Variability of Ignition Furnace Correction Factors (NCHRP 9-56)

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95th NESMEA Annual Meeting
October 22-23, 2019
Portland, ME

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Outline

- Background
- Objectives
- Methodology
- Experimental Plan Results
- Conclusions
- Recommendations/Current Research

Background

- Accurate determination of AC and aggregate gradation critical in control of quality of asphalt mixtures during construction
- Ignition method widely used to determine AC and gradation

Basic Procedure:

- Oven uses high temp. to burn asphalt off aggregate
- Procedure terminates when weight of sample stabilizes- indicating there is no more binder to ignite
- CF needed to account for difference between known binder content and ignition test results

Background

Ignition method (AASHTO T 308) and solvent extraction (AASHTO T 164) most common methods to measure AC

Condition	Standard Deviation		Acceptable Range of Two Tests	
	T 308	T 164	T 308	T 164
Single Operator Precision: AC (%)	0.069	0.18	0.196	0.52
Multilaboratory Precision: AC (%)	0.117	0.29	0.33	0.81

Background

- Share CFs is a practice by some agencies
- Approach violates AASHTO T 308 which indicates CF must be established for each mix and ignition unit
- Some states have aggregates with high mass loss and don’t allow use of ignition tests
- States like Indiana and Wisconsin have reported problems with aggregates such as dolomites
- High CFs result in more variability in measured AC content

Background

Temperature effect (Kowalski et al, 2010)

- High temp. during ignition produced decomposition which causes mass loss to continue after binder is burned off
- Mass loss f(test temp), higher loss as temp. increases
- Higher test temperature, sooner oven temp. exceeded target and sooner temp peaked
- Decreasing temp. has a significant effect on mass loss and rate of mass loss

Background

Lime effect (Prowell and Youtcheff, 2000)

- Hydrated lime has a significant effect on CF
- Lime addition decreases CF; CF varied from 0.64 with no hydrated lime to 0.13 with 2% hydrated lime
- Variability reported large enough to cause non-compliance with quality control tests according to VDOT’s specifications

Description	Average	CF
Control	5.84	0.64
+0.5% hydrated lime	5.64	0.44
+1 % hydrated lime	5.47	0.27
+2% hydrated lime	5.33	0.13

Objectives

- Assess the variability of ignition oven CFs for different ignition brand and mixes
- Evaluate effect of sharing CFs between units
- Evaluate alternatives to minimize variability on asphalt CFs

Methodology

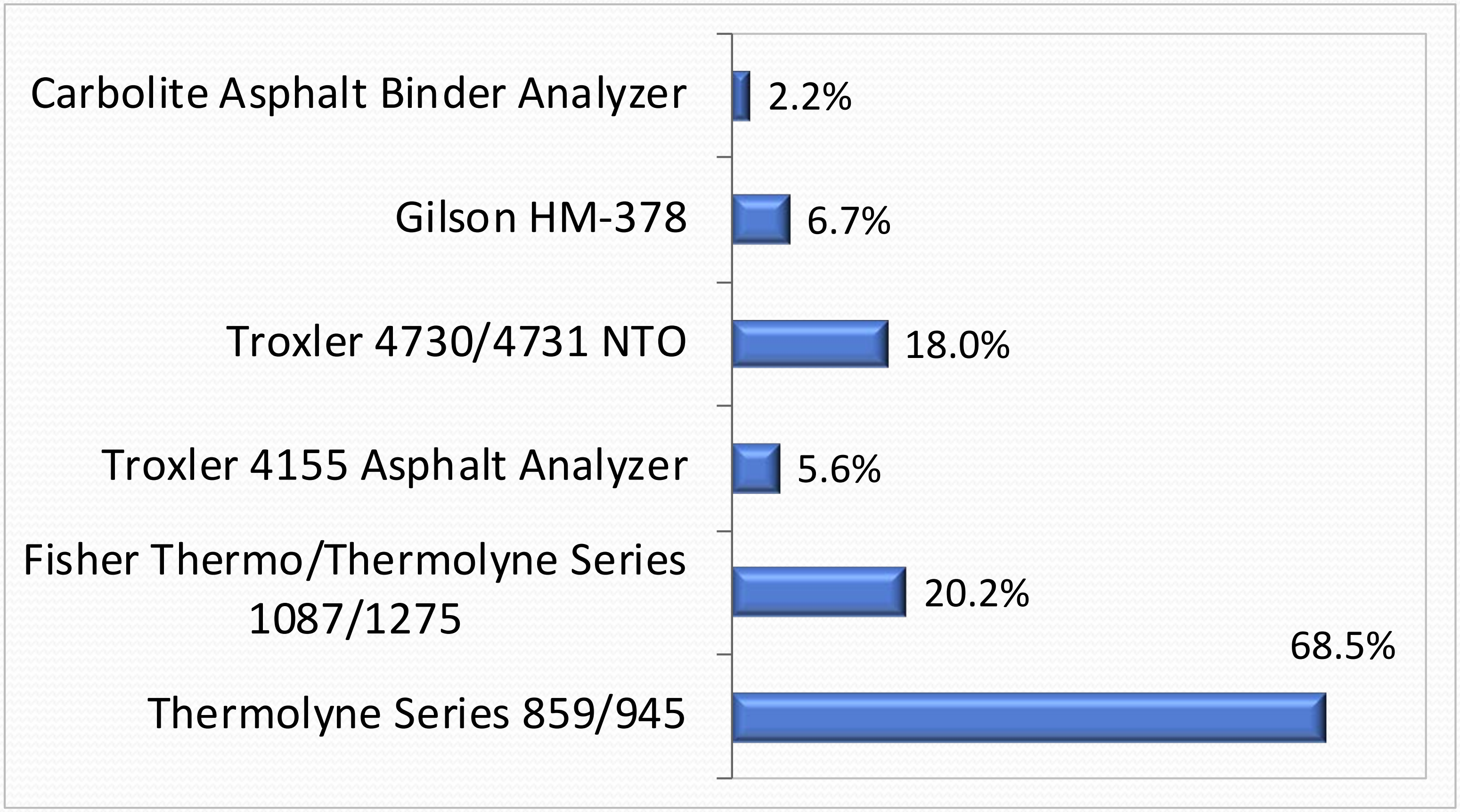
Project encompassed three tasks:

- Survey directed to state DOT and industry, regarding practices(units used, typical CFs) and factors affecting CF with ignition furnaces (temperature, use of hydrated lime, aggregate geology)
- Sensitivity study at NCAT
- Interlaboratory study- Troubleshooting outliers

Agency/ Contractor Survey

- Insight and concerns regarding use of ignition test
- 60 agency responses representing 42/50 US states, 7/10 Canadian provinces and federal lands
- Additional 37 responses from contractors and 7 responses from testing labs

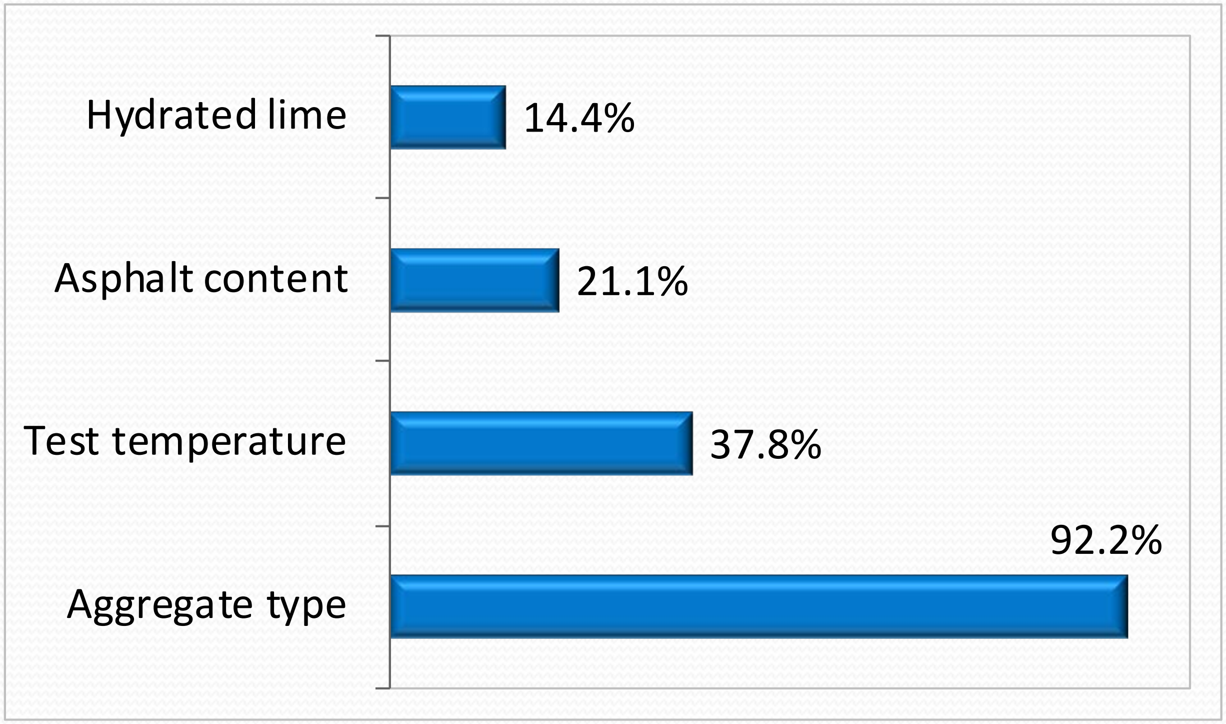
Ignition Furnace Types



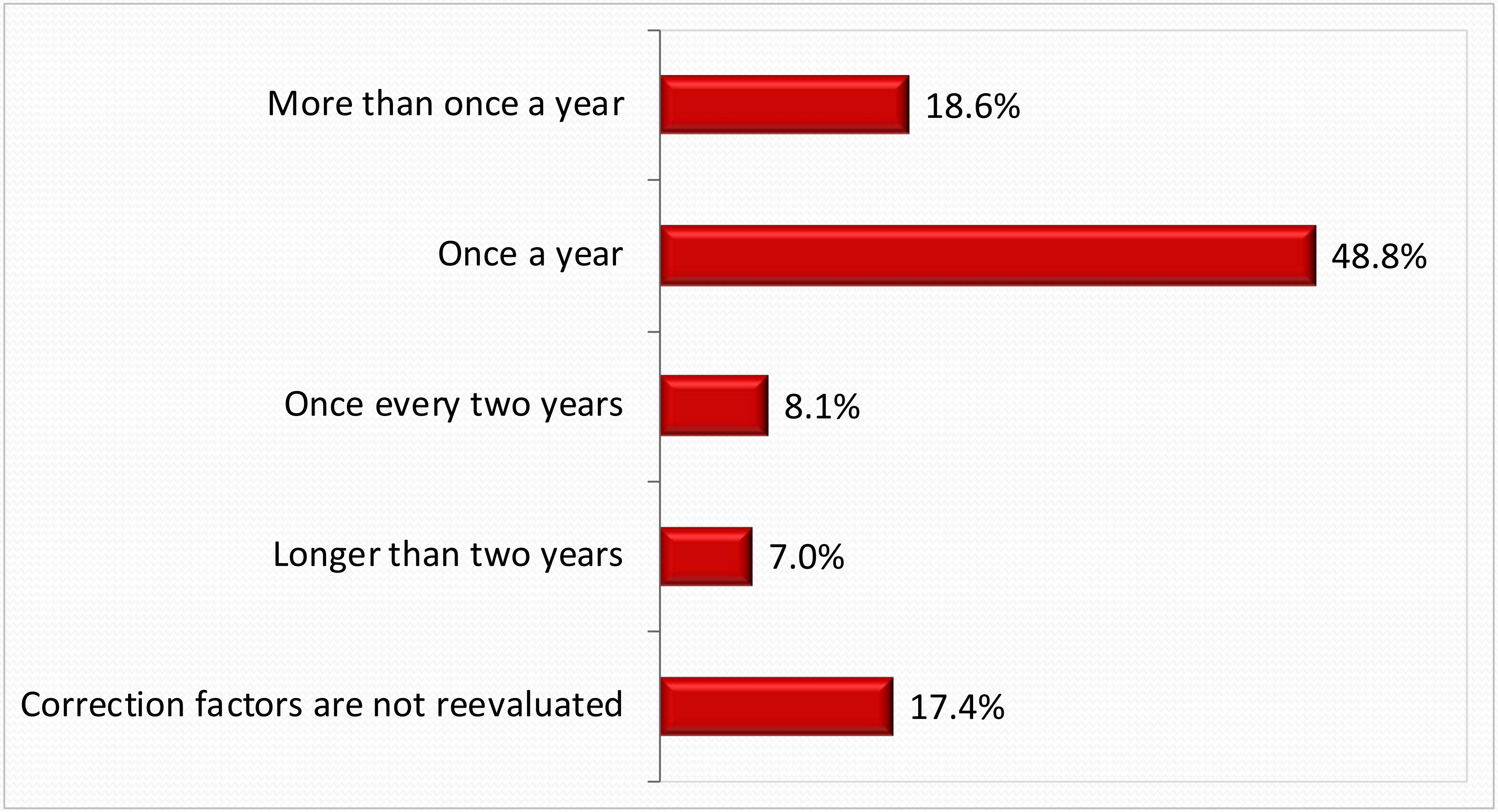
- 93.3% - use internal balances
- 56.3% indicated differences in CF with different brands, models or locations

Factors Affecting Ignition Furnace CF

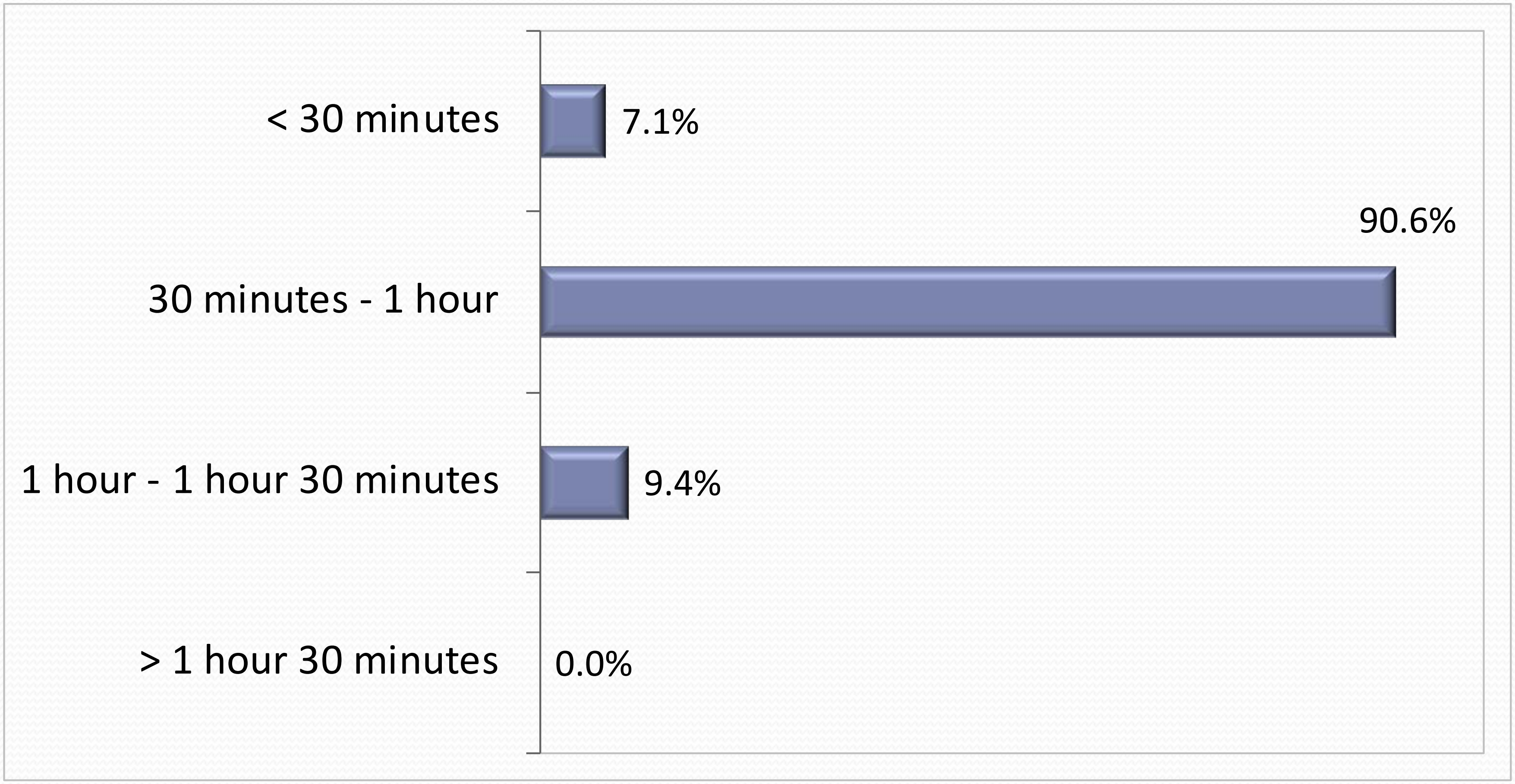
- 92.2% aggregate type significant, follow by test temperature, AC content and use of hydrated lime
- Samples with higher AC/larger samples →more asphalt to burn → higher peak test temperature
- Other factors : RAP/RAS; length of vent pipe, cleanliness of oven, how baskets are loaded



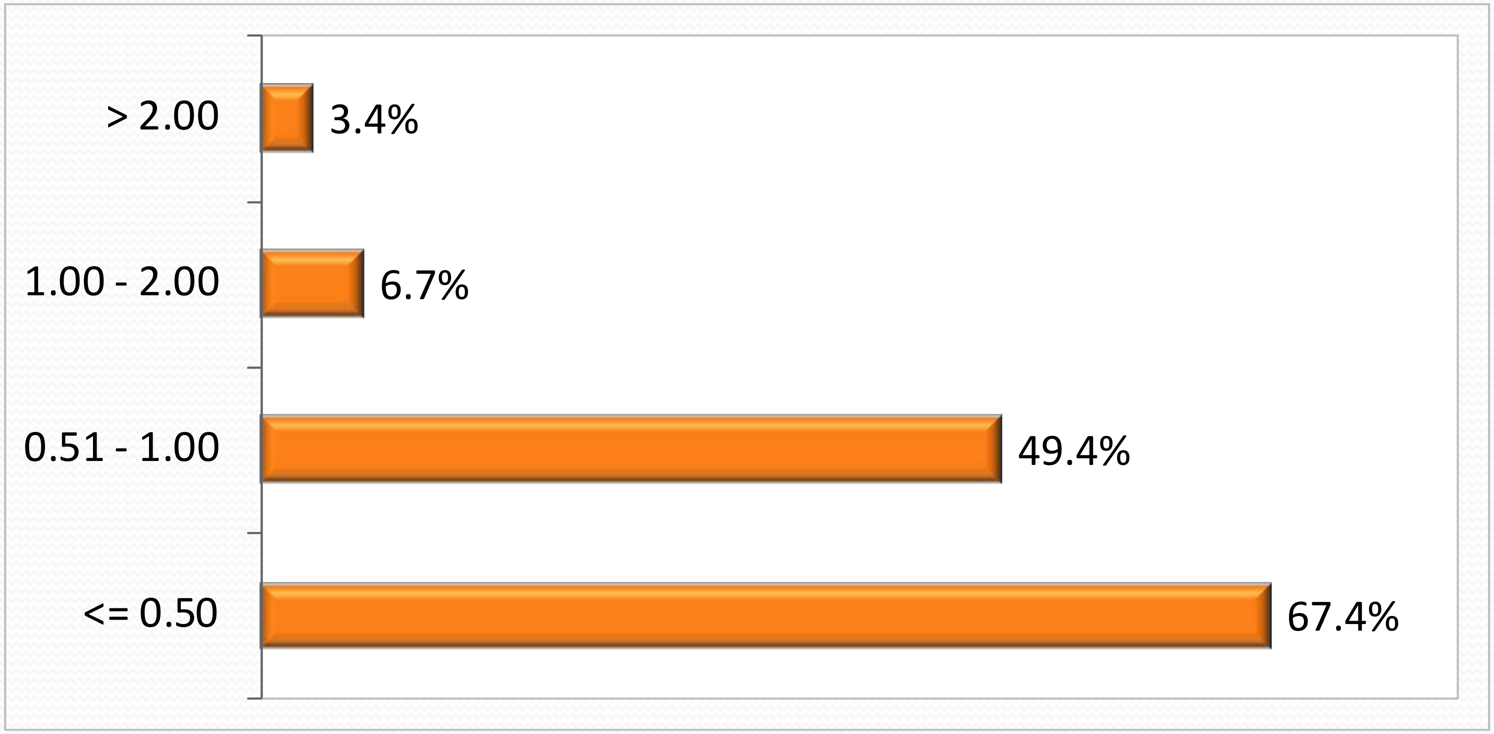
Frequency at which CF are Determined/Reevaluated



Typical Sample Burn Times



Typical Asphalt Content CF Range



- Majority indicated CF <1
- Some agencies identified CF >1 is common
- Granite, gravel and limestone most common aggregates

Aggregates/Mixes

Four Aggregates/Mixes, 12.5mm NMAS; PG 67-22

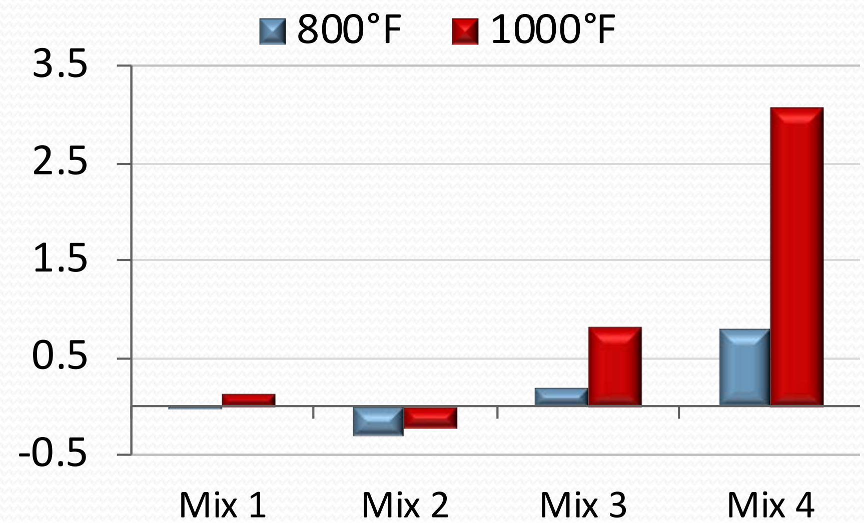
Aggregate / Mix	Aggregate Description	Source	Optimum AC %	Expected CF Range
1	Limestone and Granite	Calera, AL	5.2	0.0 - 0.5
2	Limestone and Granite with 1% Lime	Calera, AL	5.2	0.0 - 0.5
3	Limestone	Barbeau, MI	6.2	0.5 - 1.0
4	Dolomite	Delphi, IN	6.1	1.0 - 3.0

Sensitivity Study at NCAT Lab

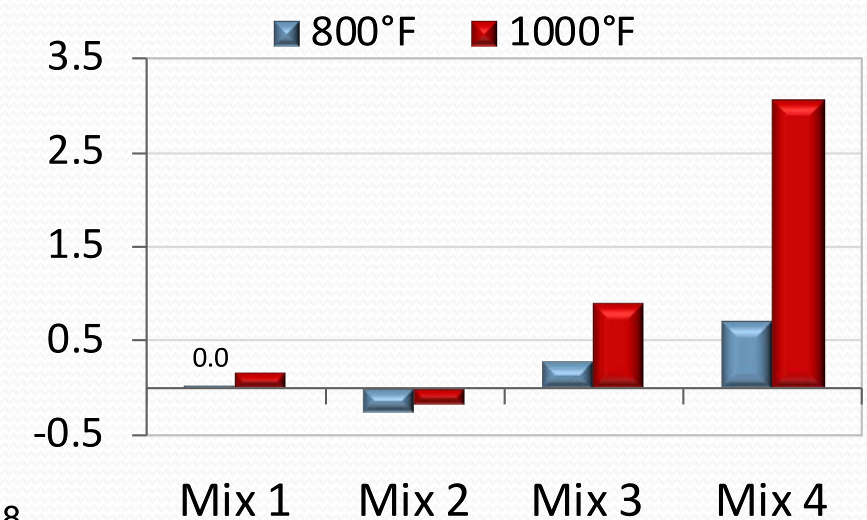
Factors	Levels
Ovens	Thermolyne, Troxler, Gilson
Test Temperature	800°F, 1000°F (Default, Option 1 for Troxler)
Air Flow	30% Open, 100% Open
Sample Mass	1500 , 2000 grams
AC Content	Optimum AC -1%, Optimum AC +1%

Sensitivity Study

- Primary factor affecting the asphalt CF was the test temperature.
- Decreasing the test temperature from 1000 °F to 800°F decreases the aggregate mass loss for all mixes that do not contain lime.



AC content =Optimum - 1%



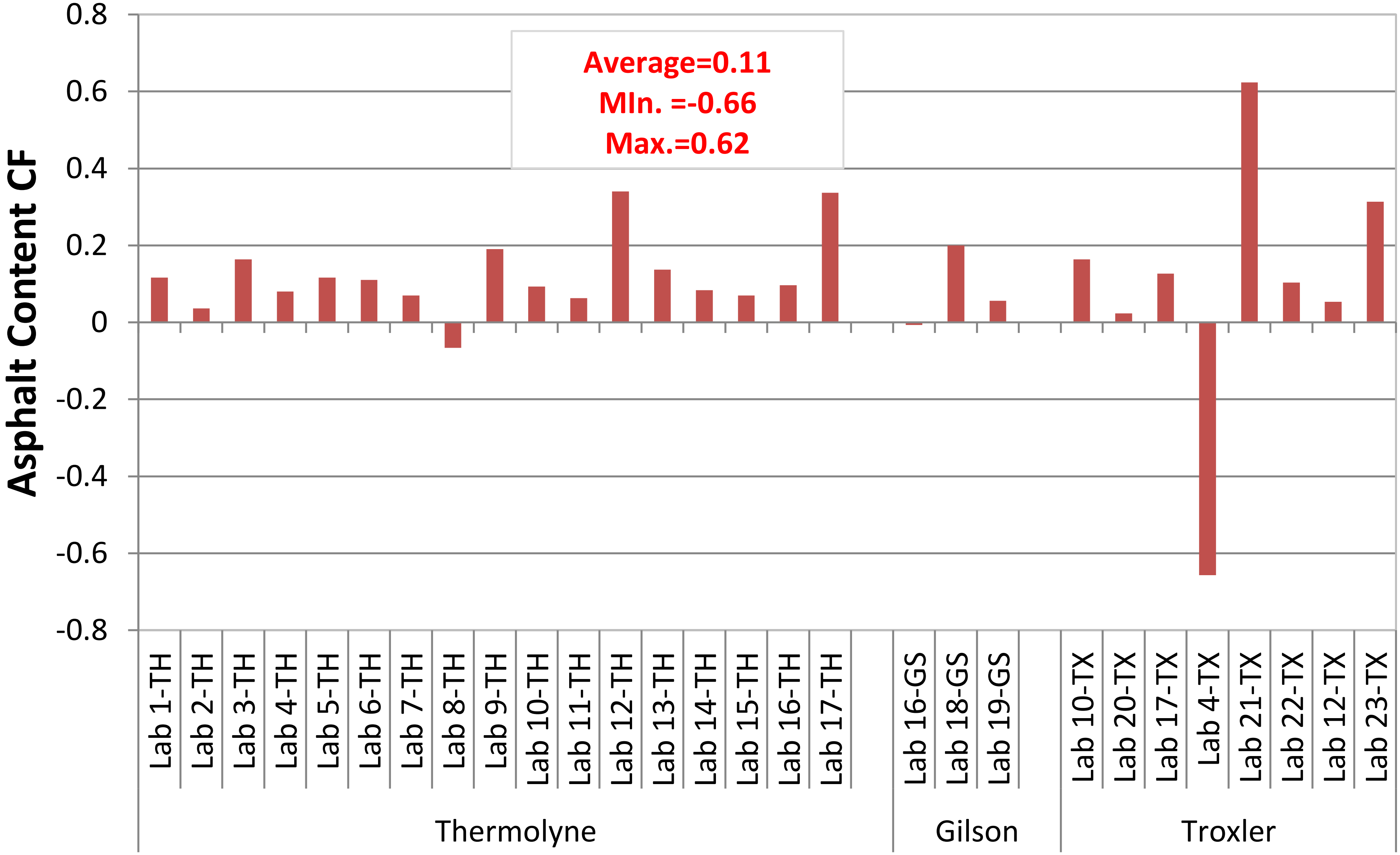
AC content =Optimum +1%

Experimental Plan-Interlaboratory Study

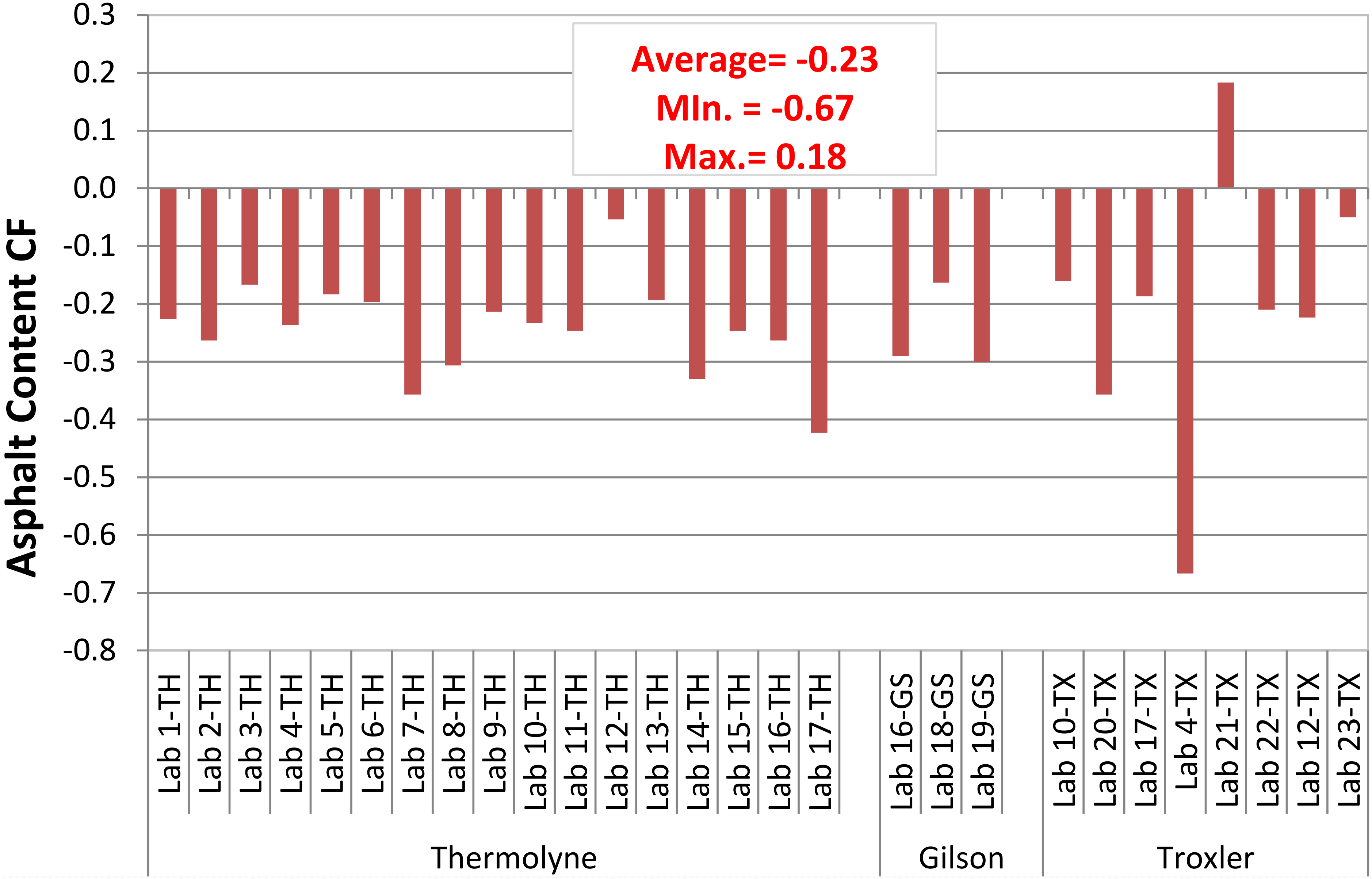
Labs	18 DOT agencies; 5 Contractors/Research
Oven brand	17 Thermolyne, 8 Troxler, 3 Gilson
Number of Mixes	Four mixes at their optimum asphalt content
Test temperature	1000°F (mixes 1-3) and 900°F (mix 4) for convection units (Thermolyne, Gilson); default and option 1 for infrared unit(Troxler)
Replicates	3 per mix

Interlaboratory Study Results

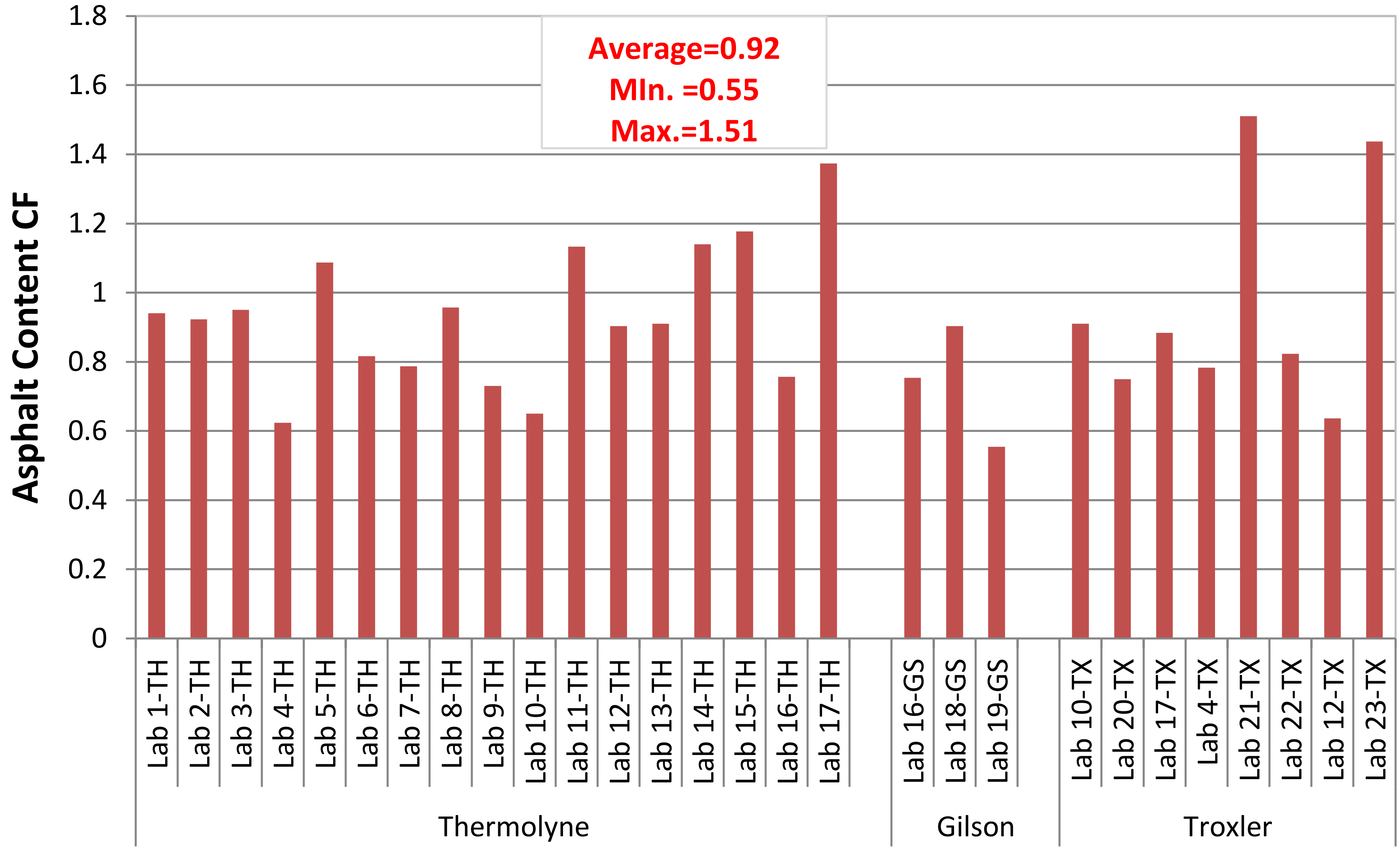
Asphalt Content CFs -Mix 1



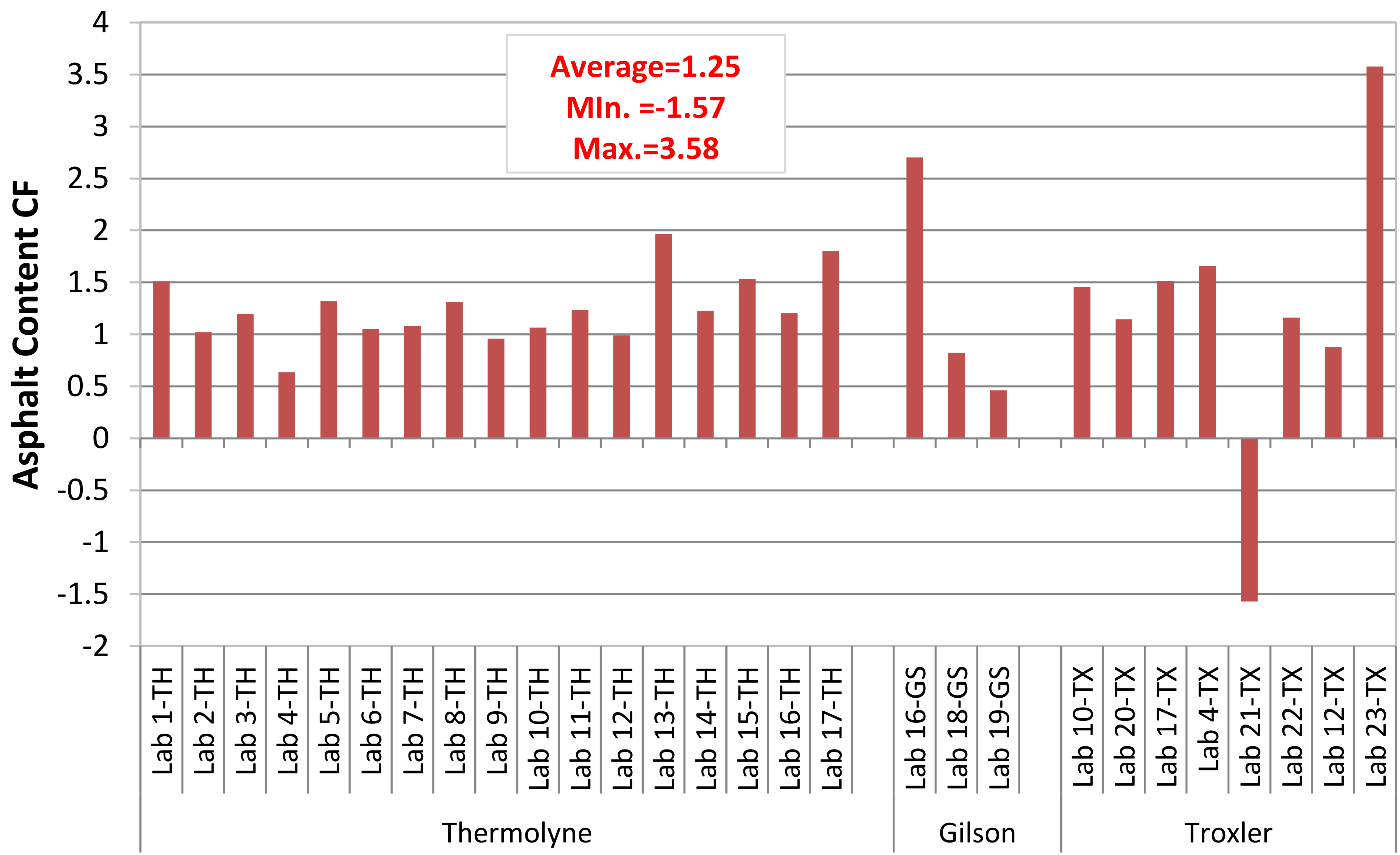
Asphalt Content CFs -Mix 2



Asphalt Content CFs-Mix 3



Asphalt Content CFs -Mix 4



Interlab. Study Data Analysis

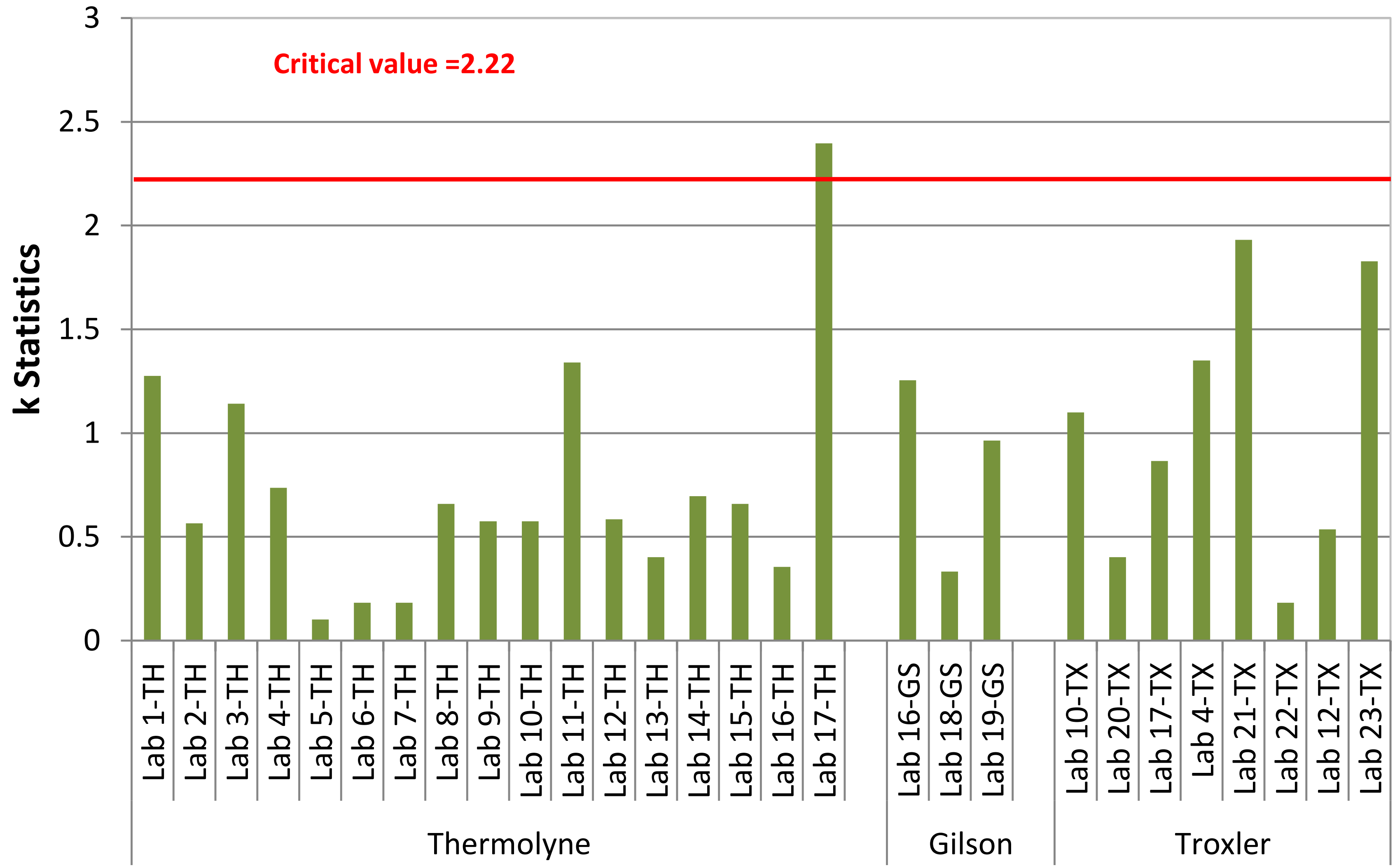
- Test results analyzed per ASTM E 691
- k and h statistics to evaluate consistency of results and possible outliers

  k=indicator of how laboratory variability compared with that of other labs

  h=indicator of how laboratory average compared with that of other labs

- Critical k and h values recommended in standard
- Each mix test results analyzed separately

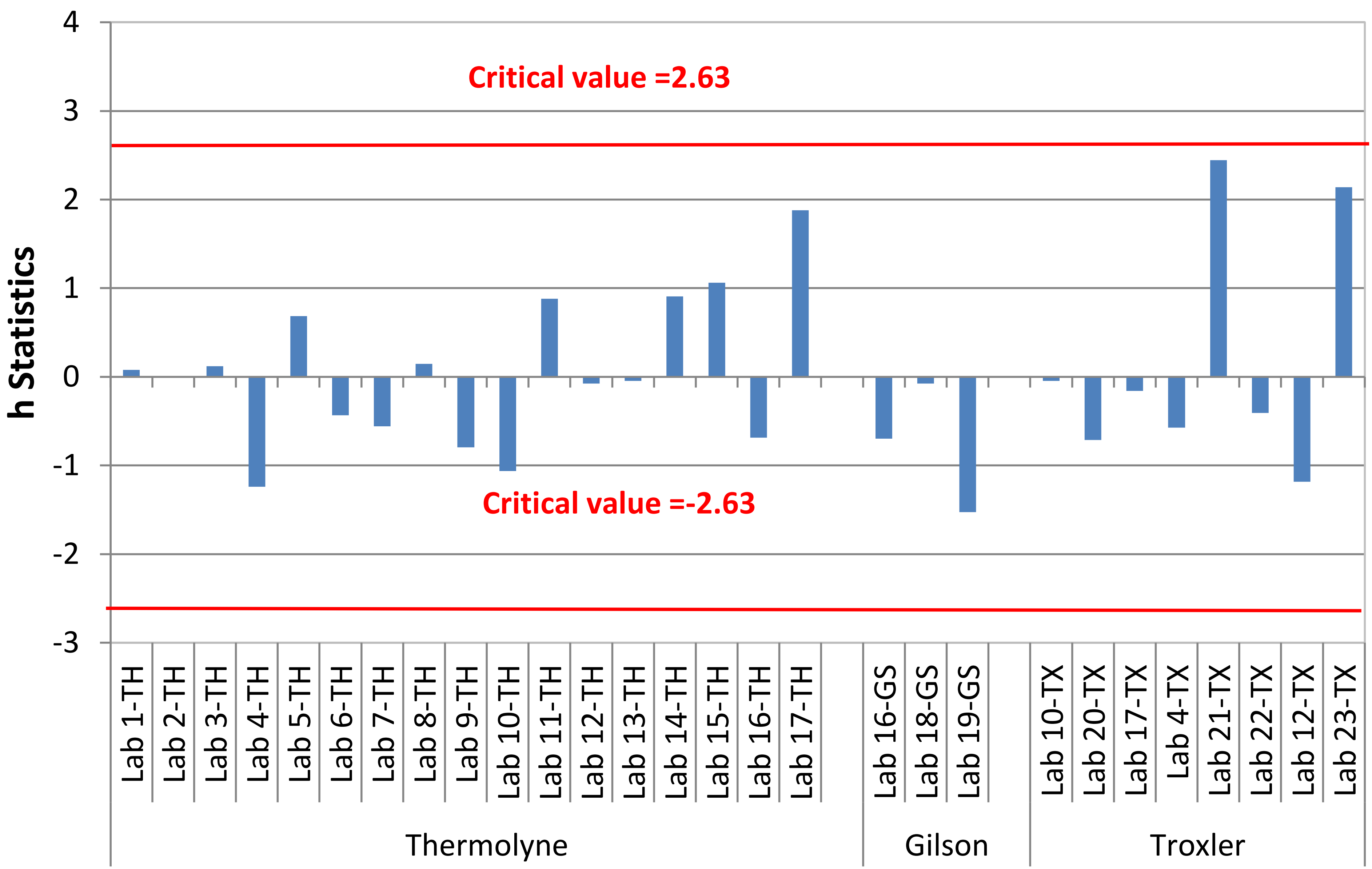
k Statistics-Mix 3 (ASTM E 691)



Lab 17-TH

k value = 2.4> k critical=2.22

h Statistics-Mix 3 (ASTM E 691)



Precision Statistics-Interlaboratory Study

Mix #	Actual AC %	Measured AC%	CF	s_r	s_R
1	5.2	5.32	0.12	0.089	0.131
2	5.2	4.97	-0.23	0.074	0.111
3	6.2	7.08	0.90	0.112	0.264
4	6.1	7.31	1.21	0.178	0.403
AASHTO T 308				**0.069**	**0.117**

Troubleshooting Outliers from Interlab. Study

Objective: Team visit labs to conduct additional testing, document specifics about tests to determine reasons for the differences in CF

Mix	Lab	k-value	h-value
1	Lab 4-TX Lab 21 TX	**3.4** **3.2**	**3.9** 1.7
2	Lab 4-TX Lab 21 TX	**4.1** 0.4	**-2.8** **2.66**
3	Lab 17-TH	**2.4**	1.69
4	Lab 16 -GS Lab 21-TX Lab 23-TX	**4.6** **3.1** 1.1	**-4.1** **4.3** **3.0**
Critical values		**2.22**	**2.59**

Observations from Outlier Study

- Equipment was not functioning correctly
- Equipment was not set up correctly or test procedures not followed
- Need good procedure to validate proper equipment operation
- Need good guidance for when and how to properly maintain equipment
- Need to participate in routine interlaboratory testing

Conclusions

- Study suggested that different precision statements may be necessary for aggregates with higher CFs
  - For mixes 1 and 2 within-lab and between-lab σ similar to AASHTO T 308
  - For mixes 3 and 4 as CF increased σ also increased
- It also suggests that precision statement in AASHTO T 308 was developed with low mass loss aggregates and are not applicable to aggregates with higher mass loss

Conclusions

- Although not recommended in AASHTO T 308, sharing CFs among different ignition furnaces appears acceptable for low CF aggregates
- Amount of lime has to be closely controlled during production otherwise this will affect the CF and result in incorrect AC content
- For mixes that do not contain lime, test conducted at 800°F significantly reduced asphalt CF, particularly for high loss aggregates

Conclusions

- Causes of differences in CF from troubleshooting study were primarily related to wrong equipment settings or other equipment issues
- Key product of this research is a Standard Practice for Installation, Operation, and Maintenance of Ignition Furnaces (AASHTO R96-19)

Recommendations/Additional Work

- Conducting ignition test with mixes containing high recycled materials content at 800°F, will allow more accurate determination of AC
- Additional work in progress as part of NCHRP 9-56A:
  - Assess the variability of asphalt CFs for mixes containing significant amounts of recycled materials compared to those with virgin binder and aggregate only.
  - Evaluate effect of reducing the test temperature of the AASHTO T 308 method to 800°F
  - Interlaboratory study to establish a new precision statement for AASHTO T 308

Acknowledgment

This research was sponsored by the NCHRP Project 09-56

Thank you!

Questions?