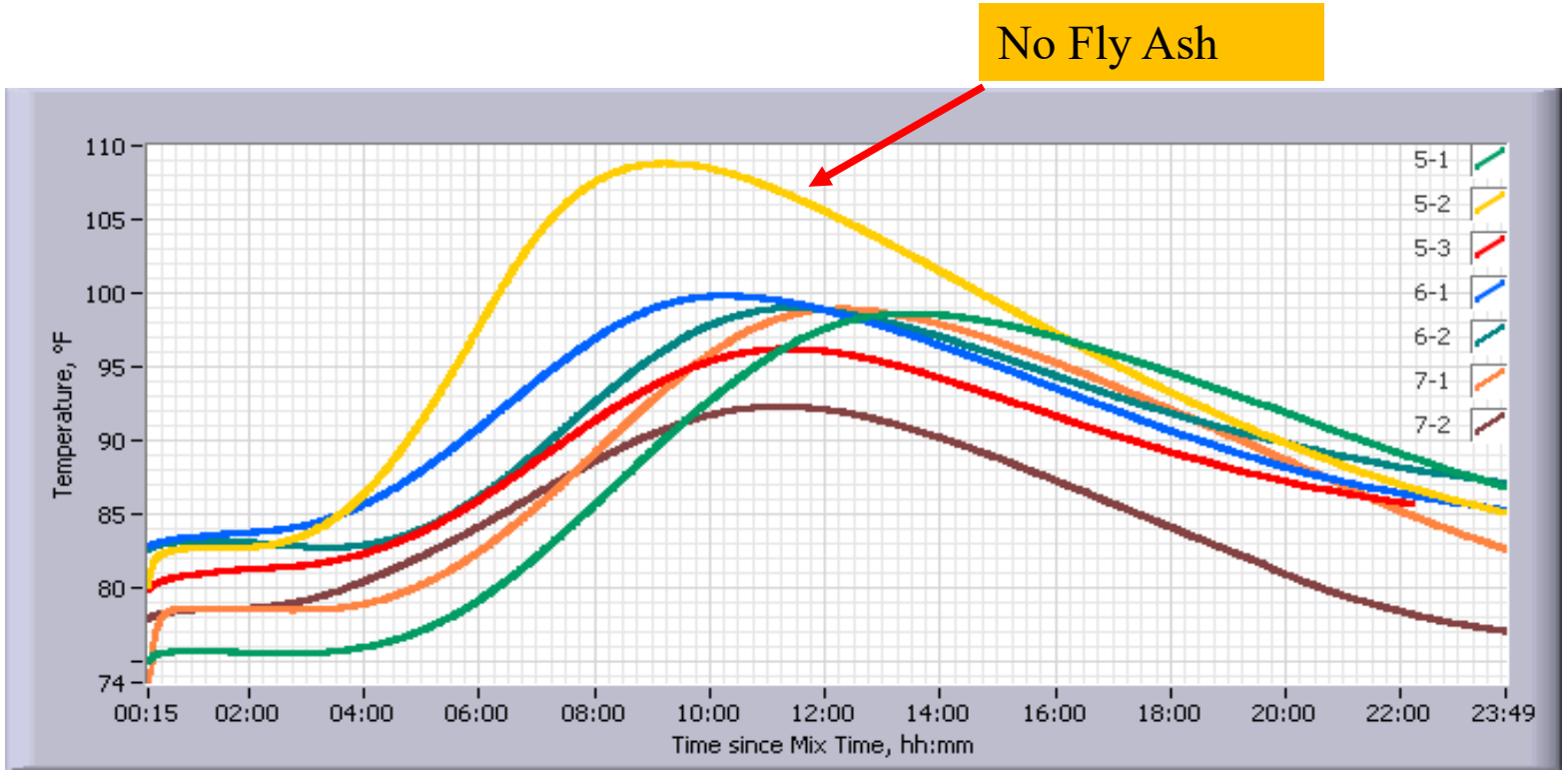
Mixture Consistency

- Production
  - Inconsistent Heat Signature Curves



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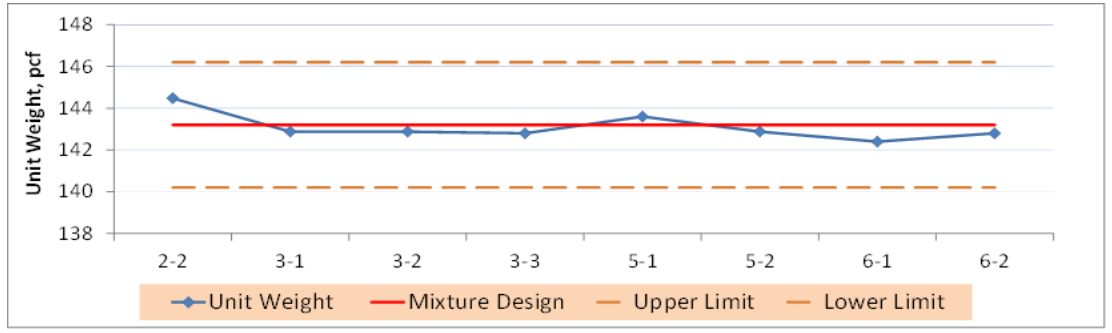
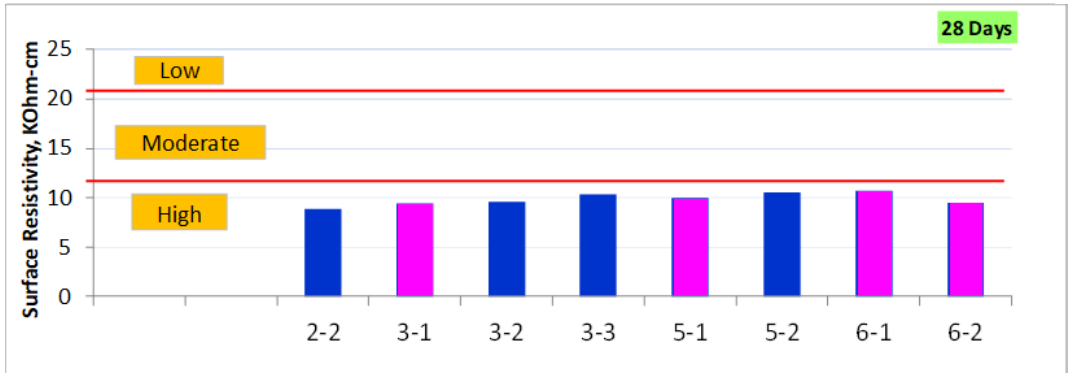
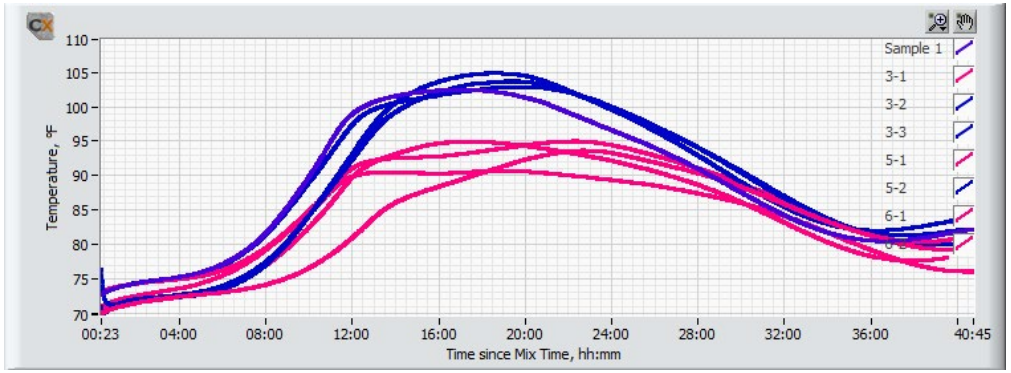
Unit Weight / Heat Signature / Permeability



Unit Weight – Real Time

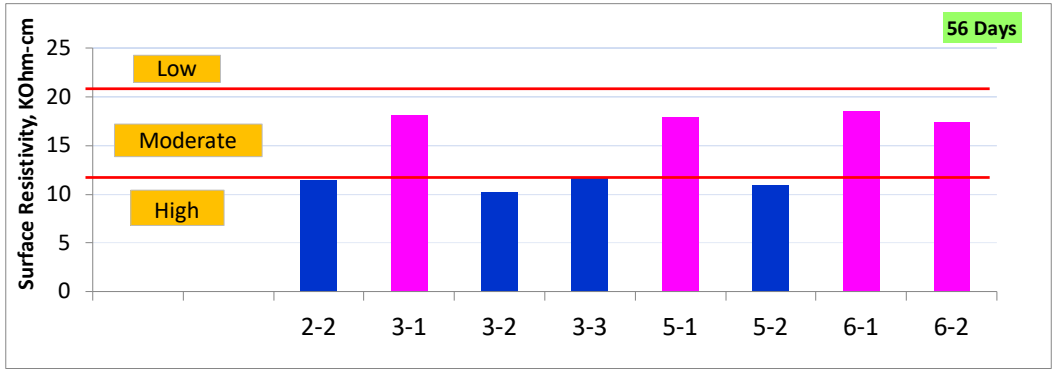


Surface Resistivity – 28 Days



Heat Signature – Info in a day

Real Time



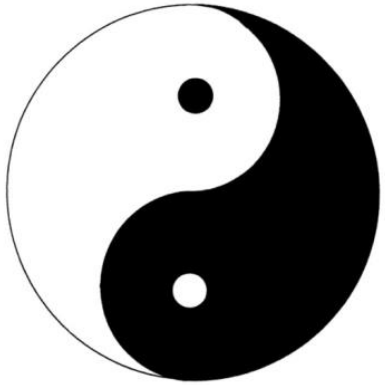
Surface Resistivity – 56 Days

28 / 56 days

Data Source: MCTC

Yin and Yang of Testing Concrete

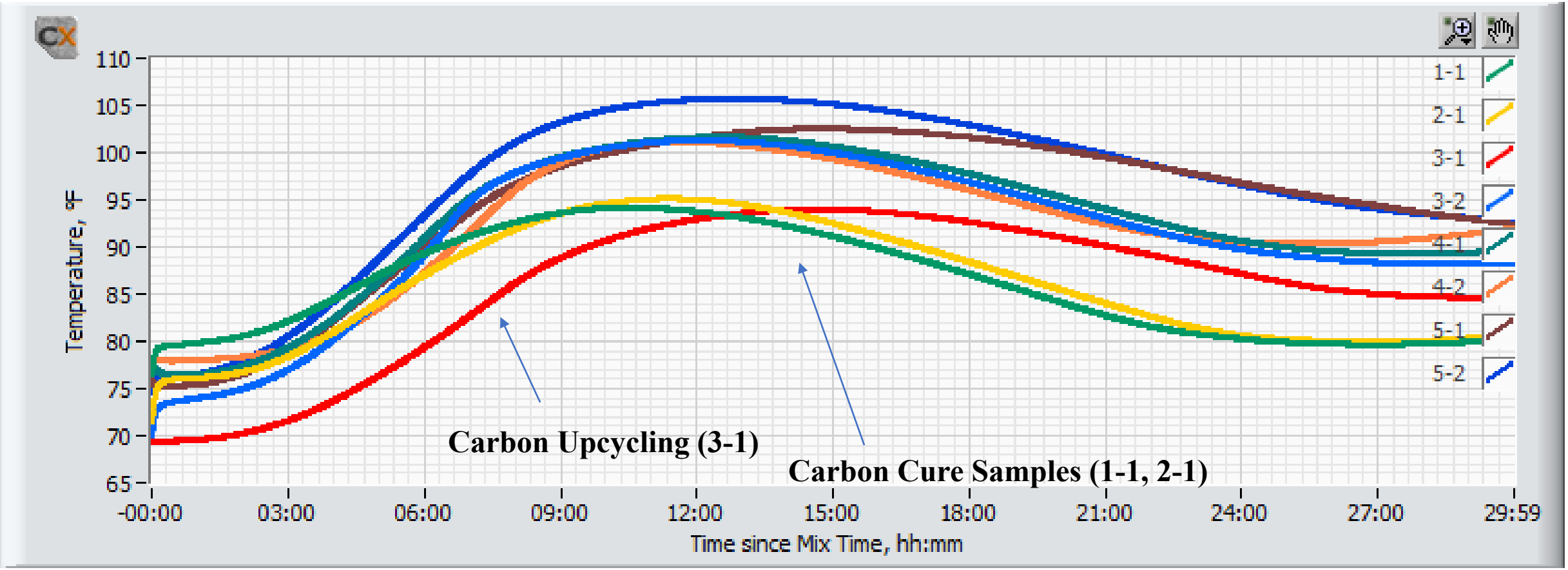
- **Unit Weight**
  - **Measures change in things that have weight**
    - Air (takes up space of things that have weight)
    - Water
    - Aggregates
- **Calorimetry**
  - **Measures change or variability in the chemistry**
    - SCMs like fly ash, slag, etc. (different sources, variability from batch to batch)
    - Cement (different sources, variability form batch to batch)
    - Admixtures (competing brands, dosages, time of addition)



Together, they should tell you if something changed!

New Materials- Heat Signature

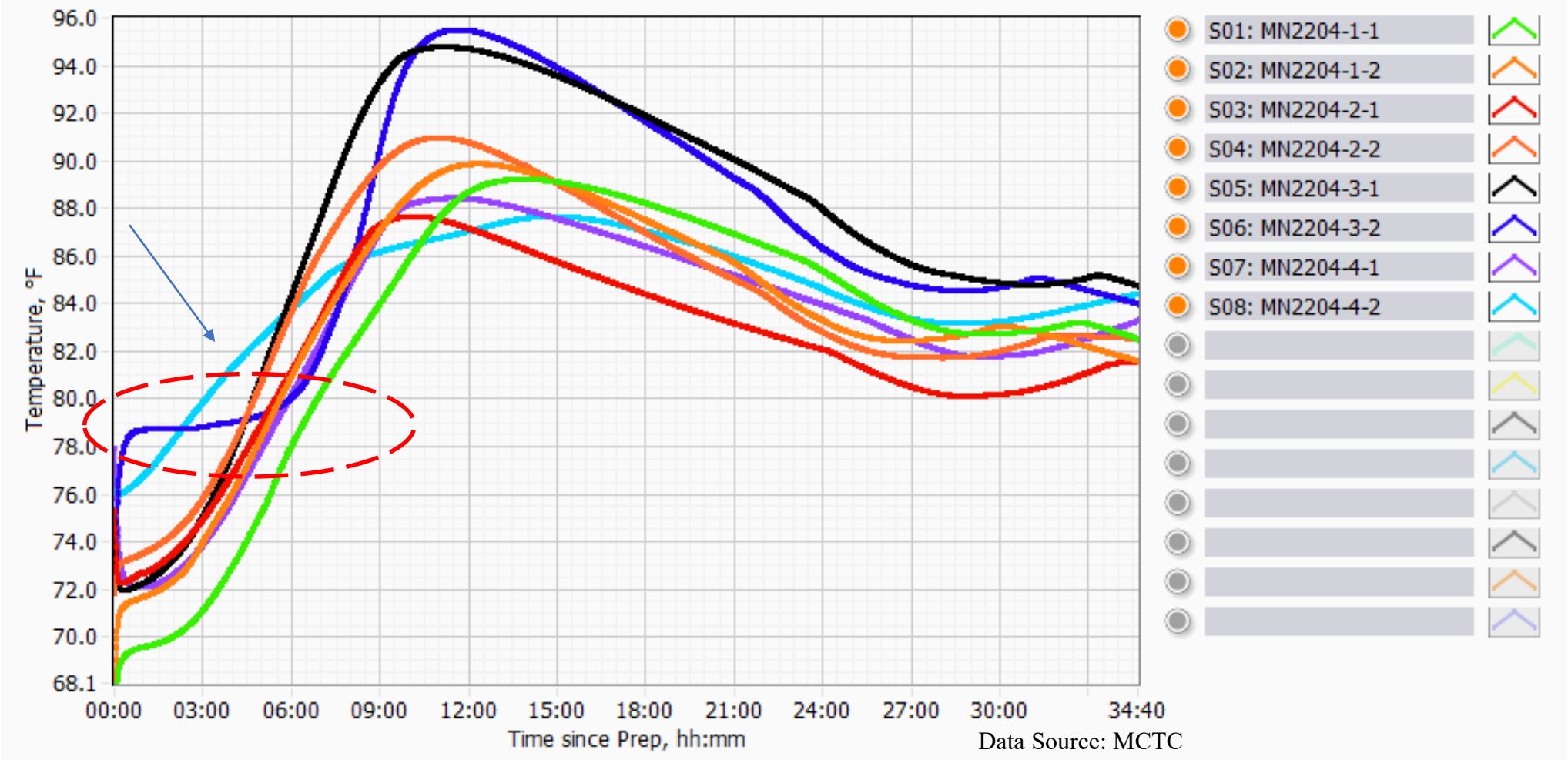
➢MnROAD 2022



Data Source: MCTC

New Materials – MnROAD 2024

➢MnROAD - 2024



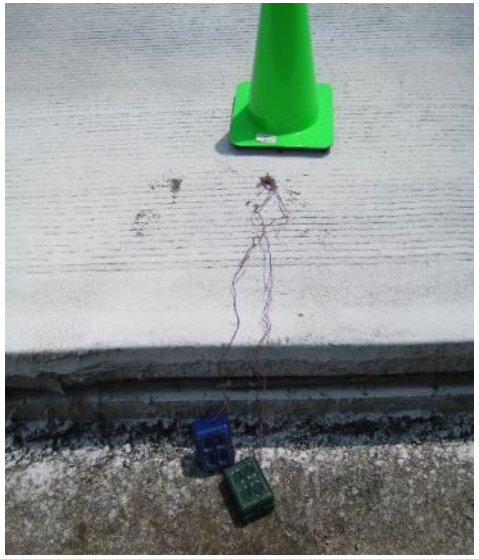
Data Source: MCTC

Recommendation

- **Mixture Design**
  - Inclusion of heat signature curve during the mixture design submittal process
  - Helps identify mixture constituents for incompatibilities, robustness (how the design can absorb small deviations), potential field issues, and optimize mixtures and dosages
  - New cementitious systems
- **Uniformity – Quality Control during production**
  - Compare heat signature curves of the same mixture during production
  - Check for consistency of cementitious systems and admixtures
  - Useful for concrete producers
- **Considerations**
  - Cannot be used for acceptance – compares curves not numbers
  - Compare curves with similar initial concrete temperatures

Future Work ??

- Propose a simpler test method (AASHTO) for Quality Control purposes
  - Precedence with maturity test method
  - ASTM C 1074-19 and AASHTO T413-2024



- Using AI to compare heat signature curves to quantify differences

Thank You!!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