# NCHRP Project 9-61

# Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures

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# Research Team

- Advanced Asphalt Technologies, LLC
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- Western Research Insititute
  - Jeramie Adams - Co-PI
- Consultants
  - Dave Anderson
  - Gayle King
  - Jim Rosenberger
  - Erick Sharp

# Outline

- Objectives
- Project Tasks
- Work Completed
- What's Next

# Objectives

- Evaluate AASHTO 240, AASHTO R 28 and alternatives
- Recommend improvements
  - New procedure
  - Modifications to existing procedures
- Calibrate the improved procedures to accurately simulate aging
  - Mixture production, transport, and placement
  - Service life of the pavement

# NCHRP 9-61 Is Not!

- A study of binder rheology
- A study of binder chemistry
- A study to relate chemical and rheological properties of binders
- A study to recommend improved specification criteria

# Approach

- Task 1. Evaluate and Select Methods
- Task 2. Prepare Experimental Plans
- Task 3. Prepare Interim Report
- Task 4. Conduct and Analyze Experiments
- Task 5. Perform Industry Impact Assessment
- Task 6. Prepare Methods in AASHTO Format
- Task 7. Prepare Final Report

# How Much Binder?

- Only a few grams if you use 4 mm DSR
  - Probably not realistic at this time
- M 320 or M 332 without direct tension
  - 35 g for verification
  - 65 g for grading
- M 320 or M 332 with Modified DENT? (per 9-59)
  - 75 g for verification
  - 105 g for grading
- M 320 or M 332 with LAS? (per 9-59)
  - 40 g for verification
  - 70 g for grading

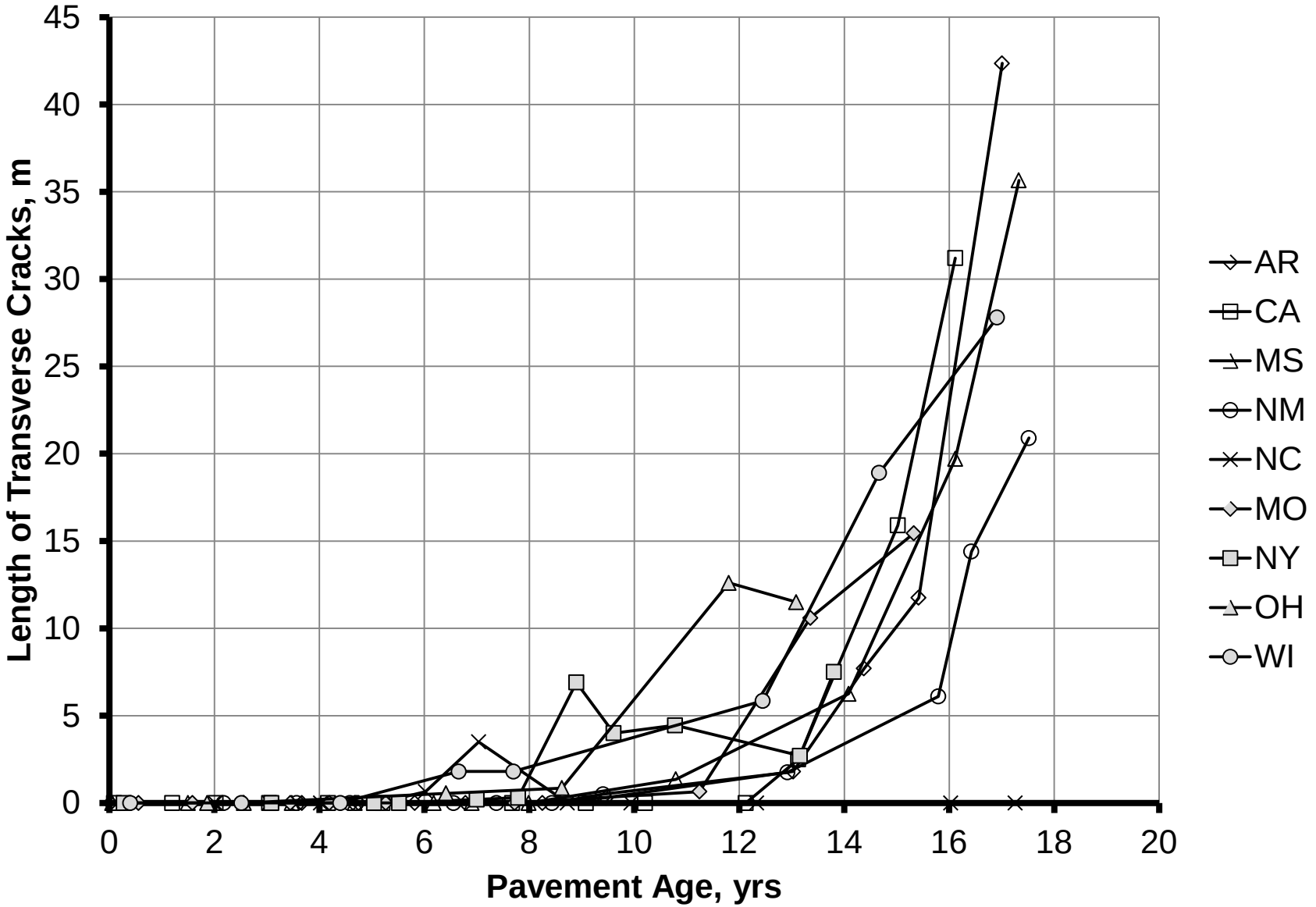
# What is Target Age for Long-Term?

- Consensus that R 28 (20 hour PAV) is not severe enough
- Research now using 40 hour PAV
- Limited field data equating either 20 or 40 hour PAV to field properties
  - SHRP A 369:  20 hr PAV ~ 4 to 8 years
  - Erskine, et al. 2012: 40 hr PAV ~ 8 years
  - AAPTP Project 06-01: No change to R 28
  - WRI Fundamental Properties of Asphalts and Modified Asphalts III : ALF, and AZ
  - Braden Smith

# Analysis of LTPP SPS 8 Sites

- New pavements on roads with limited truck traffic
- Two sections
  - 4 in AC on 8 in of aggregate base
  - 7 in AC on 12 in of aggregate base
- 15 sites constructed
- Distresses monitored every 1 to 2 years

# Transverse Cracking in SPS 8 Sections



# Practice Related T 240 Conditioning Issues

- Uniformity of the film and how well it is renewed is viscosity dependent
- Some modified binders tend to crawl out of the bottle
- Shape of the bottle makes recovery of the binder and cleaning difficult
- Procedure does not address WMA

# Short-Term Alternates

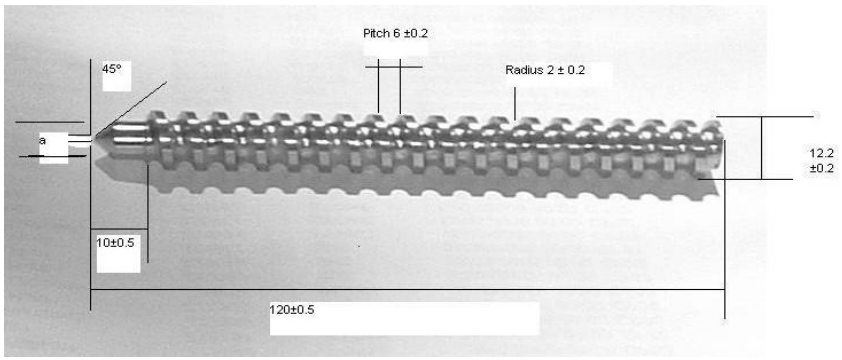
- Modified German Rotating Flask
- Stirred Air Flow Test
- Universal Simple Aging Test
- Rotating Cylinder Ageing Test
- Ageing Profile Test

# Short-Term Considerations

- Quantity of binder
- Number of binders per run
- Conditioning time
- Improves film uniformity
- Eliminates crawling from container
- Suitable for crumb rubber binders
- Simulate HMA and WMA temperatures
- Improves binder recovery
- Standard available
- Equipment availability
- Equipment cost
- Training cost

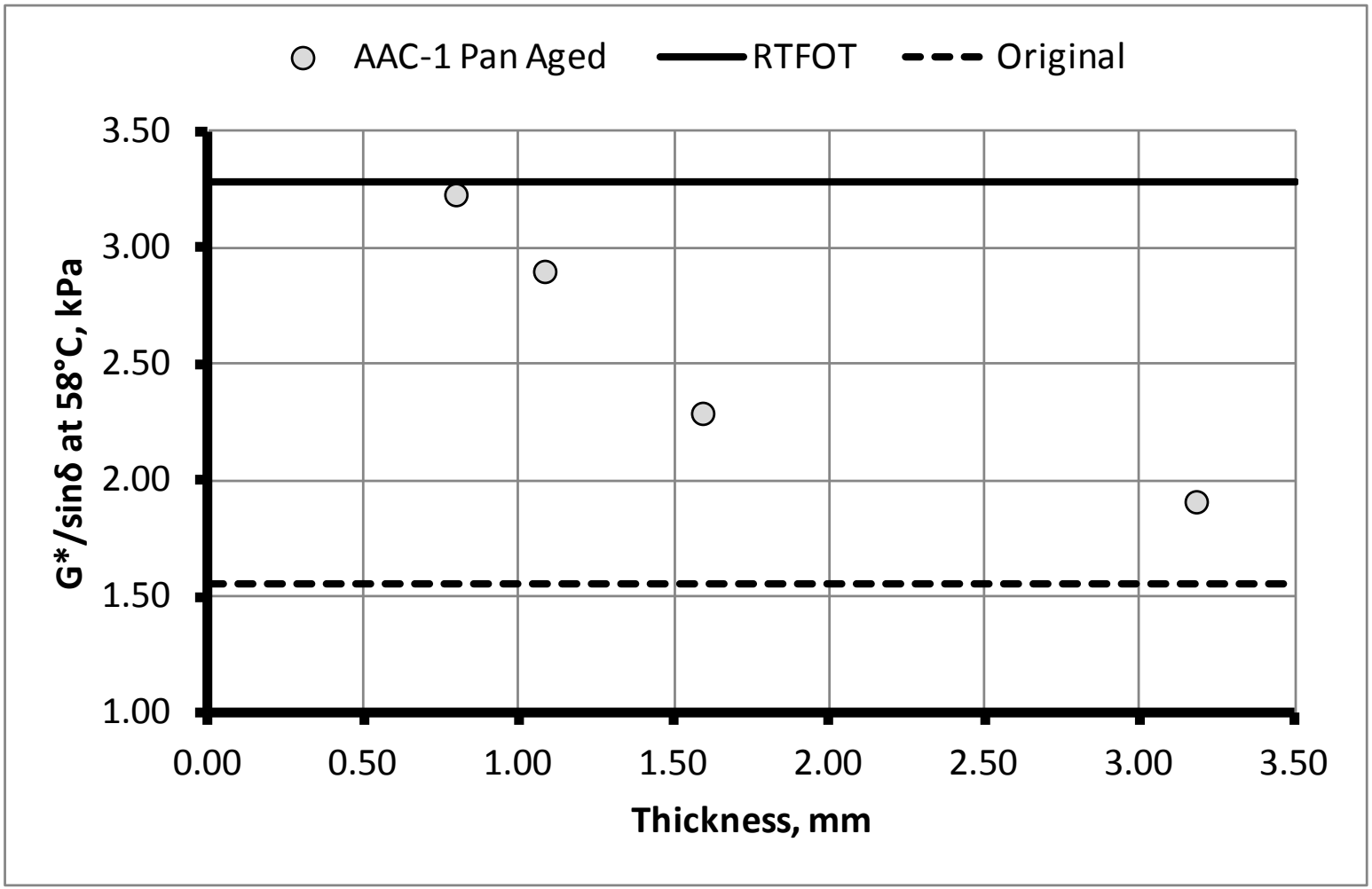
# Short-Term Selections

- Modifications to t 240 made in the U.K. Ageing Profile Test

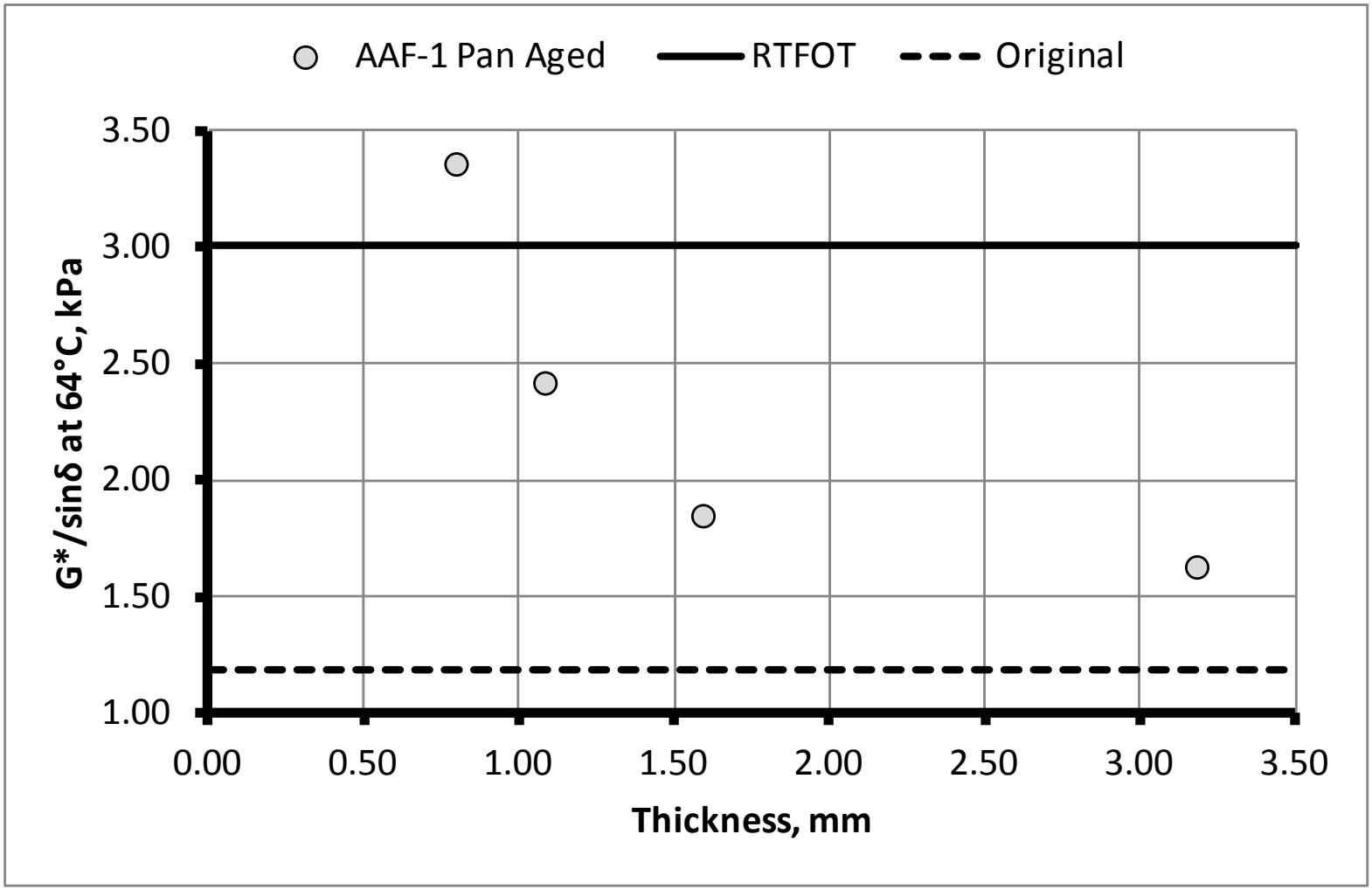



- Thicker Film USAT
  - Around 0.8 mm rather than 0.3 mm to increase yield

# AAC-1 @ 163 °C for 85 min



# AAF-1 @ 163 C for 85 min



# Practice Related R 28 Conditioning Issues

- Conditioning is not severe enough
- Service life that is simulated is not well defined

# Long-Term Alternates

- Rotating Cylinder Ageing Test
- Ageing Profile Test
- Universal Simple Aging Test
- Extended Time PAV
- Thinner Film PAV
- Increased Temperature PAV
- Mixing in PAV
  - Ultrasonic
  - Resonant Acoustic

# Long-Term Considerations

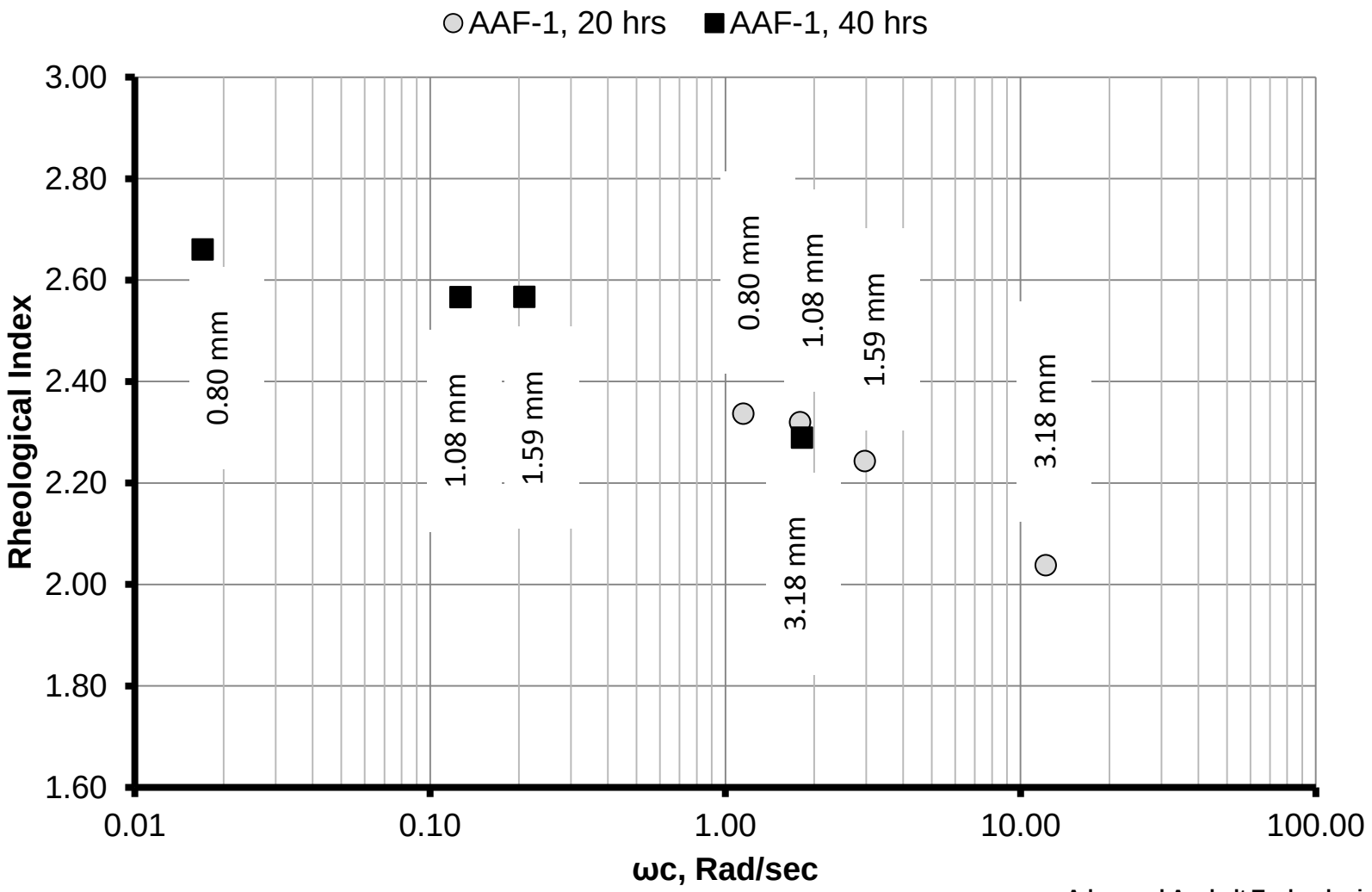
- Quantity of binder
- Number of binders per run
- Conditioning time
- Conditioning temperature
- Atmosphere (air vs oxygen)
- Pressure
- Correlated to field aging
- Standard available
- Equipment availability
- Equipment cost
- Training cost

# Long-Term Selection

- Thinner Film PAV

| Film Thickness, mm | Surface Area Required, $cm^2$ | |
|---|---|---|
| | Verification (75 g assumed) | Grading (105 g assumed) |
| 3.18 | 233 | 330 |
| 1.59 | 465 | 660 |
| 0.8 | 925 | 1313 |
| 0.3 | 2467 | 3500 |

# AAF-1 Master Curve Parameters

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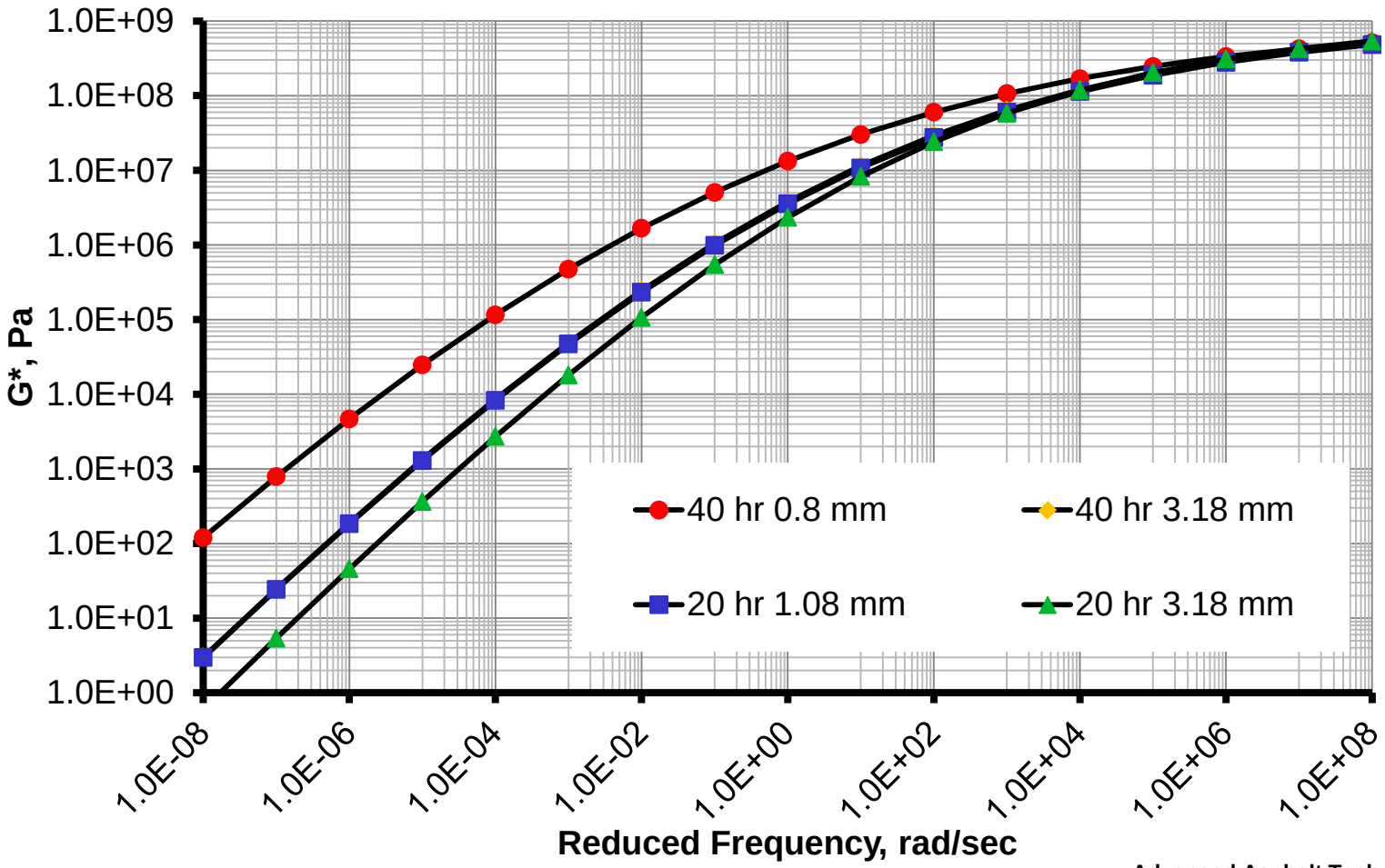
# AAF-1 Master Curves

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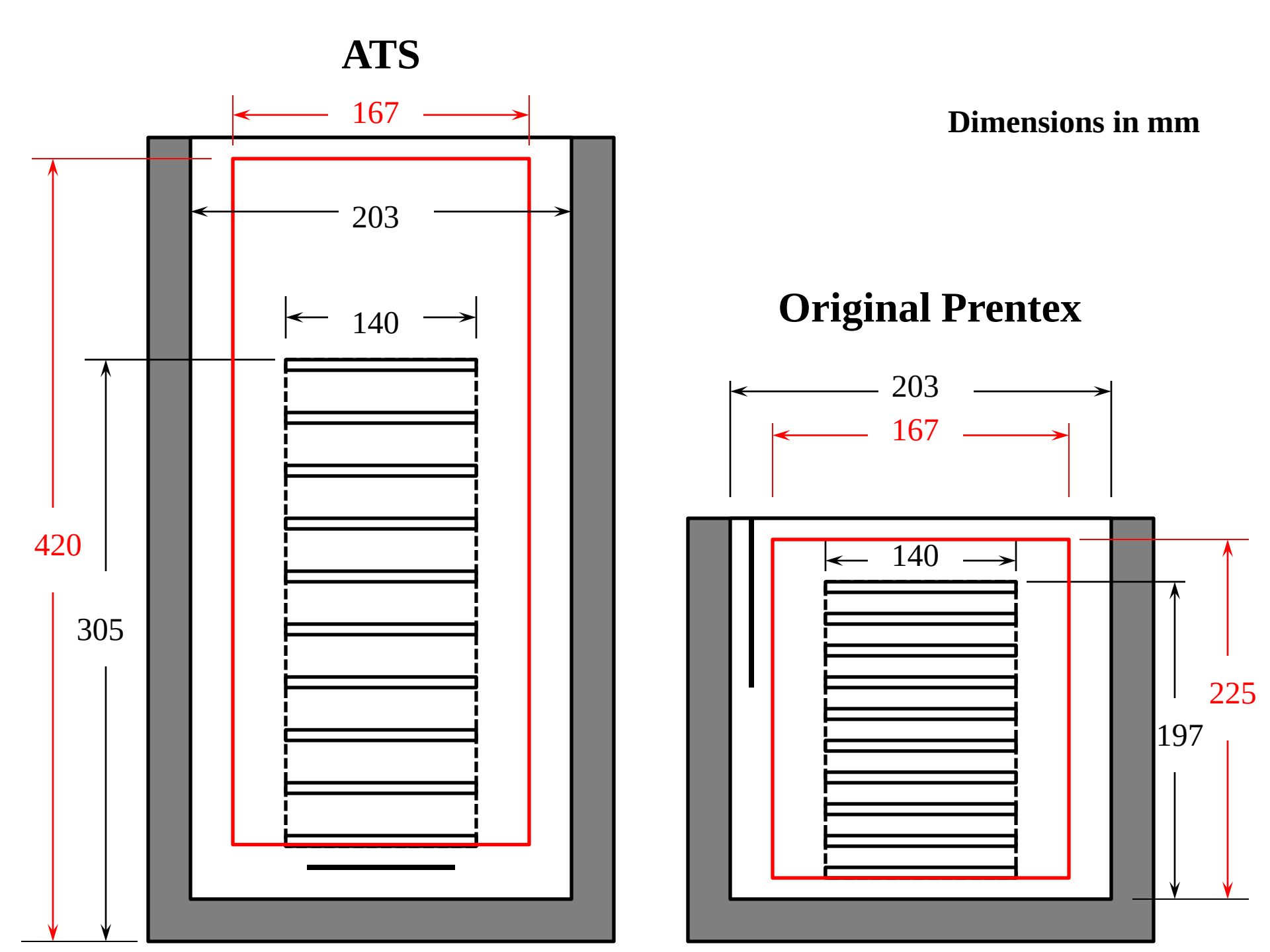
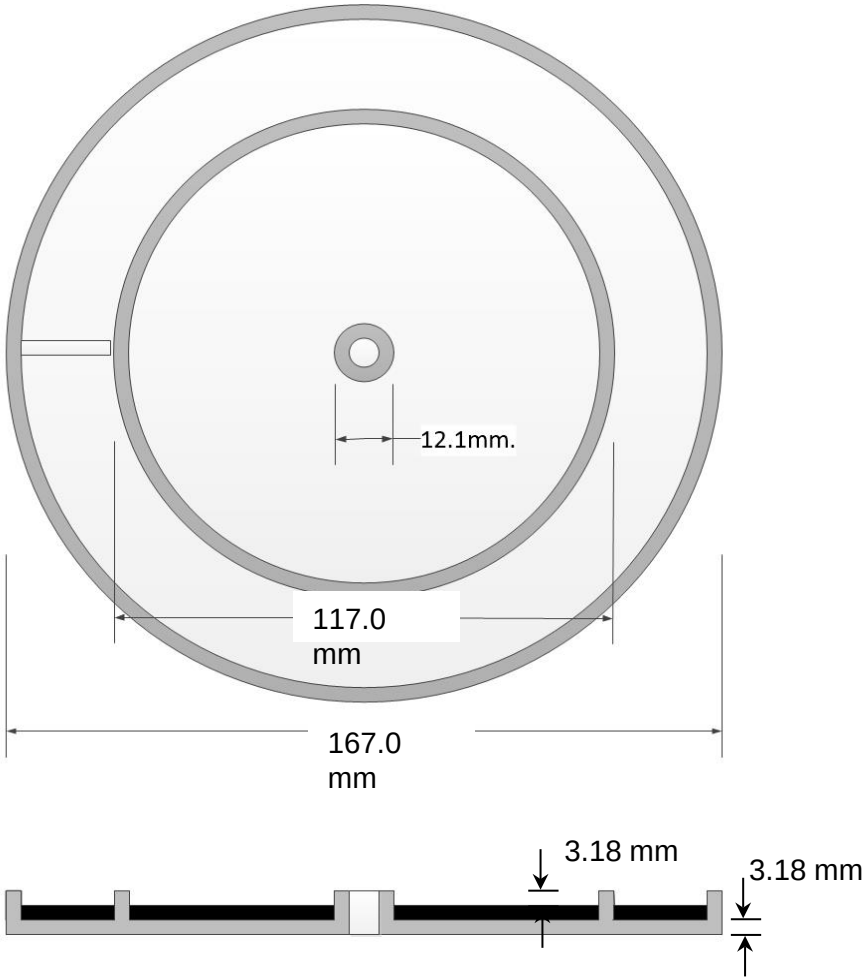

ATS
167
203
140
420
305
Dimensions in mm
Original Prentex
203
167
140
225
197

# Example PAV Pan for 0.8 mm Film



# Proposed Phase 2 Experiments

- Short-Term Final Selection
- Short-Term Calibration
- PAV Thickness, Time, Temperature
- Long-Term Calibration
- Sensitivity Study

# Short-Term Selection

- Make final selection of short-term procedure
  - Thin film aging (0.8 mm)
  - UK mixing screw
  - NCHRP 9-61 improved mixing screw
- Compare binder conditioning procedures to binder recovered from short-term oven aged mixtures
  - NCHRP 9-52 recommendations
    - HMA 2 hours at 135 °C
    - WMA 2 hours at 116 °C

# Short-Term Selection

| Aging Methods | Neat PG 52-34 | | Polymer (Terpolymer) PG 64-34 | | Neat PG 64-22 | | Polymer (SBS) PG 76-22 | | GTR ASTM D 6114 |
|---|---|---|---|---|---|---|---|---|---|
| | WMA | HMA | WMA | HMA | WMA | HMA | WMA | HMA | HMA |
| AASHTO T 240 | X | X | X | X | X | X | X | X | X |
| UK Mixing Screw | X | X | X | X | X | X | X | X | X |
| NCHRP 9-61 Mixing Screw | X | X | X | X | X | X | X | X | X |
| Static Thin Film (0.8 mm) | X | X | X | X | X | X | X | X | X |
| Recovered, NCHRP 9-52 Oven Aging | X | X | X | X | X | X | X | X | X |

Response variables:

- High temperature continuous grade
- Master curves
- CS+SO
- GPC for modified binders

# Short-Term Calibration

- Calibrate the selected procedure (varying conditioning time) to reproduce properties of binder recovered from short-term conditioned loose mix
- NCHRP 9-52 recommendations
  - HMA 2 hours at 135 °C
  - WMA 2 hours at 116 °C
- High Temperature Continuous Grade

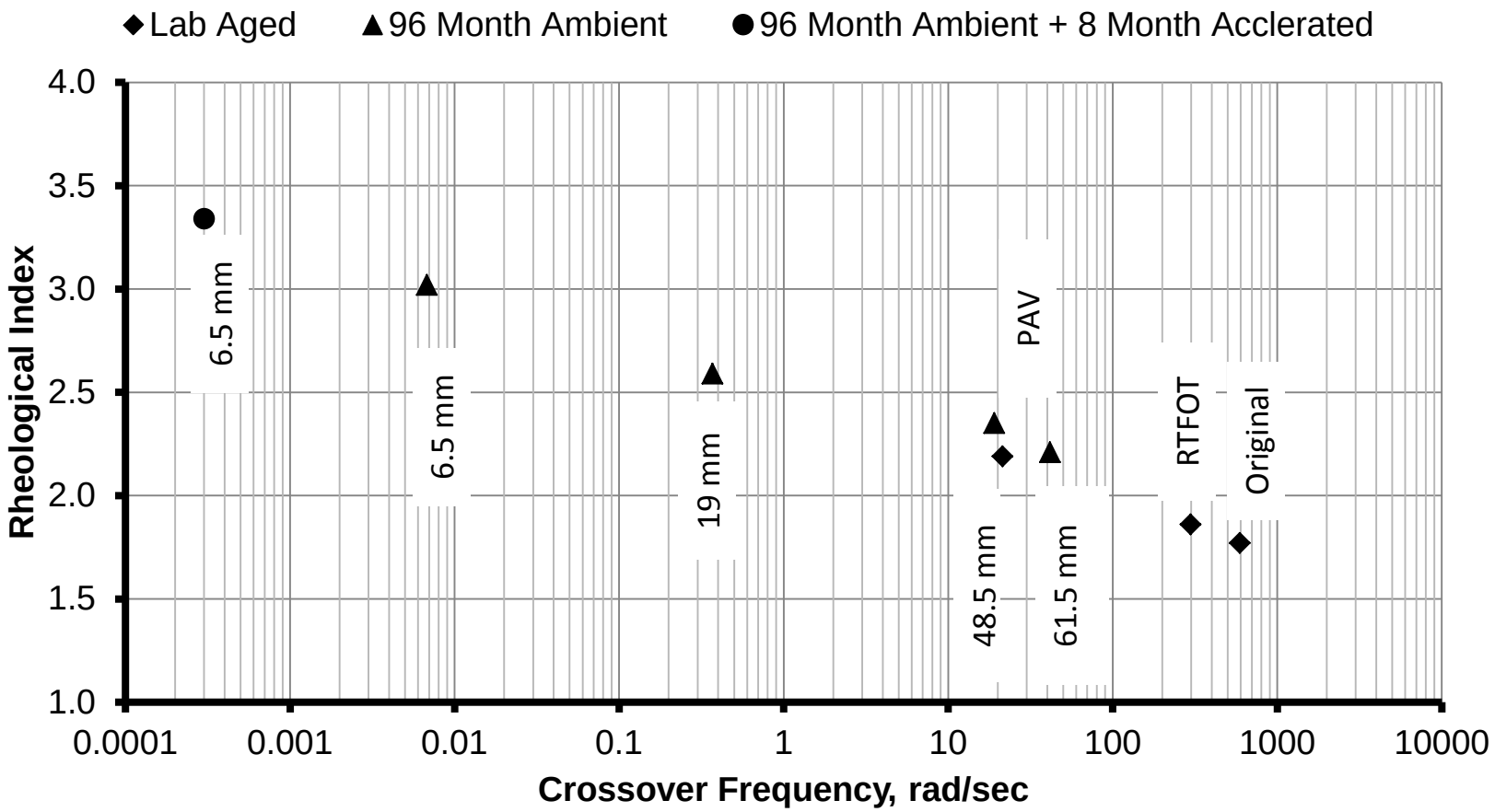
# Short-Term Calibration

| Mix Temp | Binder Properties | | | Mix Properties | | |
|---|---|---|---|---|---|---|
| | Binder Type | Low Temp Grade | Aging Index | 19 mm | 9.5 mm | SMA |
| | | | | Sandstone | Limestone | Diabase with Limestone Filler |
| WMA | Neat | -34 or -28 | Low | X | X | X |
| | | | High | X | X | X |
| | | -22 or -16 | Low | X | X | X |
| | | | High | X | X | X |
| | Modified | -34 or -28 | Low | X | X | X |
| | | | High | X | X | X |
| | | -22 or -16 | Low | X | X | X |
| | | | High | X | X | X |
| HMA | Neat | -34 or -28 | Low | X | X | X |
| | | | High | X | X | X |
| | | -22 or -16 | Low | X | X | X |
| | | | High | X | X | X |
| | Modified | -34 or -28 | Low | X | X | X |
| | | | High | X | X | X |
| | | -22 or -16 | Low | X | X | X |
| | | | High | X | X | X |

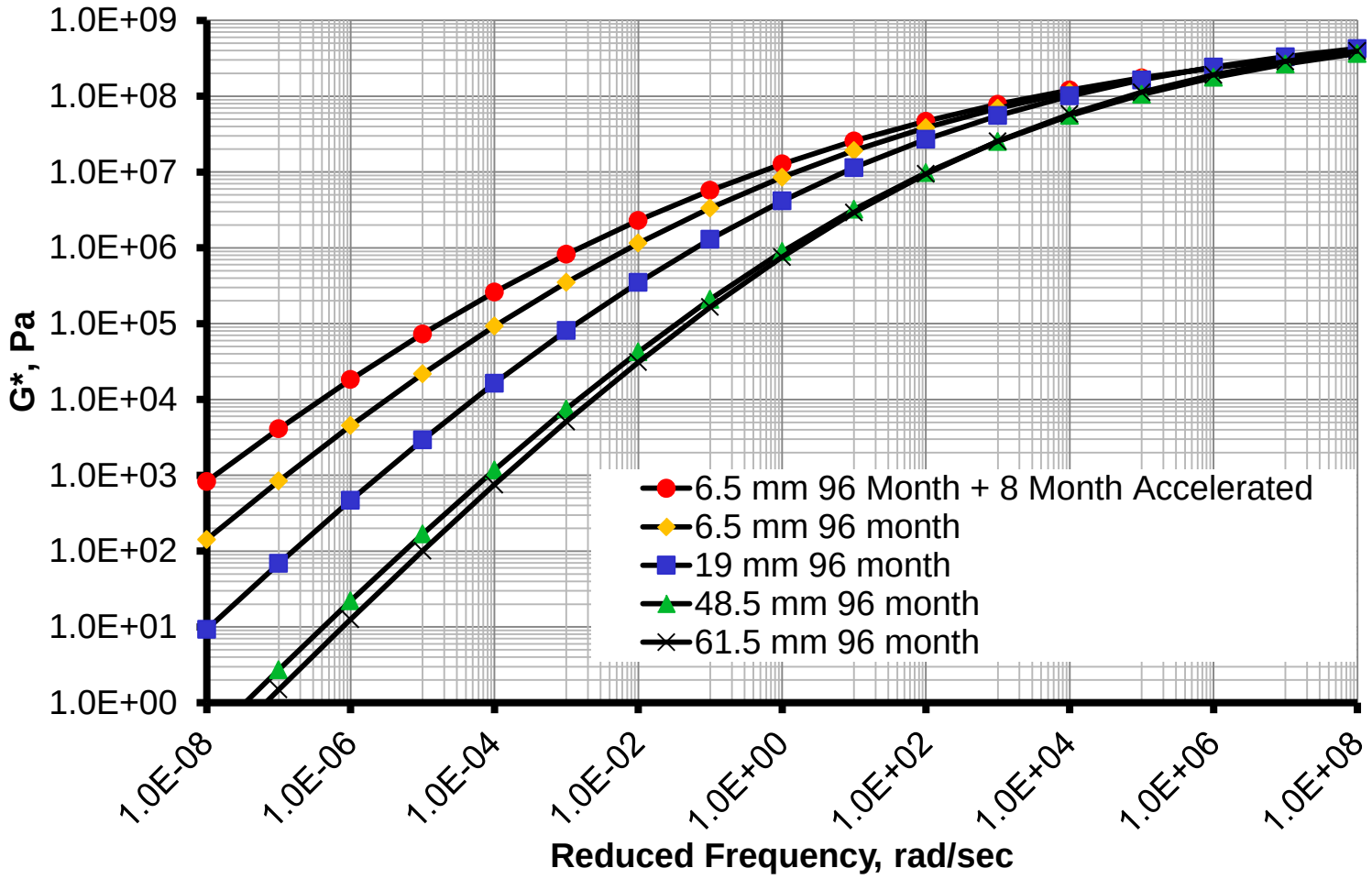
# PAV Thickness, Time, Temperature

- Investigate how to reasonably simulate more aging using the PAV
- Vary thickness, time, temperature
- Compare rheological and chemical properties to recovered binders from ARC Arizona (hot,16 yrs) and Minnesota (cold, 11yrs) sections
- Binder master curves, carbonyl + sulfoxide

# ALF Field Aging



# ALF Master Curves

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# ARC AZ and MN Binders

| Site | Grade | Source | Modification |
|---|---|---|---|
| Arizona US 93 | PG 76-16 | WTI/WTS blend | Airblown |
| | PG 76-16 | Venezuelan | N/A |
| | PG 76-16 | Rocky Mountain Blend | N/A |
| | PG 76-16 | Canadian Blend | N/a |
| Rochester, MN | PG 58-34 | Canadian Blend | Terpolymer |
| | PG 58-28 | Canadian Blend | N/A |
| | PG 58-28 | Middle East Blend | N/A |
| | PG 58-28 | Venezuelan Blend | N/A |

# Partial Factorial

| Temp, C | Thickness, mm | Time, hrs | | |
|---|---|---|---|---|
| | | 20 | 30 | 40 |
| 90 | 3.18 | | X | |
| | 1.59 | X | | X |
| | 0.80 | | X | |
| 100 | 3.18 | X | | X |
| | 1.59 | | X | |
| | 0.80 | X | | X |
| 110 | 3.18 | | X | |
| | 1.59 | X | | X |
| | 0.80 | | X | |

Response surface experiment
Process improvement experiments

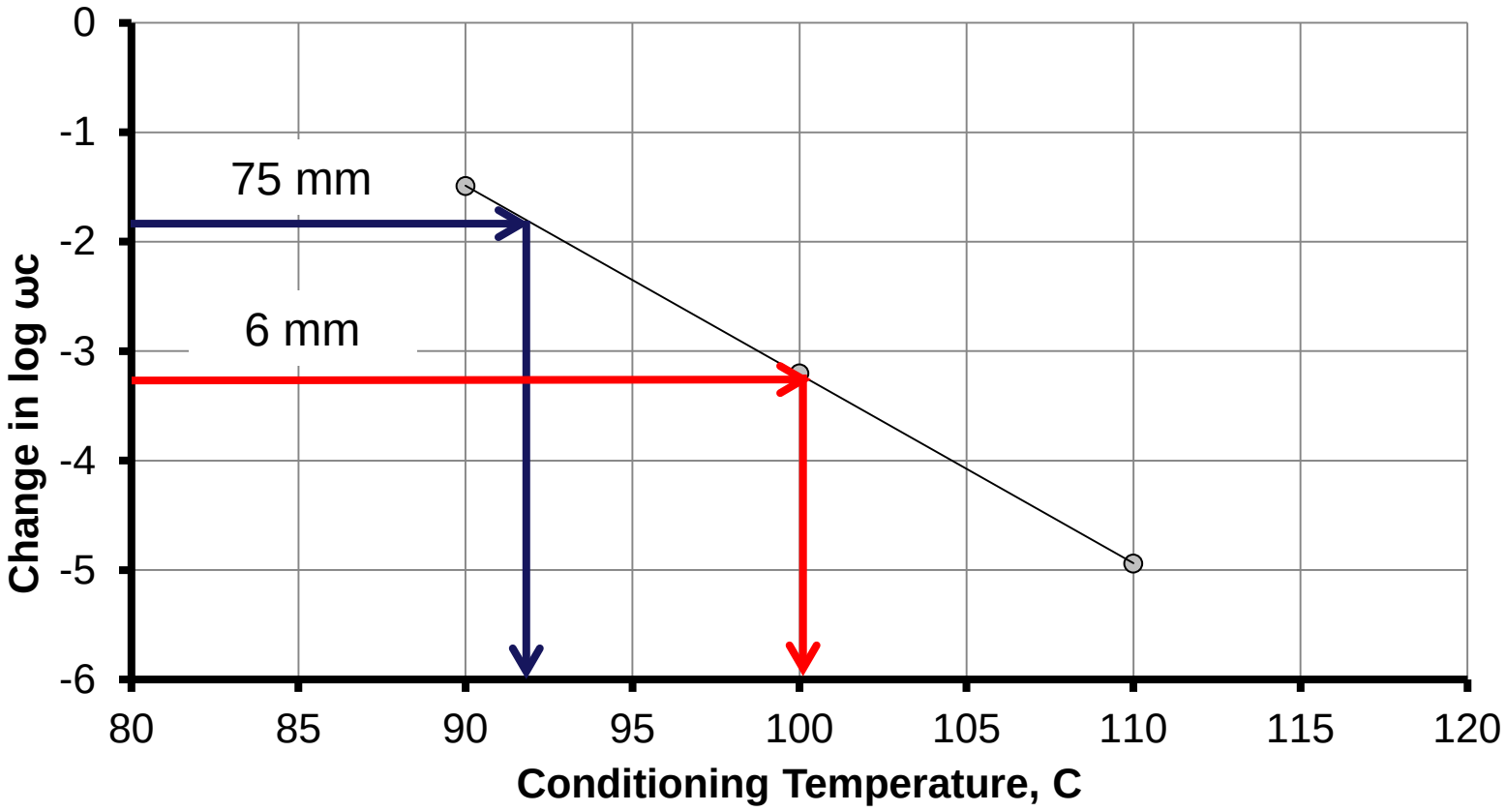
# Output of Thickness, Time, Temperature Experiment

- Film thickness
- Conditioning time
- Range of useable temperatures

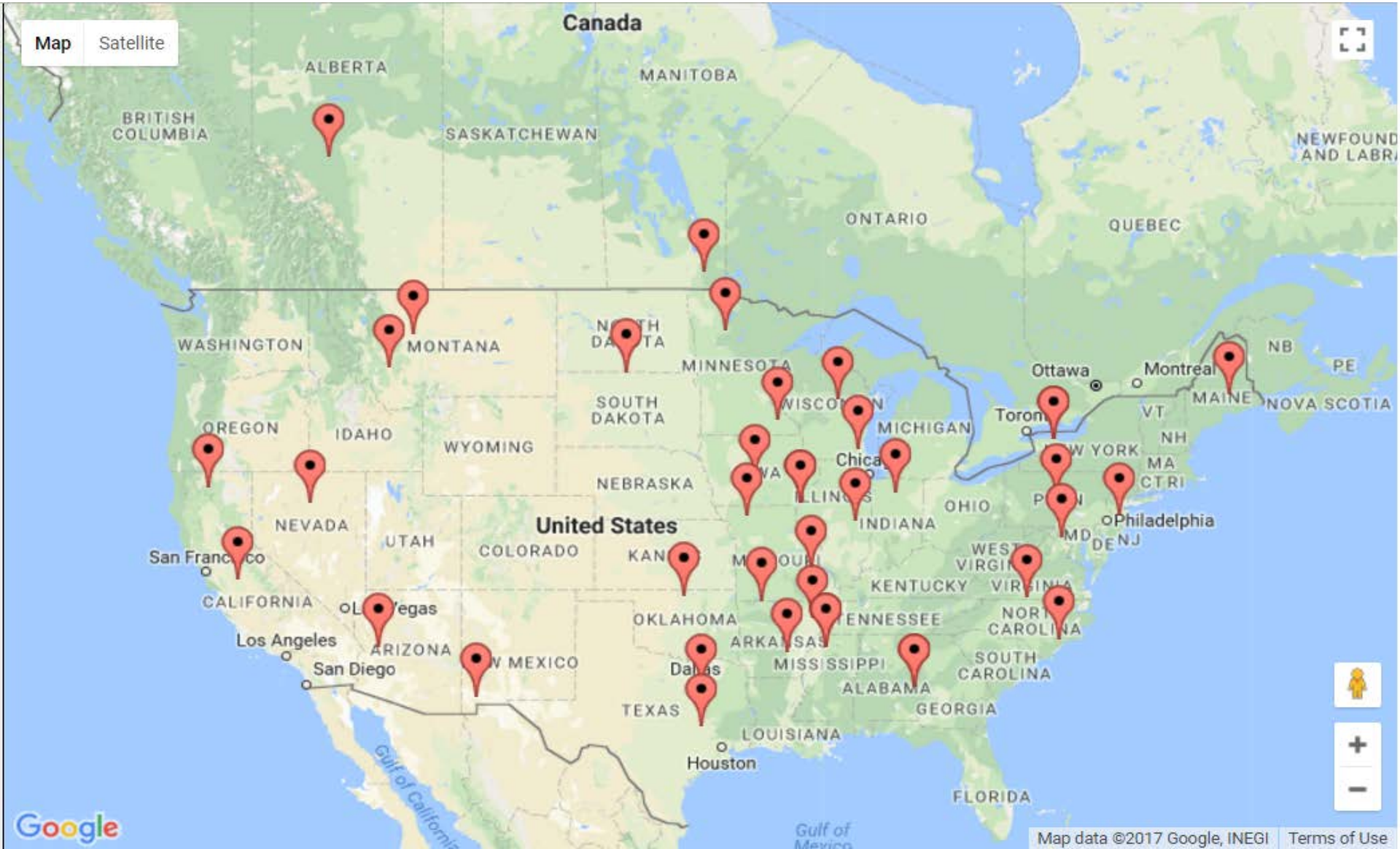
# Long-Term Calibration

- Using thickness and time from the previous experiment, vary the conditioning temperature to determine conditioning temperature that reproduces the properties of binder recovered from field cores
- Binder master curves, carbonyl + sulfoxide

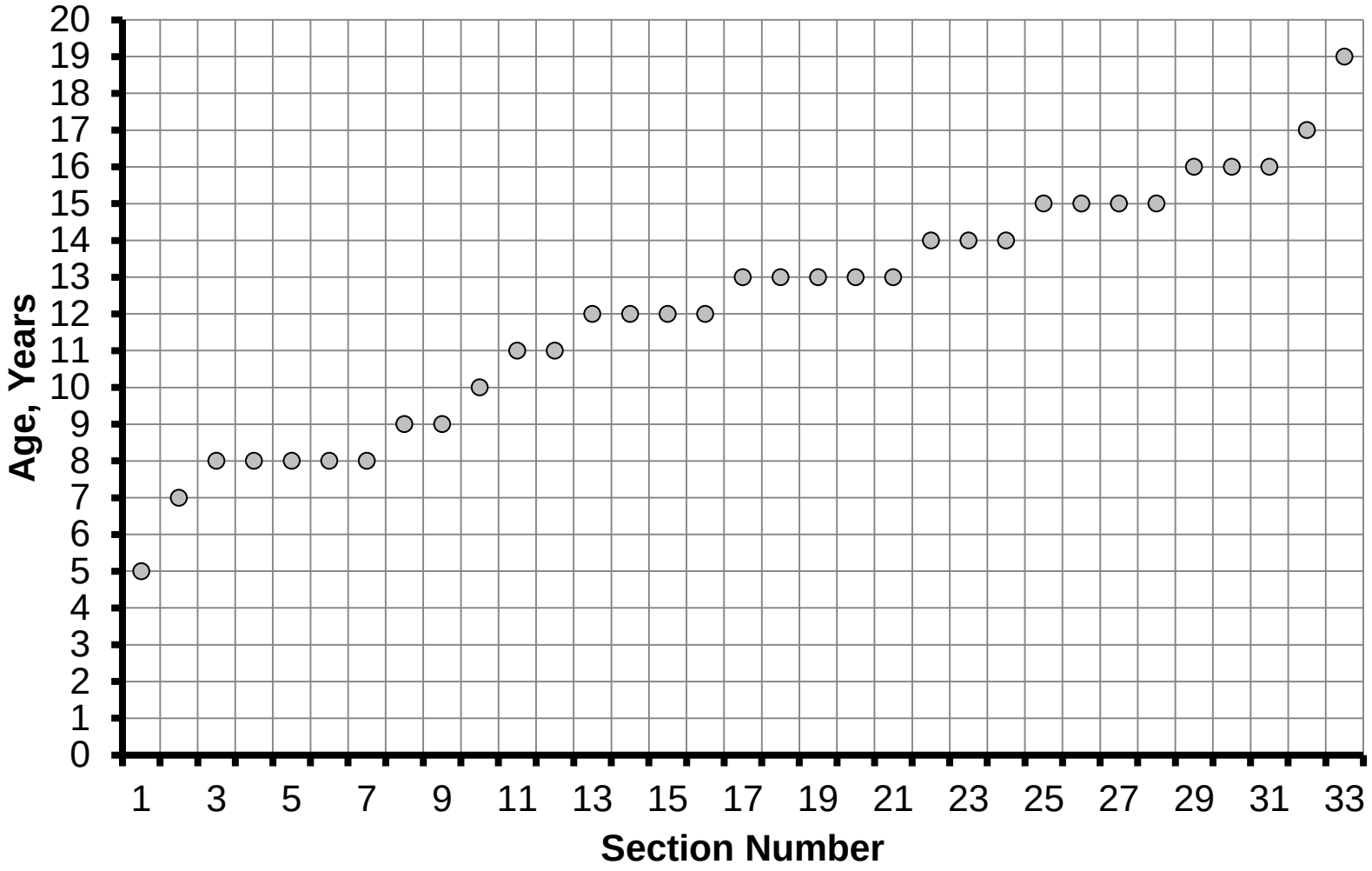
# Example


0
-1
-2
-3
-4
-5
-6
75 mm
6 mm
Change in log ωc
80
85
90
95
100
105
110
115
120
Conditioning Temperature, C

# Available Original Binders and Cores From LTPP



# Age

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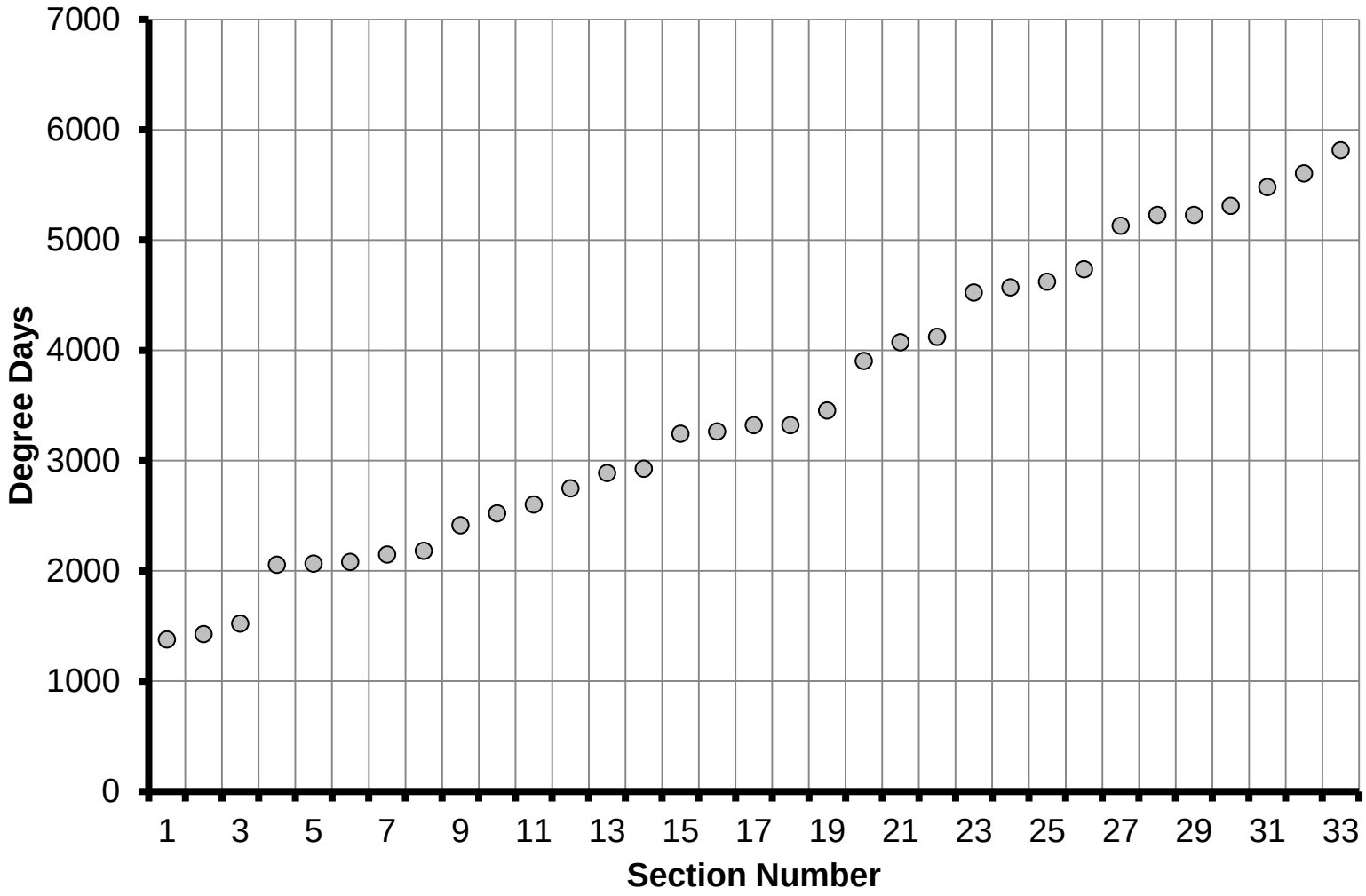
# Degree Days


7000
6000
5000
4000
3000
2000
1000
0
Degree Days
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Section Number

# Regression Analysis of Conditioning Temperatures

- Factors
  - Climate
  - Age
  - Depth in pavement
  - Air voids
  - Binder volume
- Use regression model to recommend final lab conditioning temperatures

# Sensitivity Study

- M 320 and M 332 Grade several binders
  - Current T 240 and R 28
  - Improved procedures developed in NCHRP 9-61
  - Materials with proven performance
  - Newer materials
  - 8 to 10 binders
- Information for the Industry Assessment