# Effect of Specimen Preparation Variables on AMPT Tests

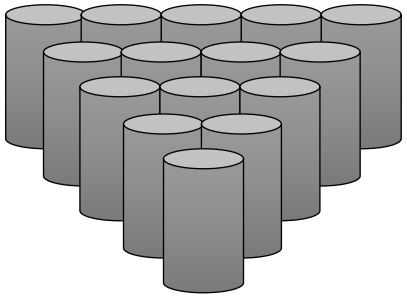
FHWA Cooperative Study at
Asphalt Institute

# Research Team

- Principal Investigator
  - Mike Anderson, Asphalt Institute
- Joint effort between Asphalt Institute and Advanced Asphalt Technologies
- Two phase study
- AMPT Implementation

# Background

- NCHRP 9-29, Phase VI, Report 702

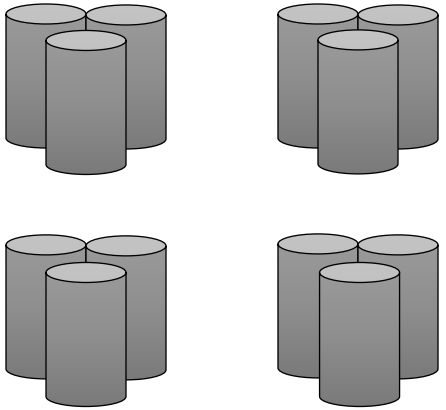


**Specimens made in a single lab**

**Tested by 8 participating labs**

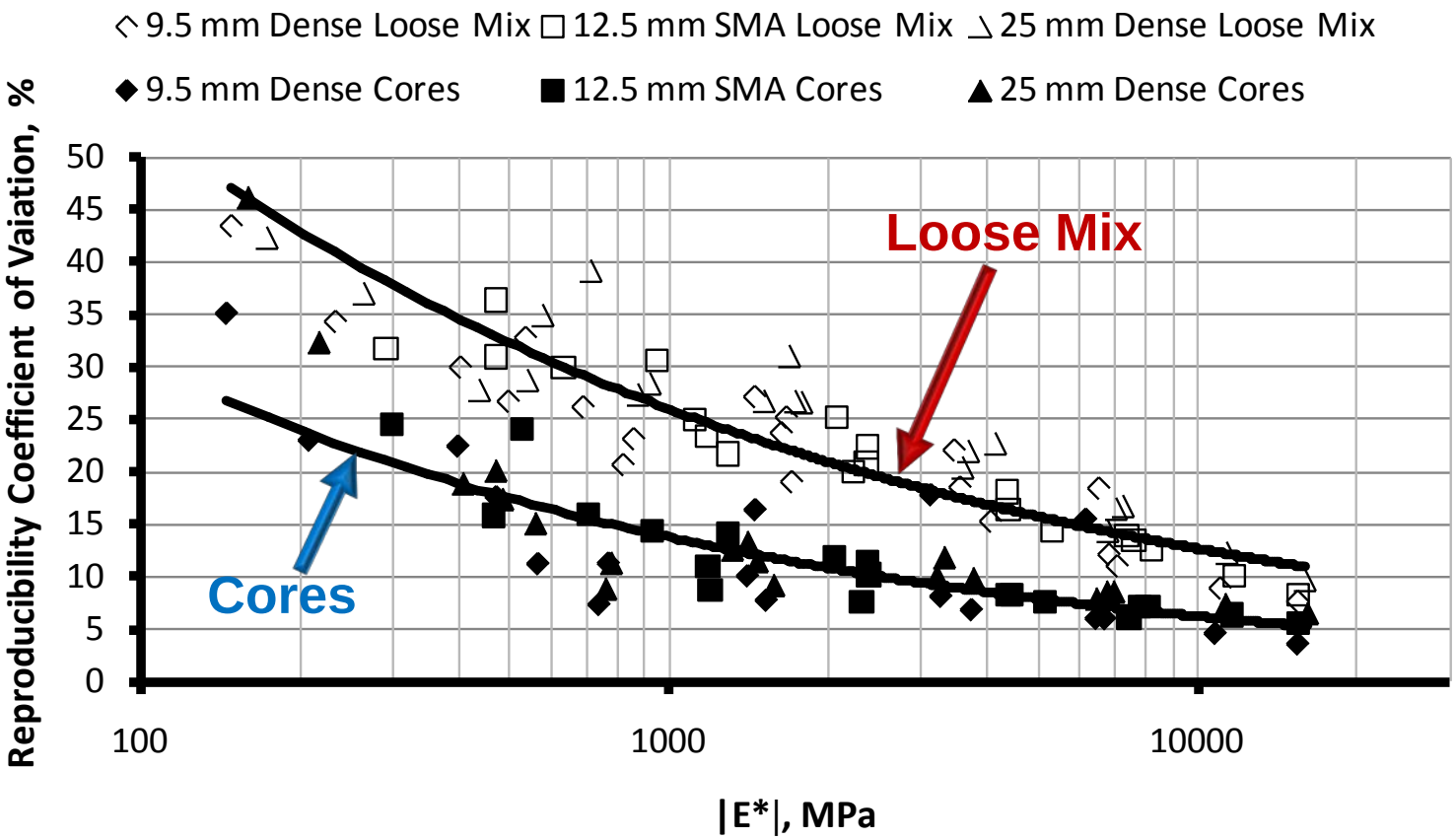
**Loose mix shipped to participating labs**

**Specimens were made & tested in 8 different labs**



# Background

- NCHRP 9-29 ILS Results:



# Phase I

- Focused on sample conditioning (AASHTO R 30) by examining ovens.
- Phase I evaluations:
  1. How different is the temperature distribution in various forced-draft ovens?
  2. Does the oven quality make any difference in conditioning of the samples?
  3. Does frequent opening/closing of the ovens' door affect the conditioning of the loose mixtures?

# Ovens in Phase I

**Grieve** (50 $ft^3$)


**Grieve** (26 $ft^3$)


**Blue-M** (8.3 $ft^3$)

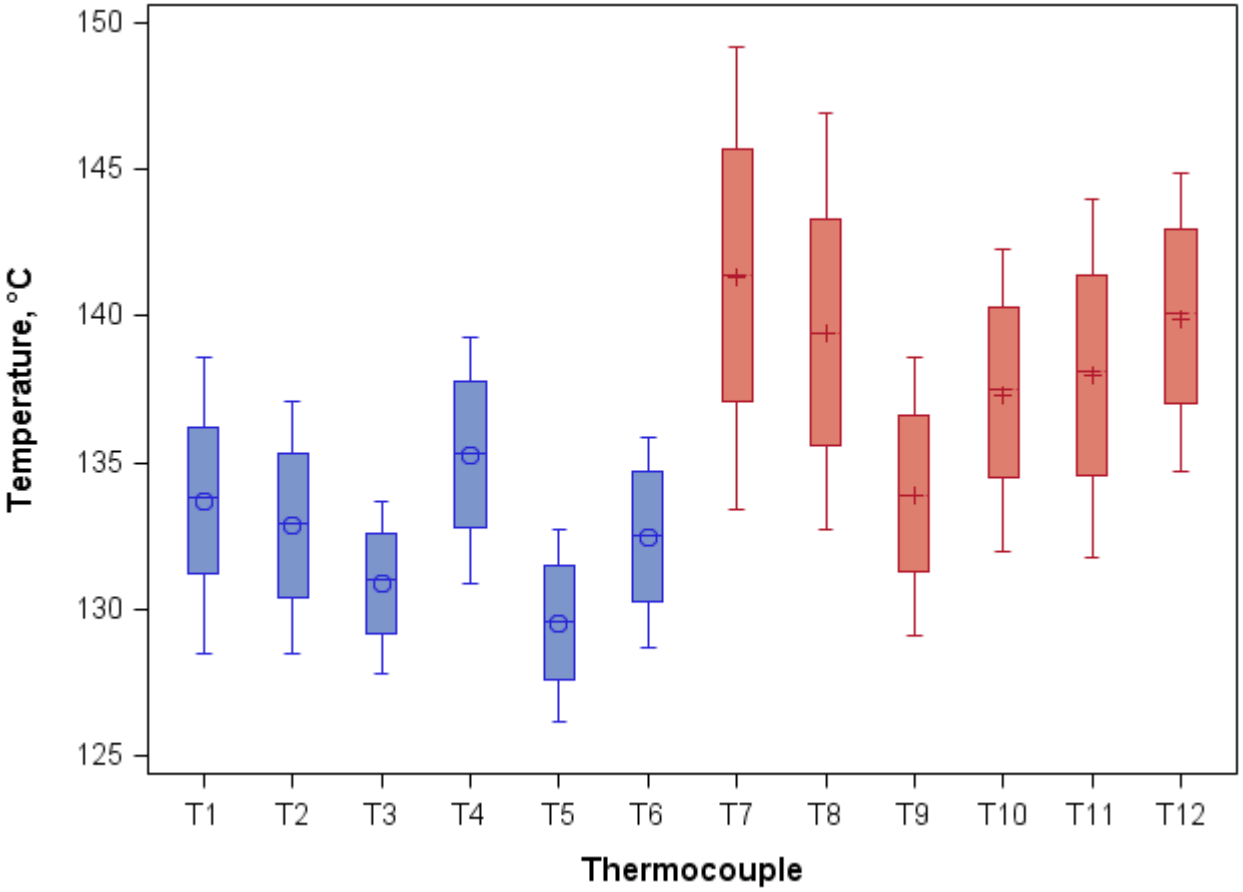
**Quincy**
(7.8 $ft^3$)

# Different Evaluations

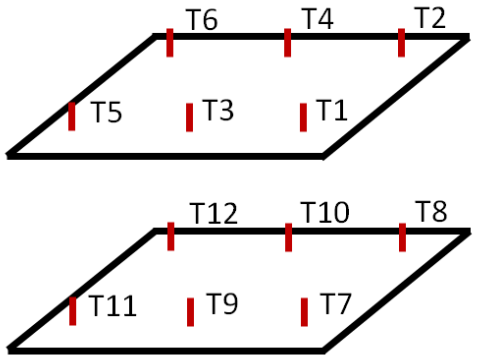
1. Oven temperature: Empty oven
2. Mix temperature: Loaded oven with mix
3. Oven temperature: Loaded oven with mix + opening doors
4. Mix temperature: Loaded oven with mix + opening door

# Evaluation 1: Quincy oven temperature

## Closed oven, 4-hour conditioning simulation



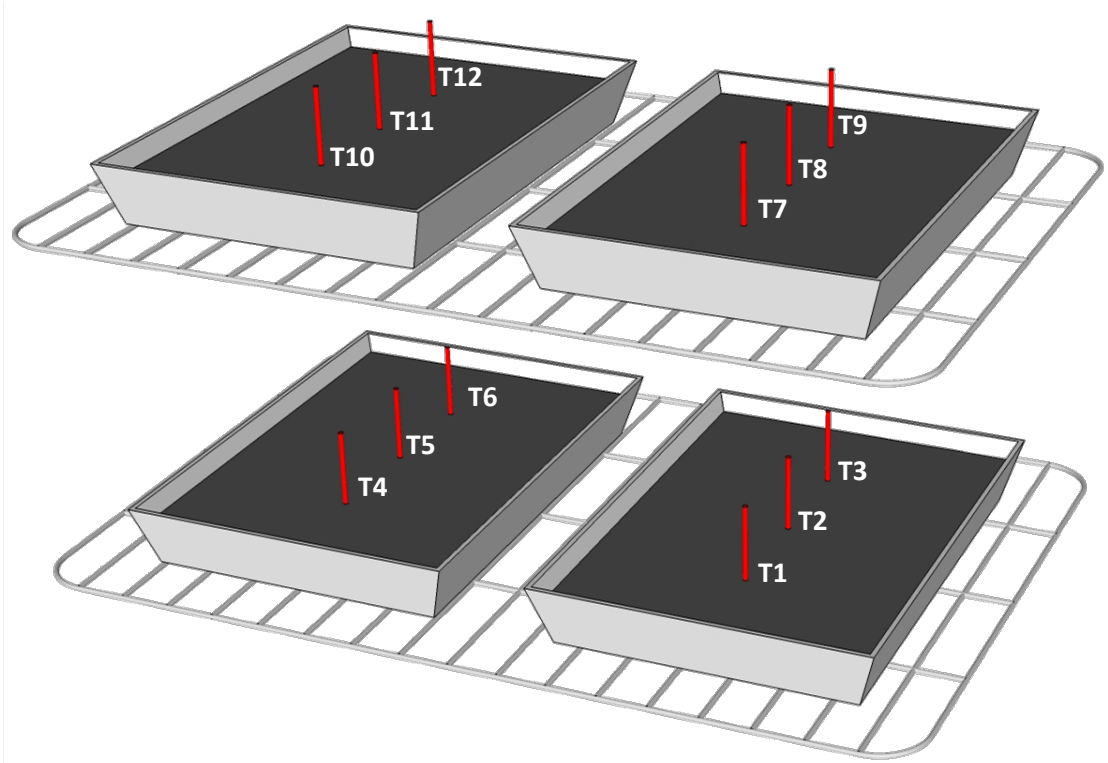

**Temperature variability**
**126.2 – 149.2 °C**



# Evaluation 2: Loose Mix Temperature

**Closed oven, 4-hour conditioning simulation**

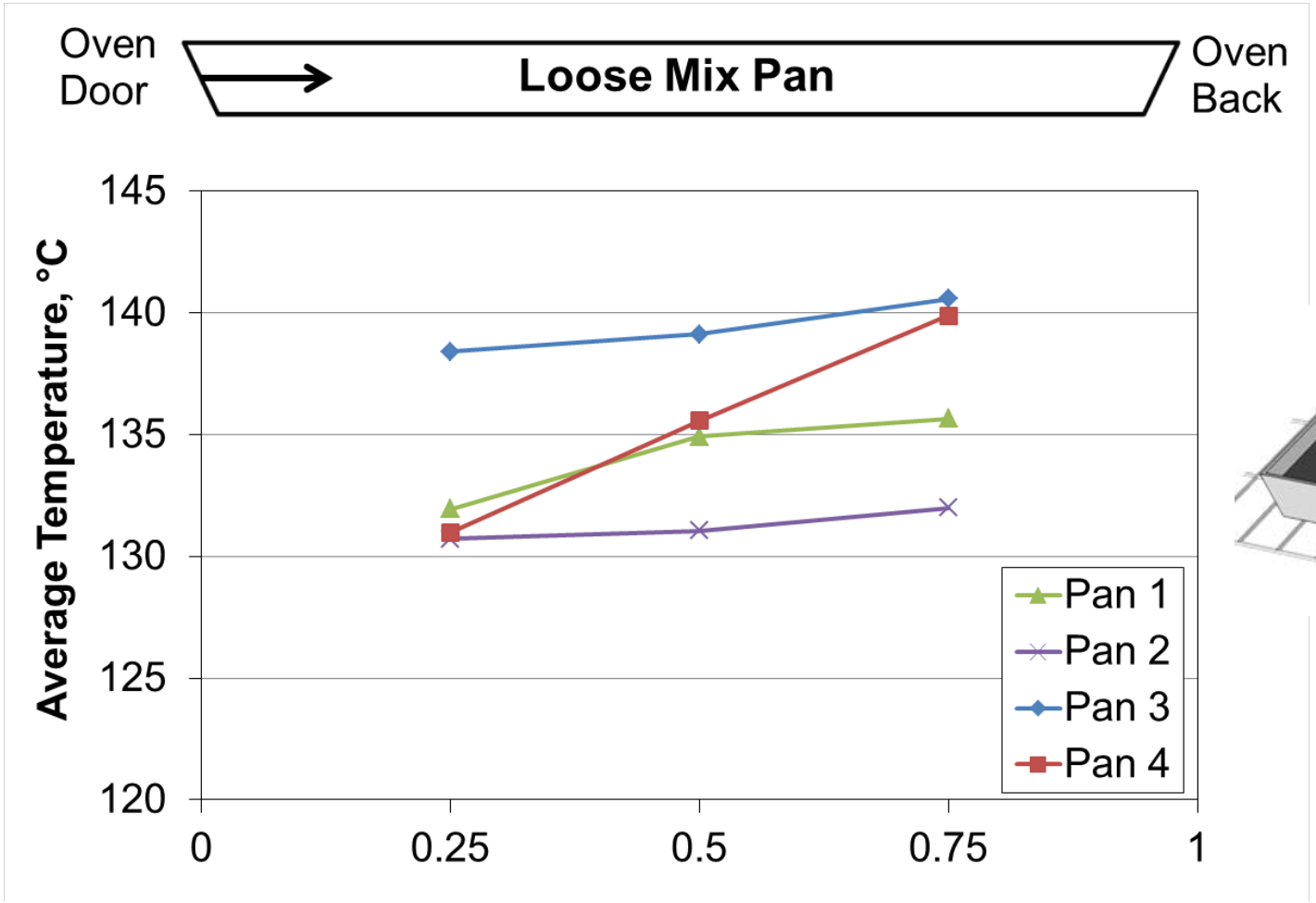
Example probe location. Three probes per pan on 2-shelf Blue-M & Quincy ovens; two probes per pan on 3-shelf Grieve oven.

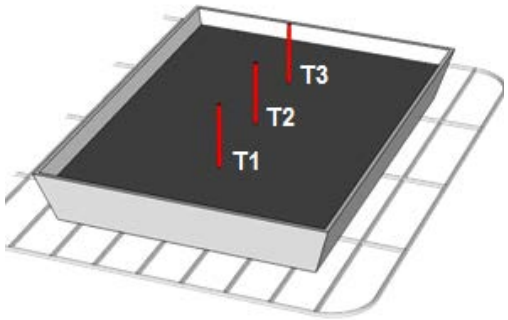




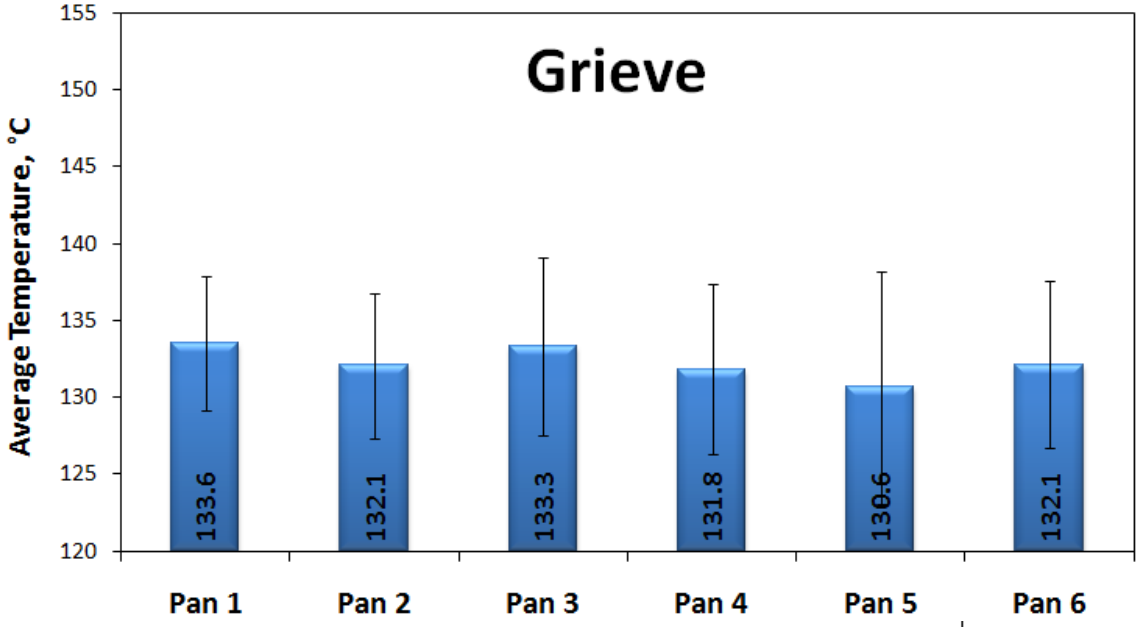
**12-channel data logger**

# Evaluation 2: Mix Temperature in Quincy Oven

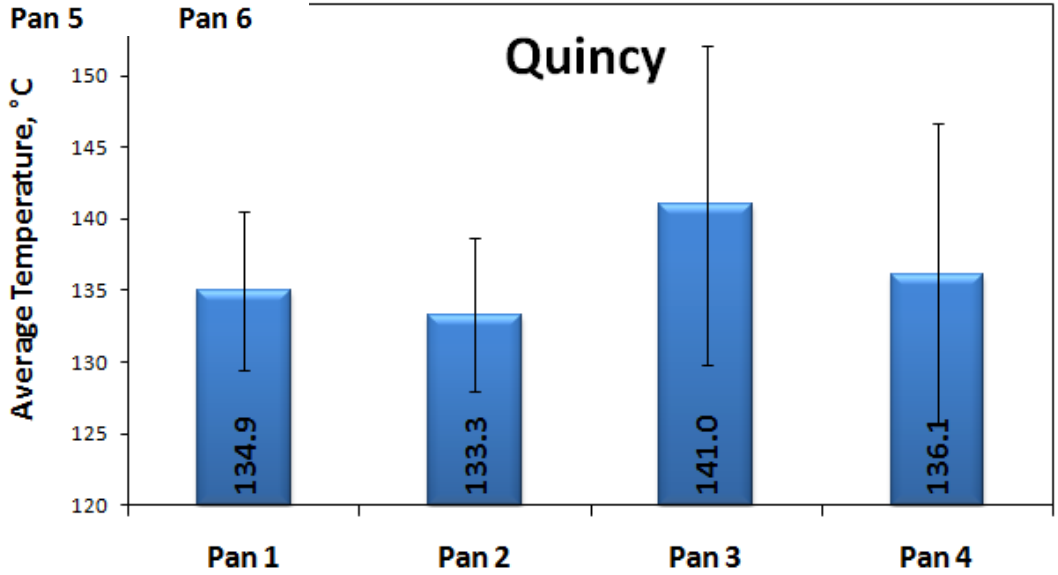


# Evaluation 3 – Opening & Closing Oven Doors



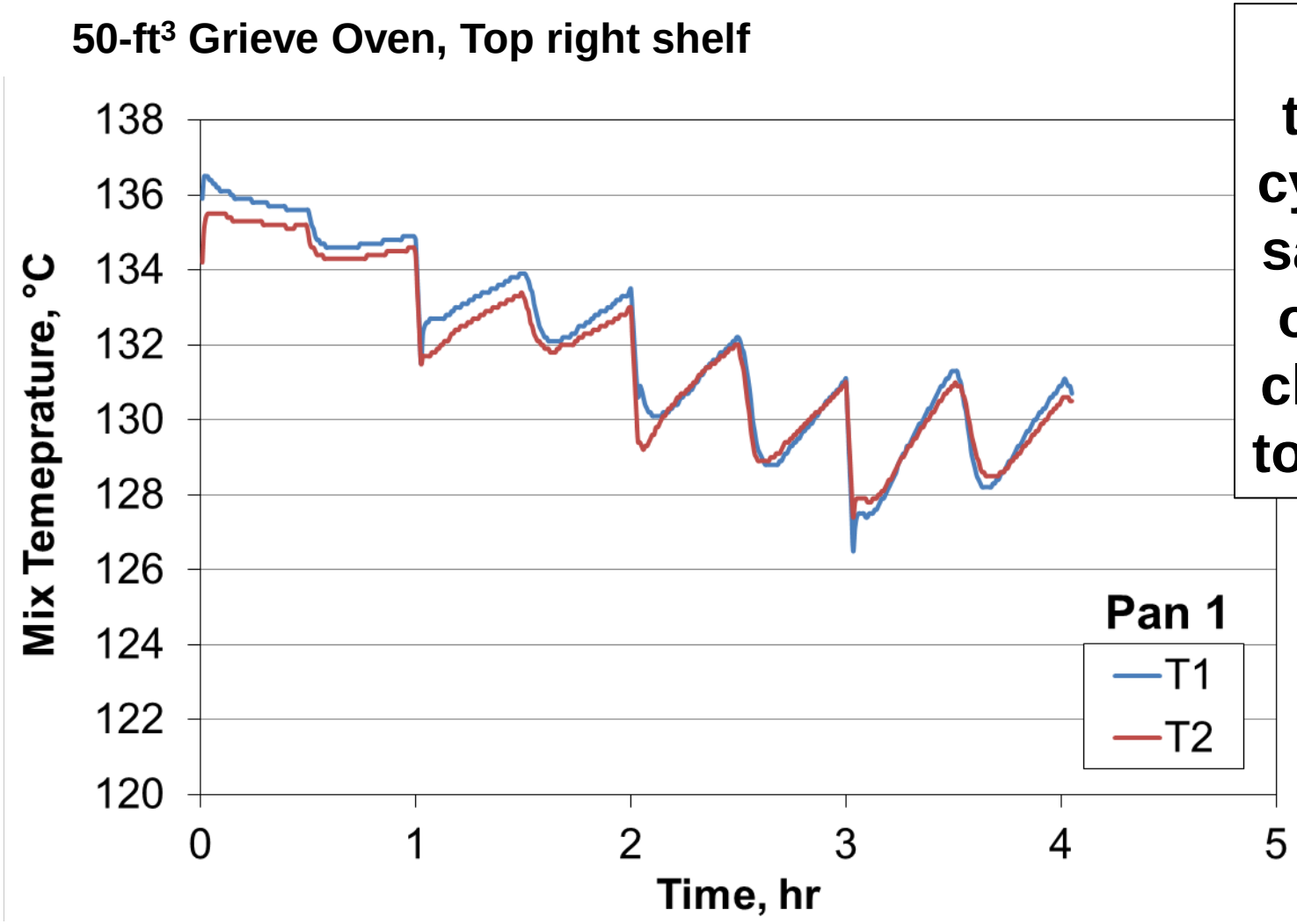

**Oven <u>air</u> temperature. Oven door opened/closed regularly to stir the mix.**



# Evaluation 4 – Opening & Closing Oven Doors

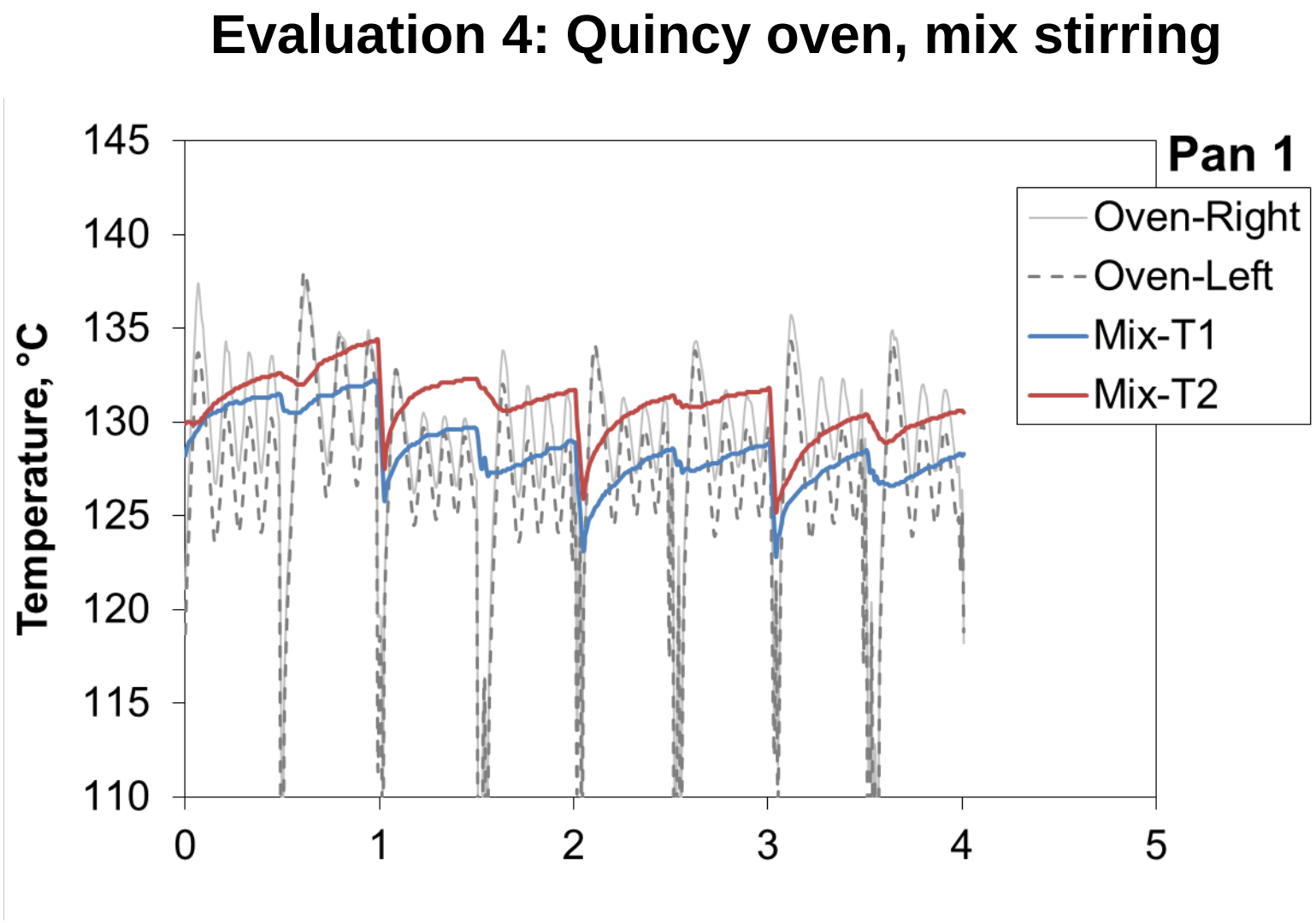
**Temperature of <u>mix</u> samples. Oven door opened/closed regularly to stir the mix.**

# Evaluation 4: Loose Mix Temperature




**Typical temperature cycling of mix samples from opening and closing doors to stir the mix.**

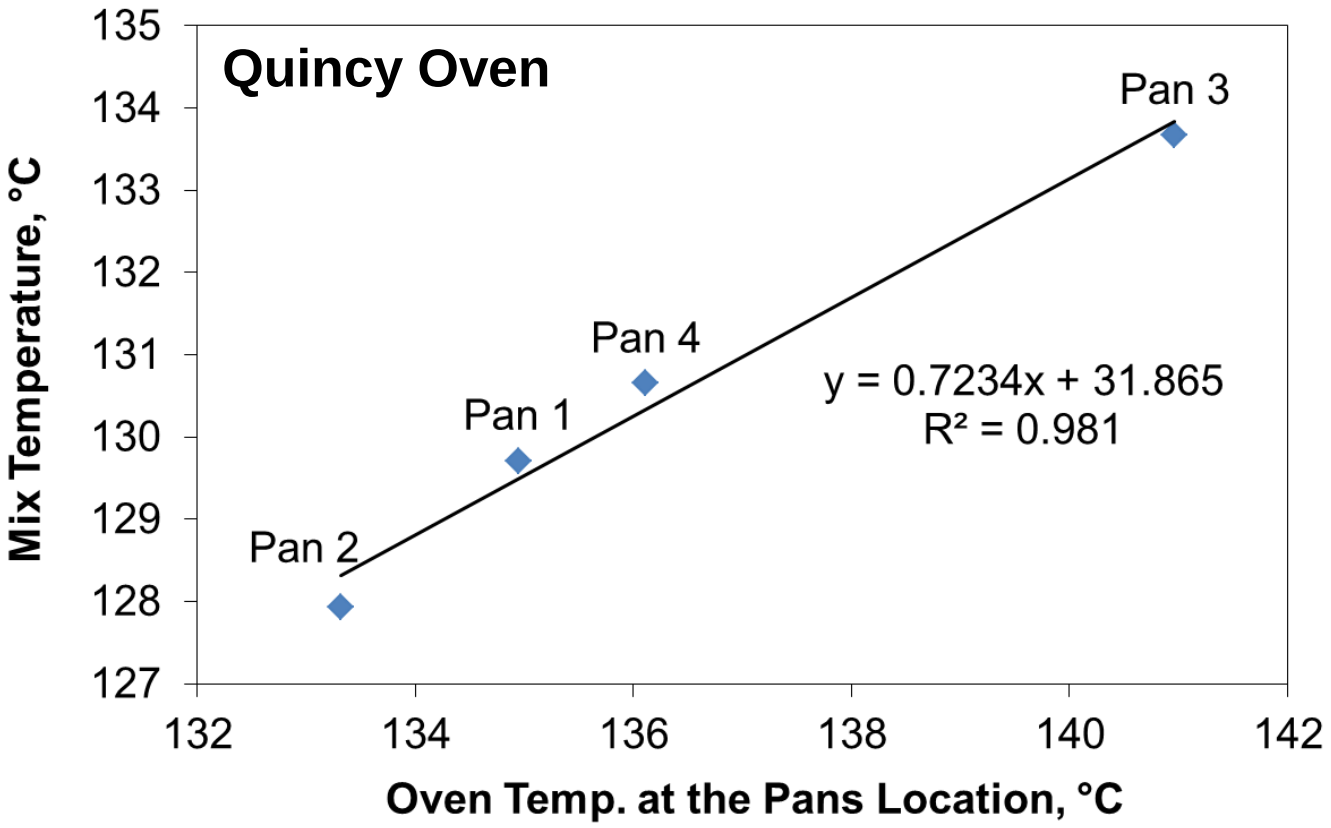
# What Happens When I Open the Door?



# What Happens When I Open the Door?

## Evaluations 3 & 4: Stirring the mix

### Comparison of oven air and mix temperatures



# Phase 1 Conclusions

- Oven quality and power makes a large difference in stability and recovery
- Opening the oven doors to stir the mix may not be prudent and can lower the mix temperature (less aged) in some ovens
- Mix temperature varies during conditioning!

# Phase II Objectives

- To identify the sample preparation variables that significantly affect the AMPT test results
- To determine the acceptable range for the significant factors
- To make recommendations to minimize the AMPT test variability

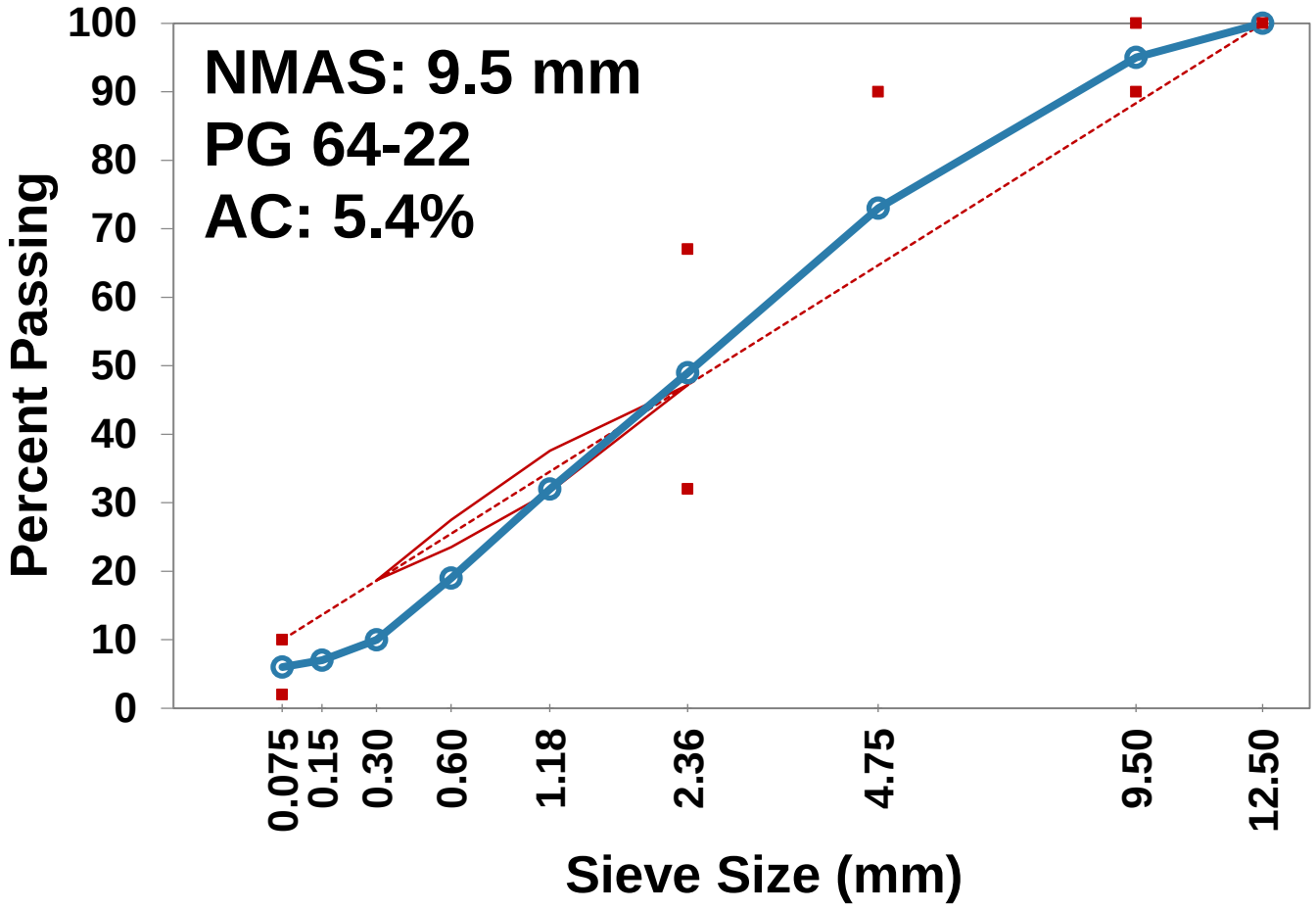
# Variables

| No. | | Low | High |
|---|---|---|---|
| 1 | Mixing Temperature | 139°C (282°F) | 159°C (318°F) |
| 2 | Binder Time at Mixing Temperature | 30 min | 3 hours |
| 3 | Mixer Type | Bucket with hand agitation | Planetary with wire whip |
| 4 | Mixing Time | 90 sec | 180 sec |
| 5 | Loose Mix Conditioning Temp. | 130°C (266°F) | 140°C (284°F) |
| 6 | Loose Mix Conditioning Depth | 25 mm | 50 mm |

# Variables

| No. | | Low | High |
|---|---|---|---|
| **7** | Loose Mix Stirring | Not stirring | Stirring every 60-min |
| **8** | Mold Loading | Scoop | Gyro loader |
| **9** | Placement in Mold | No Rodding | Rodding 10 times at 2/3 depth |
| **10** | Additional Time at Compaction Temp. | 0 min | 30 min |
| **11** | Gyratory Specimen Height | 170 mm | 180 mm |
| **12** | Test Specimen Air Voids | 6.0±0.5% | 8.0±0.5% |

# Lab Standard Mix




| Sieve | JMF |
|---|---|
| 3/8 " | 95 |
| #4 | 73 |
| #8 | 49 |
| #16 | 32 |
| #30 | 19 |
| #50 | 10 |
| #100 | 7 |
| #200 | 6.0 |

# Input from AI-FHWA Studies

- Ambient Specimen Storage (TRB 2014)
  - Storage time
  - Storage in bag
  - Time of cutting/coring
- Effect of mixing, conditioning, and compaction temperatures (TRB 2014)
  - Various temperatures and conditioning durations for neat and modified binders

# Ruggedness Study

Experiment Design:

***Resolution IV, 1/256$^{th}$ Partially Replicated Factorial* Design**

- No main effects are confounded with any 2-factor interactions
- With three replicates, total number of 96 samples will be tested

# Test Matrix

| | Specimen Groups | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
| **Mixing Temp.** | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + |
| **Binder Time at Mix T.** | - | - | + | + | - | - | + | + | - | - | + | + | - | - | + | + | - | - | + | + | - | - | + | + | - | - | + | + | - | - | + | + |
| **Mixer Type** | - | - | - | - | + | + | + | + | - | - | - | - | + | + | + | + | - | - | - | - | + | + | + | + | - | - | - | - | + | + | + | + |
| **Mixing Time** | - | - | - | - | - | - | - | - | + | + | + | + | + | + | + | + | - | - | - | - | - | - | - | - | + | + | + | + | + | + | + | + |
| **Mix Cond. Temp.** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| **Mix Cond. Depth** | - | + | + | - | + | - | - | + | + | - | - | + | - | + | + | - | + | - | - | + | - | + | + | - | - | + | + | - | + | - | - | + |
| **Mix Stirring** | - | - | - | - | + | + | + | + | + | + | + | + | - | - | - | - | + | + | + | + | - | - | - | - | - | - | - | - | + | + | + | + |
| **Mold Loading** | - | - | + | + | - | - | + | + | + | + | - | - | + | + | - | - | + | + | - | - | + | + | - | - | - | - | + | + | - | - | + | + |
| **Placement in Mold** | - | + | - | + | - | + | - | + | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | - | + | - | + | - | + | - | + |
| **Time at Comp. Temp.** | - | - | + | + | + | + | - | - | - | - | + | + | + | + | - | - | + | + | - | - | - | - | + | + | + | + | - | - | - | - | + | + |
| **Specimen Height** | - | + | - | + | + | - | + | - | - | + | - | + | + | - | + | - | + | - | + | - | - | + | - | + | + | - | + | - | - | + | - | + |
| **Specimen Air Voids** | - | + | + | - | - | + | + | - | - | + | + | - | - | + | + | - | + | - | - | + | + | - | - | + | + | - | - | + | + | - | - | + |

**3 replicates, 96 total specimens**

# Test Matrix

**Specimen #7**

| | Specimen Groups | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
| Mixing Temp. | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + |
| Binder Time at Mix T. | - | - | + | + | - | - | + | + | - | - | + | + | - | - | + | + | - | - | + | + | - | - | + | + | - | - | + | + | - | - | + | + |
| Mixer Type | - | - | - | - | + | + | + | + | - | - | - | - | + | + | + | + | - | - | - | - | + | + | + | + | - | - | - | - | + | + | + | + |
| Mixing Time | - | - | - | - | - | - | - | - | + | + | + | + | + | + | + | + | - | - | - | - | - | - | - | - | + | + | + | + | + | + | + | + |
| Mix Cond. Temp. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Mix Cond. Depth | - | + | + | - | + | - | - | + | + | - | - | + | - | + | + | - | + | - | - | + | - | + | + | - | - | + | + | - | + | - | - | + |
| Mix Stirring | - | - | - | - | + | + | + | + | + | + | + | + | - | - | - | - | + | + | + | + | - | - | - | - | - | - | - | - | + | + | + | + |
| Mold Loading | - | - | + | + | - | - | + | + | + | + | - | - | + | + | - | - | + | + | - | - | + | + | - | - | - | - | + | + | - | - | + | + |
| Placement in Mold | - | + | - | + | - | + | - | + | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | - | + | - | + | - | + | - | + |
| Time at Comp. Temp. | - | - | + | + | + | + | - | - | - | - | + | + | + | + | - | - | + | + | - | - | - | - | + | + | + | + | - | - | - | - | + | + |
| Specimen Height | - | + | - | + | + | - | + | - | - | + | - | + | + | - | + | - | + | - | + | - | - | + | - | + | + | - | + | - | - | + | - | + |
| Specimen Air Voids | - | + | + | - | - | + | + | - | - | + | + | - | - | + | + | - | + | - | - | + | + | - | - | + | + | - | - | + | + | - | - | + |

**3 replicates, 96 total specimens**

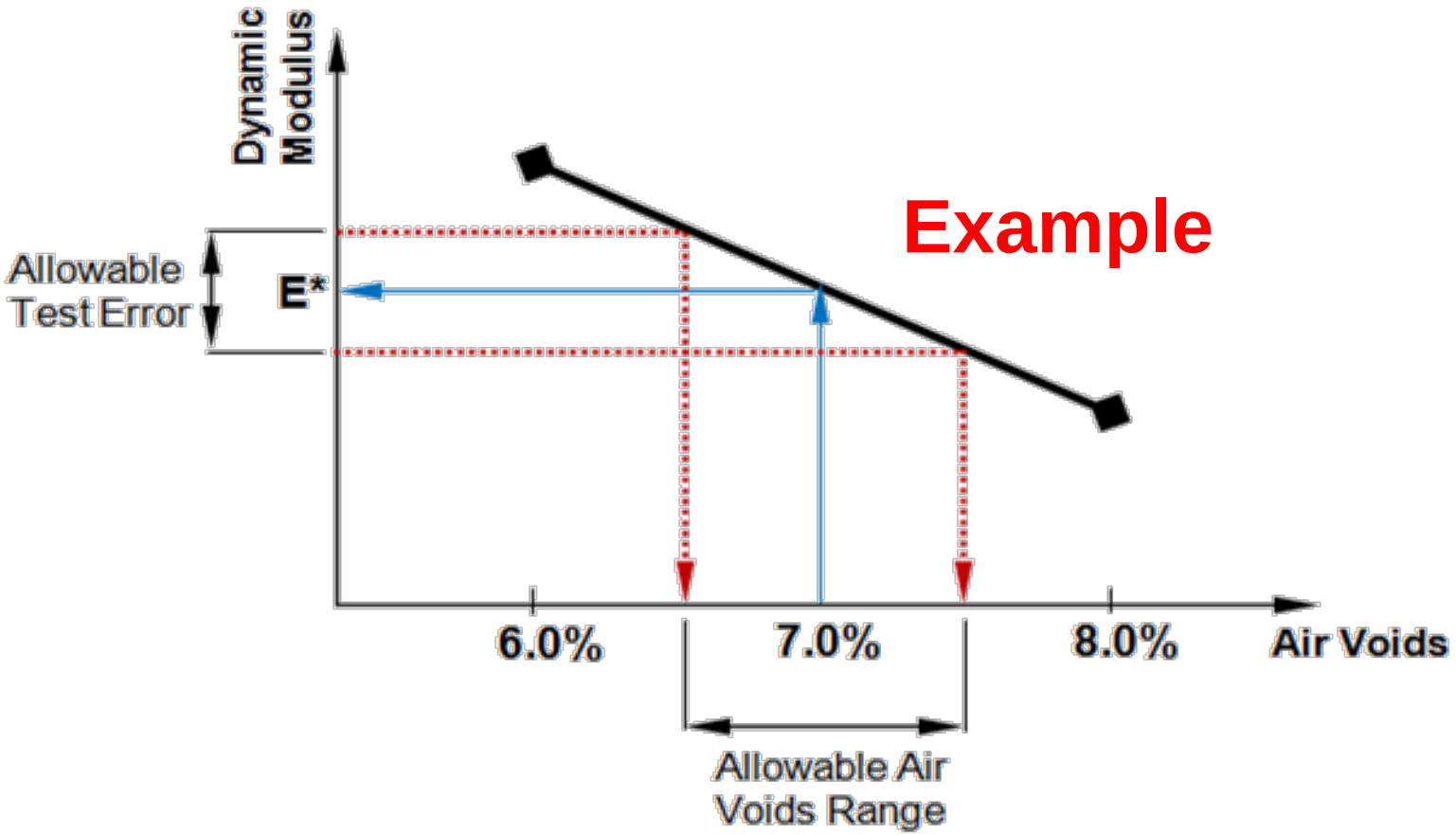
# Example: Specimen #7

| | Factor | Level | Level Value |
|---|---|---|---|
| 1 | Mixing Temperature | - | 139°C (282°F) |
| 2 | Binder Time at Mixing Temp. | + | 3 hours |
| 3 | Mixer Type | + | Planetary with wire whip |
| 4 | Mixing Time | - | 90 sec |
| 5 | Loose Mix Conditioning Temp. | - | 130°C (266°F) |
| 6 | Loose Mix Conditioning Depth | - | 25 mm |
| 7 | Loose Mix Stirring | + | Stirring every 60-min |
| 8 | Mold Loading | + | Gyro loader |
| 9 | Placement in Mold | - | No rodding |
| 10 | Additional Time at Compaction Temp. | - | 0 min |
| 11 | Gyratory Specimen Height | + | 180 mm |
| 12 | Test Specimen Air Voids | + | 8% |

# Phase II Goal

- Quantitative Factors:
  - Determine the allowable tolerances of factors based on allowable E* test error
- Qualitative Factors:
  - Improving AMPT tests reproducibility
- Interactions
  - Refining the AASHTO PP 60 standard

# Phase II Goal

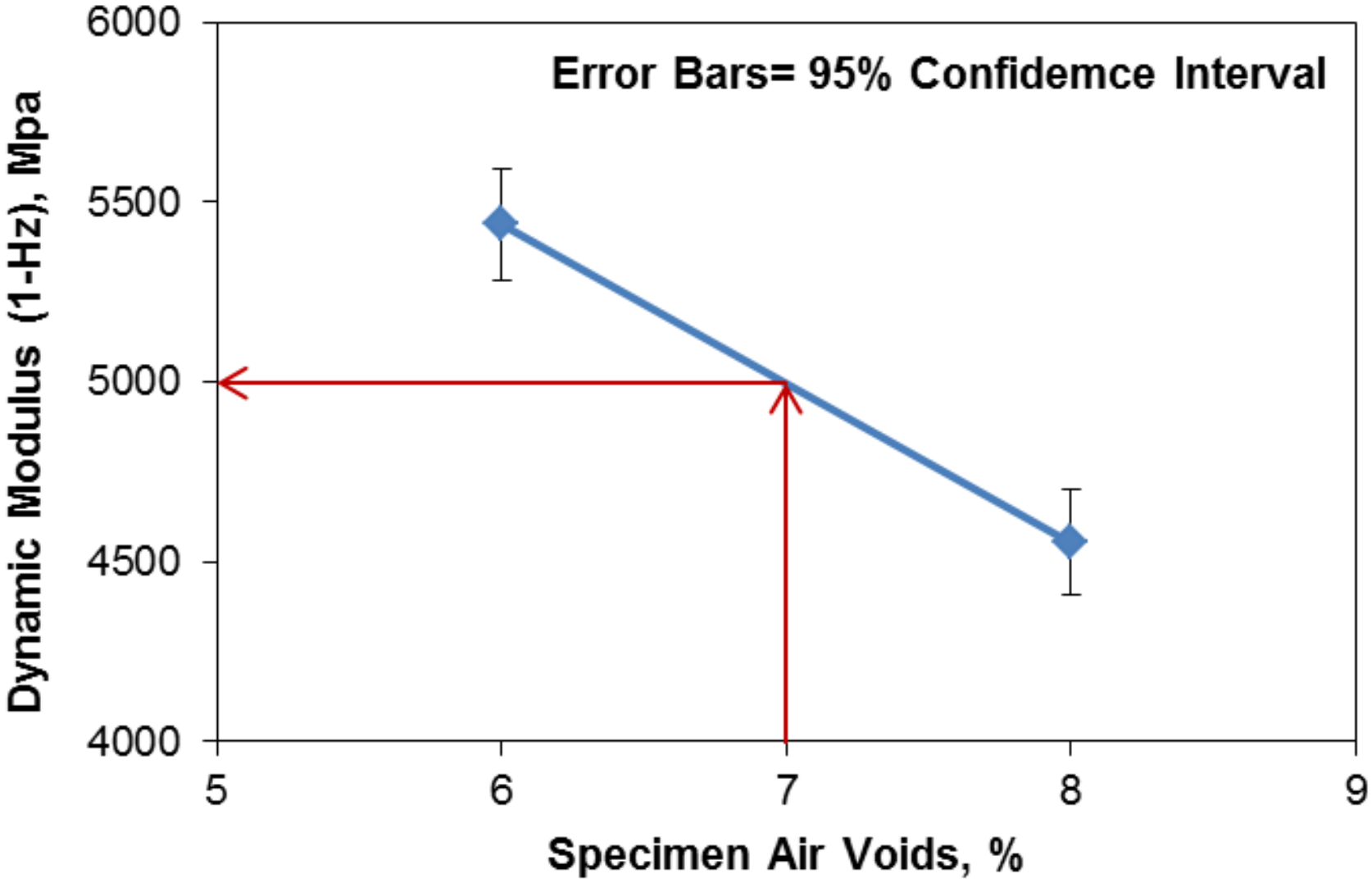


# Results Using Dynamic Modulus at 1Hz, 20°C

95% confidence interval

| Factor | | DF | SS | F | P-value | Significant |
|---|---|---|---|---|---|---|
| X1 | Mixing Temperature | 1 | 6.52E+10 | 0.340874 | 0.5613 | - |
| X2 | Binder Time at Mixing Temperature | 1 | 6.20E+11 | 3.241336 | 0.0762 | - |
| X3 | Mixer Type | 1 | 1.02E+11 | 0.533999 | 0.4674 | - |
| X4 | Mixing Time | 1 | 1.72E+11 | 0.901408 | 0.3458 | - |
| X5 | Loose Mix Conditioning Temperature | 1 | 2.98E+12 | 15.6048 | 0.0002 | Yes |
| X6 | Loose Mix Conditioning Depth | 1 | 2.36E+11 | 1.233152 | 0.2707 | - |
| X7 | Loose Mix Stirring | 1 | 9.16E+11 | 4.794213 | 0.032 | Yes |
| X8 | Mold Loading | 1 | 6.79E+11 | 3.552436 | 0.0637 | - |
| X9 | Placement in Mold | 1 | 6.06E+11 | 3.168072 | 0.0796 | - |
| X10 | Additional Time at Compaction Temp. before Loading in Mold | 1 | 4.25E+11 | 2.222326 | 0.1407 | - |
| X11 | Gyratory Specimen Height | 1 | 2.33E+10 | 0.121895 | 0.7281 | - |
| X12 | Test Specimen Air Voids | 1 | 1.88E+13 | 98.28483 | <.0001 | Yes |

# Air Voids and E* Variability



# Conclusions

- Significant variables:
  - Loose mix conditioning temp
  - Loose mix stirring
  - Test sample air voids had highest impact
    - 1% increase in the specimen air voids => 1-Hz dynamic modulus decreased by 442 Mpa
  - Three other factors had P-values between 0.005 and 0.010 and may prove to be significant
    - Binder holding time at mixing temperature, mold loading with gyro loader, and rodding the loose mix while placing it in the mold

# Conclusions

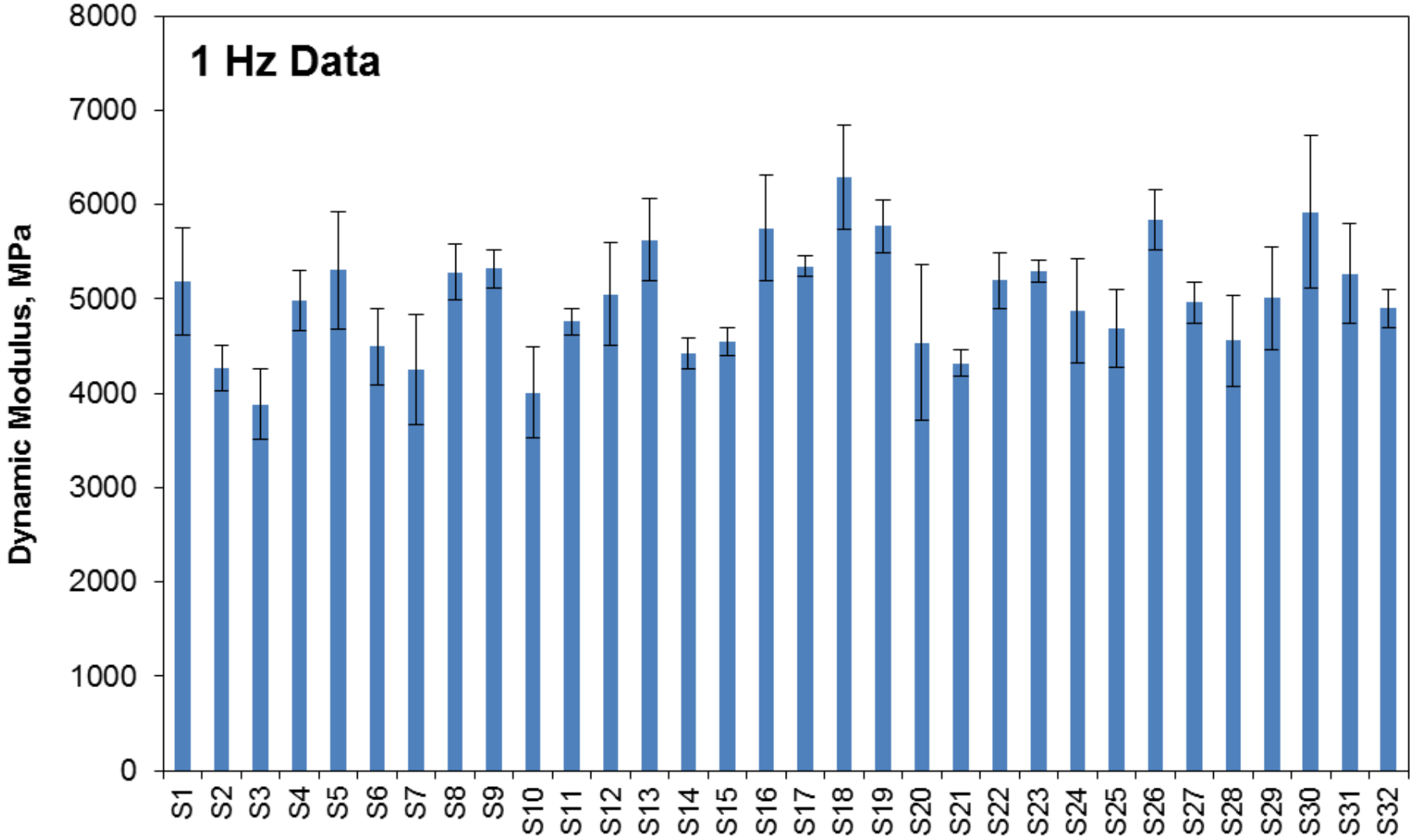
- COV of the dynamic modulus data was between 2.0 and 18.2%
  - Higher than typical values of 10% max.
  - Eleven specimens groups had COV values higher than 10%.
- COV of the flow number data was higher than dynamic modulus but within typical range for flow number
  - Just run for informational purposes

# Recommendations

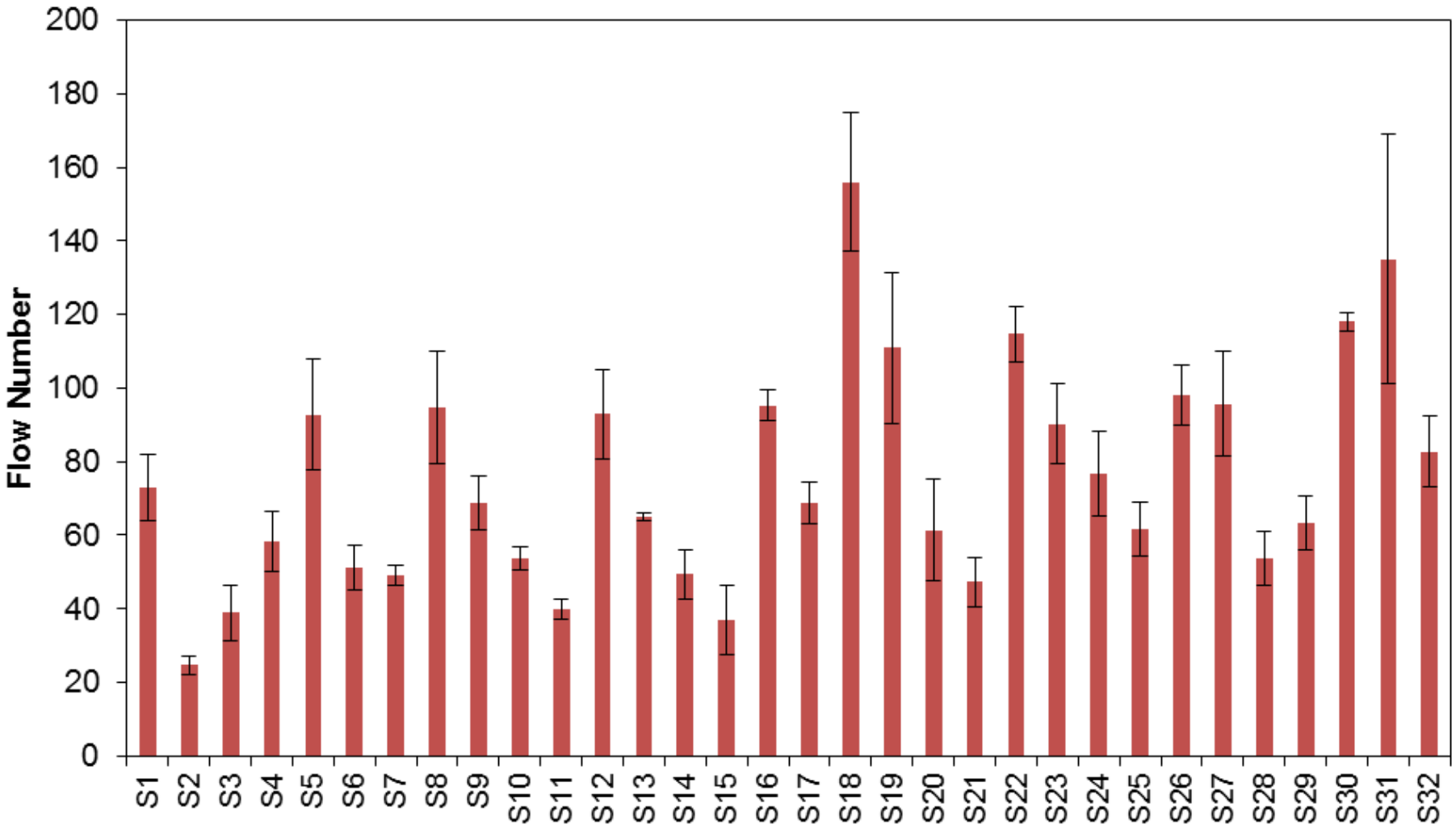
- Remanufacture samples to for improved COV
  - Make one additional specimen for each of these groups and use the trimmed average of four samples for the data analysis to improve the results in this partial factorial experiment design
- New standard practice should be created for sample preparation
  - Not limited to AMPT E* samples
  - Would apply to IDT, DC(t), and beam fatigue
  - Possible apply to APA, HWT, and other proof tests

# Thank you

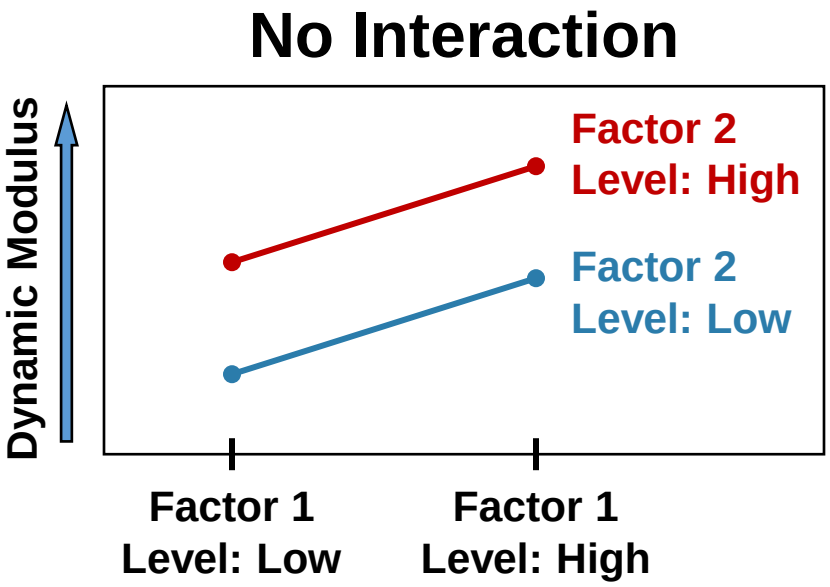
# Average Dynamic Modulus Data at 1.0-Hz Loading Frequency, 20°C

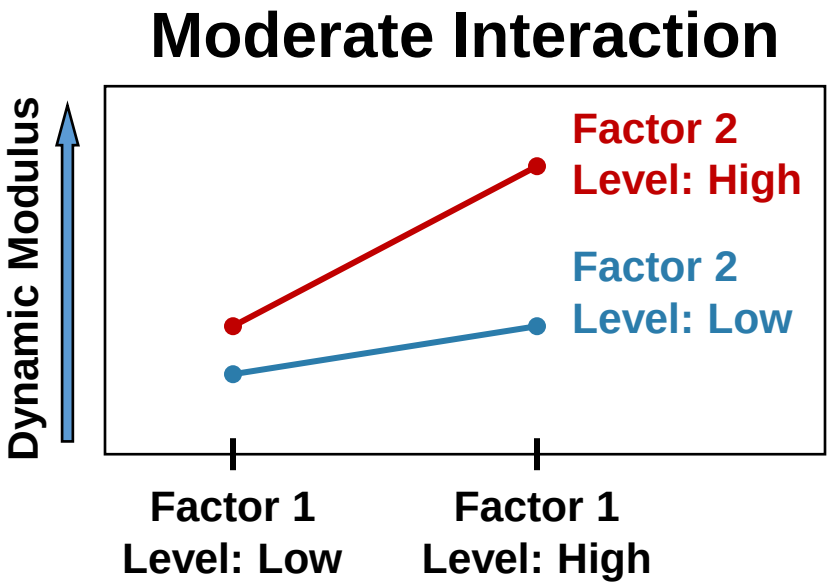


# Average Flow Number Data at 54°C



# Interactions



# Interactions