Improving Accuracy ofAsphalt Content By The Ignition Method – NCHRP 9-56

Pennsylvania Asphalt Pavement Association 2018

AMS LLC

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Ignition Method Implemented by VDOT in 1995

- National Center for Asphalt Technology (NCAT) and VDOT studies indicated the method was more accurate than other methods
- Provided gradation sample
- Results in 45-60 minutes
- More than 100 units in use in Virginia, 70 contractor and 30 VDOT

Many Slides in this Presentation from: TRB WEBINAR: IMPROVING ACCURACY OF ASPHALT CONTENT DETERMINATION BY IGNITION TEST

NCHRP Project 9-56

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Outline

- Project Scope
- Objectives
- Background
- Methodology
- Results
- Conclusions
- Recommendations/Further Research

Project Objectives

- Determine significant factors that affect asphalt correction factors (CF) for ignition furnaces to minimize their variability
- Evaluate effect of sharing CFs between units
- Develop guidelines for installation, operation, and maintenance of ignition furnaces

Background

- Accurate determination of AC and aggregate gradation critical in control of quality of asphalt mixtures during construction
- Ignition method per AASHTO T 308 is 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
Types of Ignition Ovens

Convection Units

- Chamber heated using radiant heat source-electric heating element-heat air, then sample
- Asphalt ignites-blower pulls air into chamber to maintain ignition
- Released gases further oxidized while passing out through a secondary chamber
- Exhaust is cooled by mixing with air
- Ovens may have internal balance or not

Background
Types of Ignition Ovens

Infrared Units

- Infrared heating element to heat sample
- Electromagnetic energy waves to transfer heat energy to sample-stimulating molecules in mix- sample heats furnace by conduction/convection
- Troxler units: 3 burning profiles: default, option 1-soft aggregates, option 2-high AC, stone matrix or modifiers

Background

- Most research studies conducted in mid to late 1990s and early to mid 2000s during its implementation
- Evaluated effectiveness, accuracy of new method (compared to extraction and compared units/brands available)
- Studies focused on evaluating variables related with the mix components and not operation

Background

Temperature effect (Kowalski et al, 2010), Indiana Dolomite

- 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 temperature exceeded target and sooner temperature peaked
- Decreasing temperature 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

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

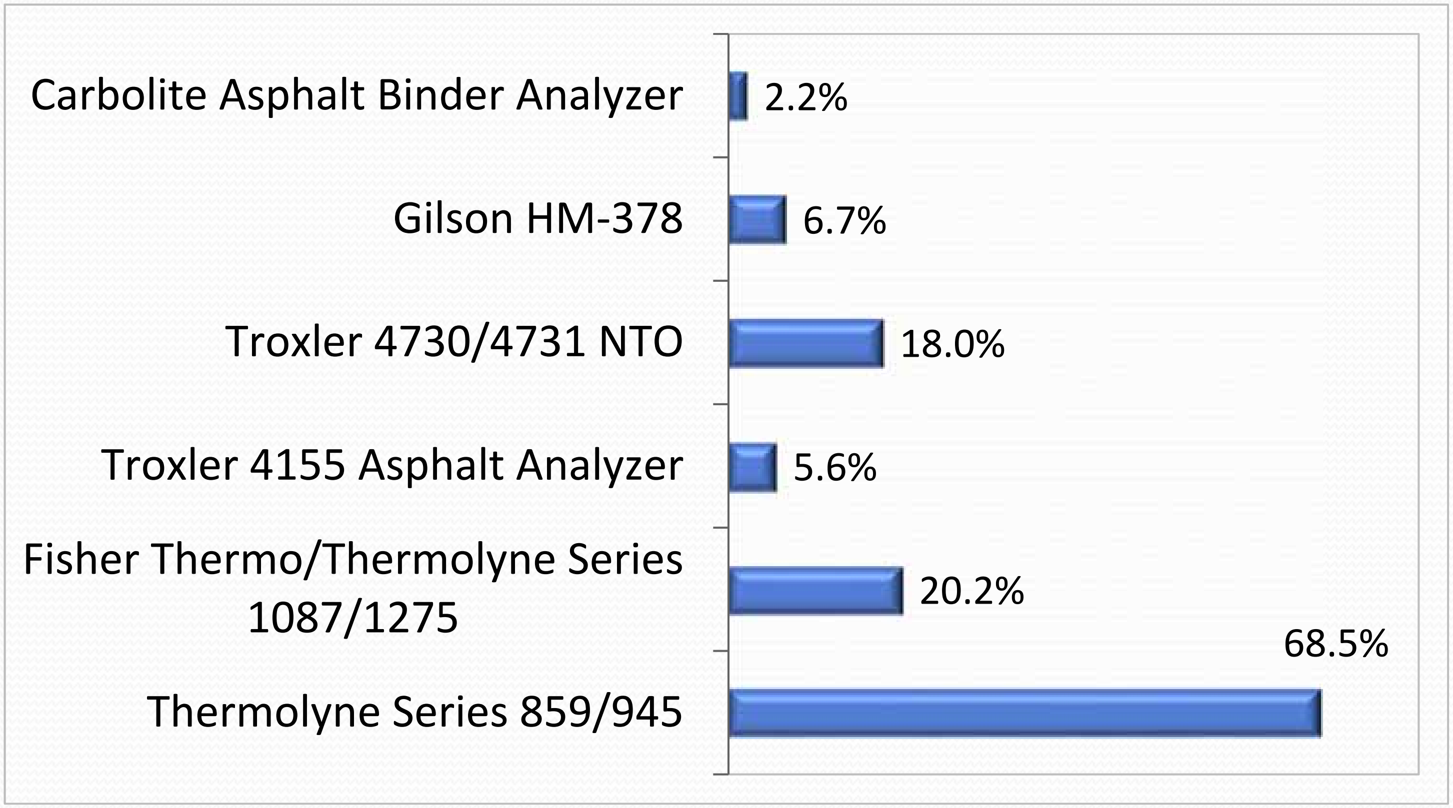
Background

- 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 test
- States like Indiana and Wisconsin have reported problems with aggregates such as dolomites
- High CFs result in more variability in measured AC content

Agency/ Contractor Survey

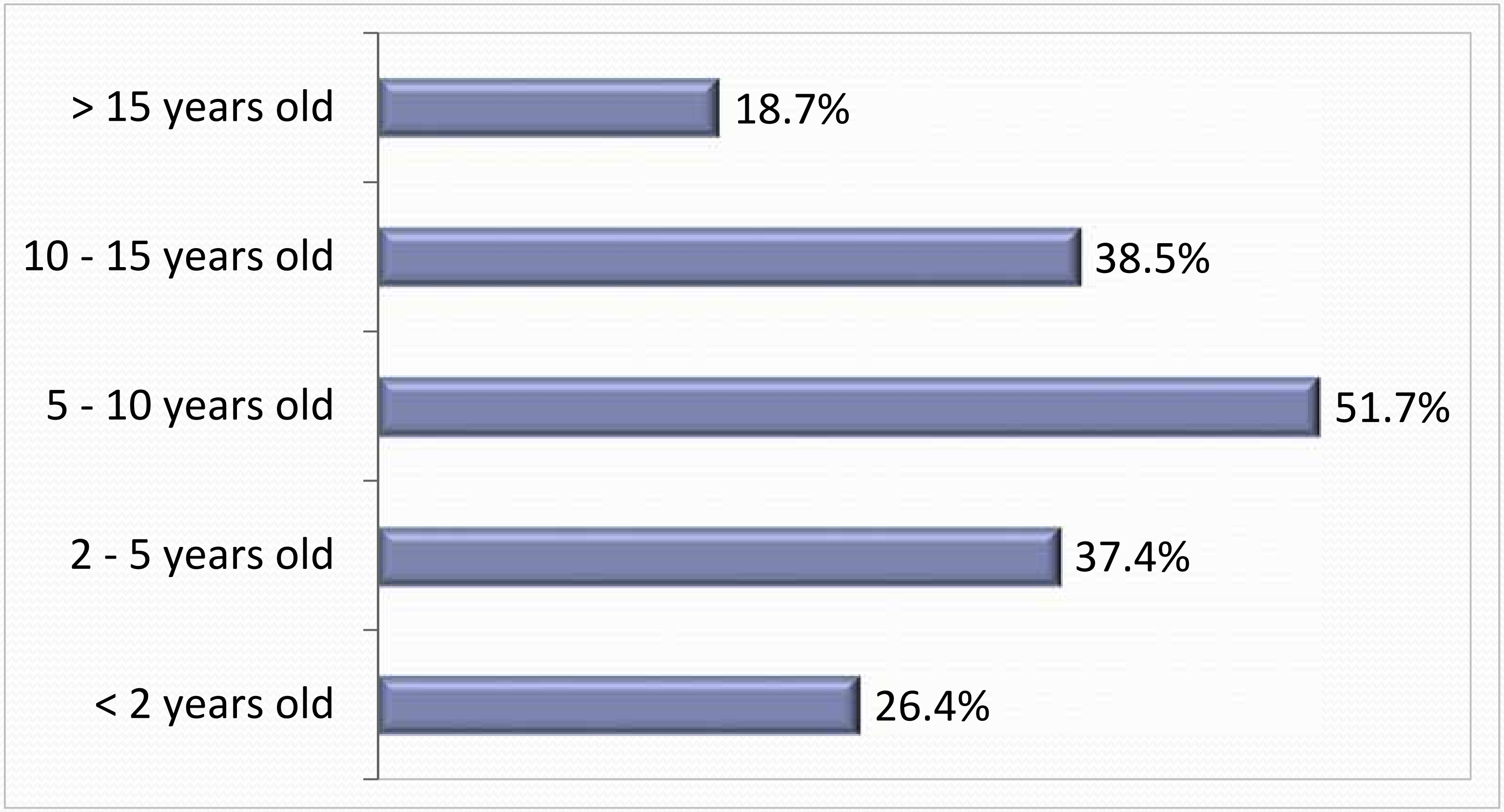
- Insight and concerns regarding use of ignition test
- 60 agency responses representing 42/50 US states, 7/10 Canadian provinces and federal lands
- Additional 37 responses from contractors and 7 responses from testing labs
- Most respondents use AASHTO T 308 or agency modification

Ignition Furnace Types



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

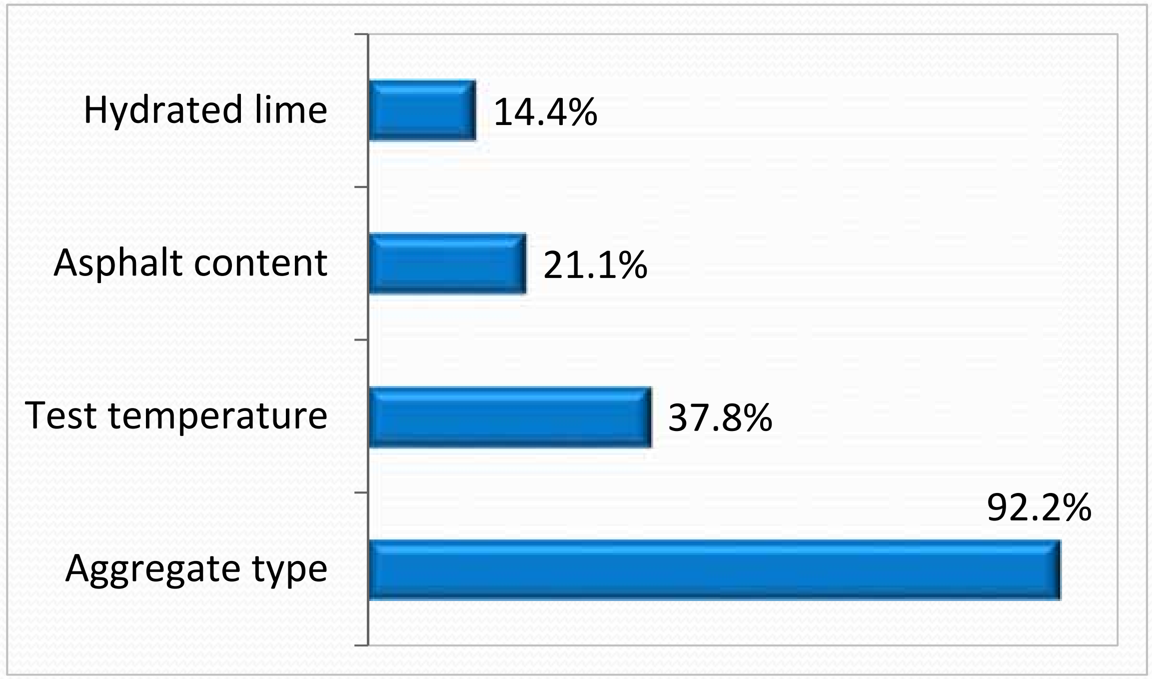
Ages of Furnaces Operated



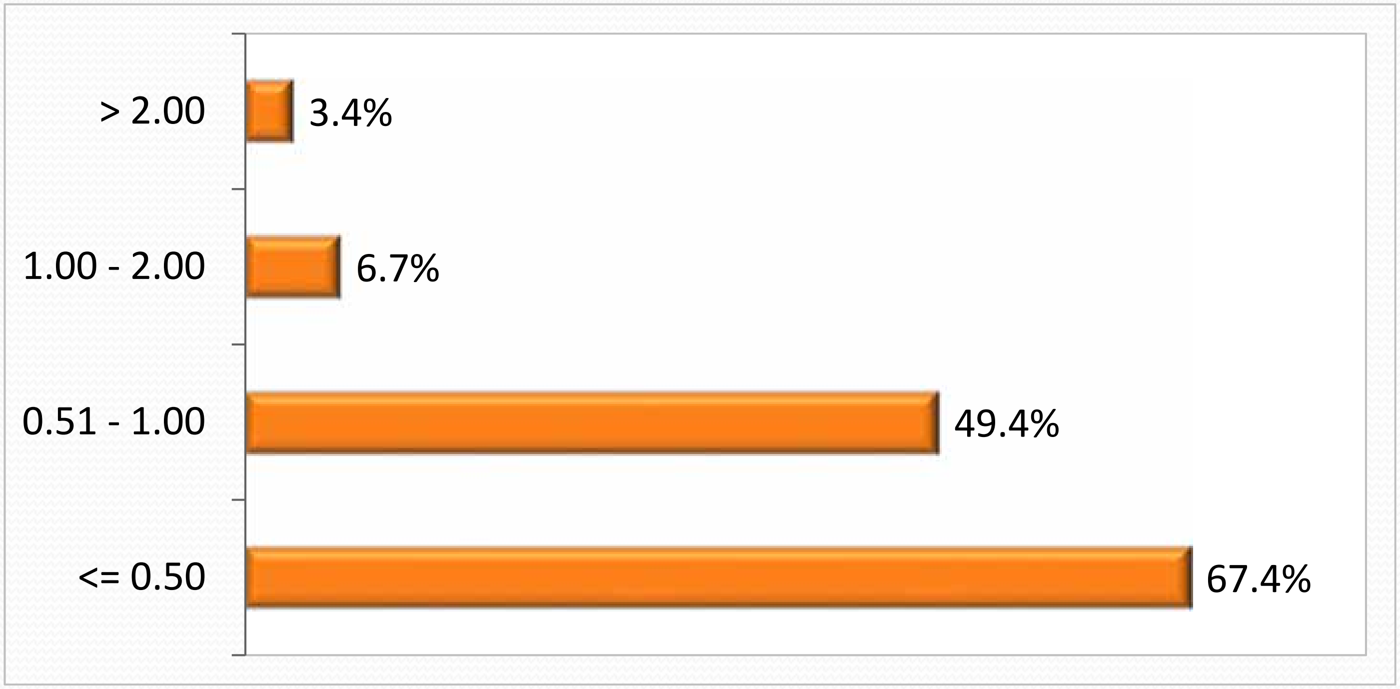
Range of furnace ages appears to be normally distributed with a median age of 5-10 years

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 basket are loaded

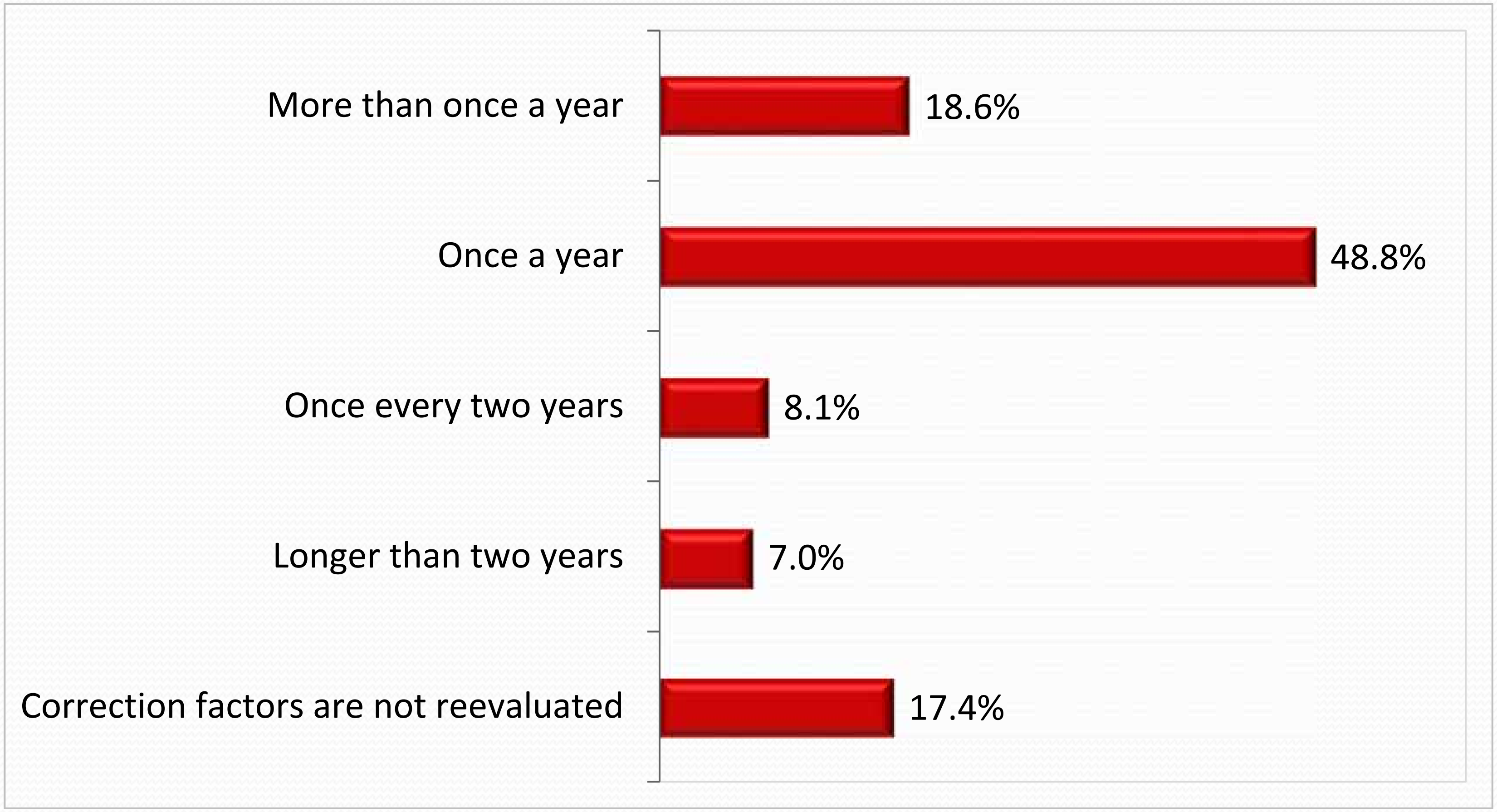


Typical Asphalt Content CF Range

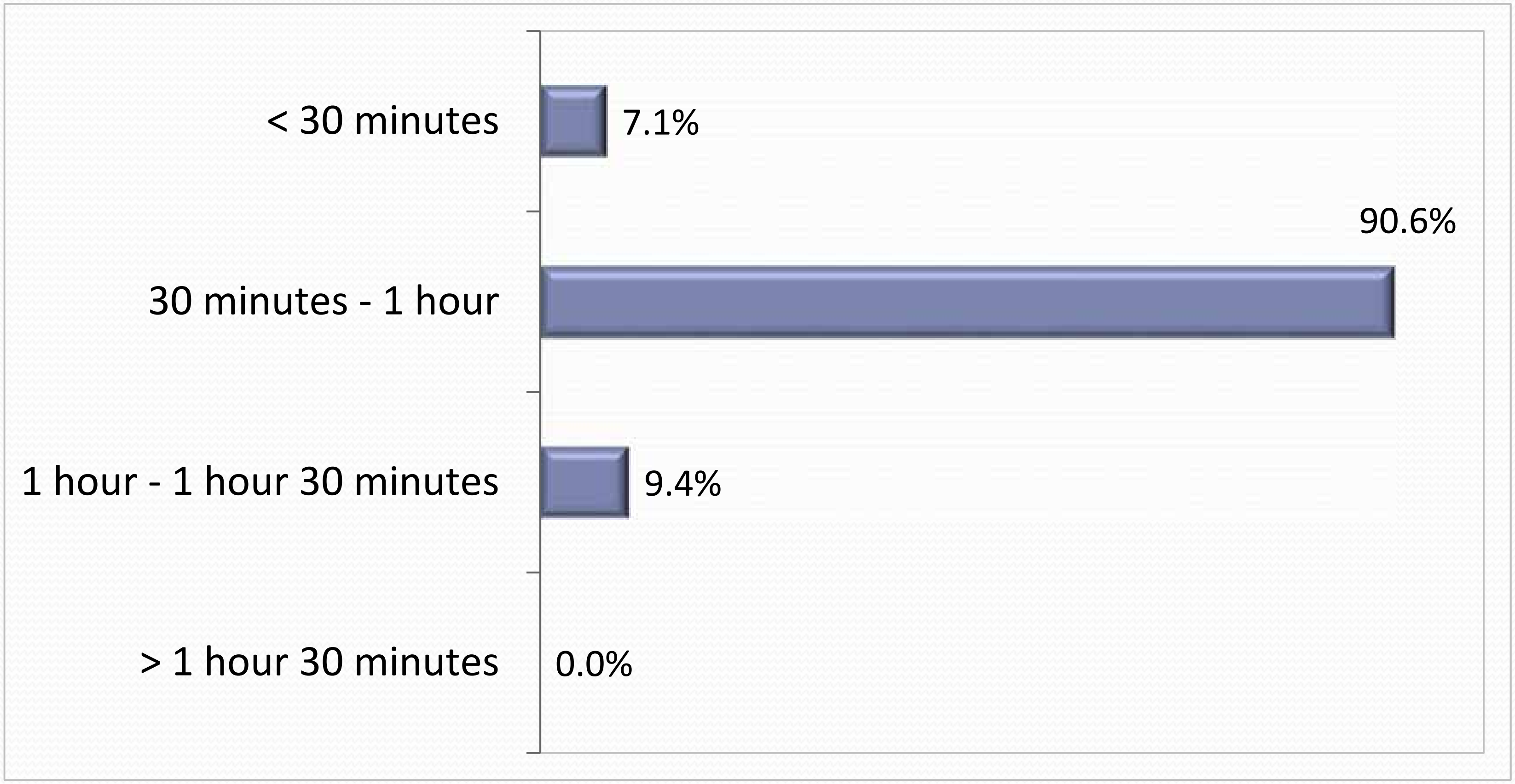


- Majority indicated CF <1
- Some agencies identified CF >1 is common
- Granite, gravel and limestone most common aggregates

Frequency at which CF are Determined/Reevaluated

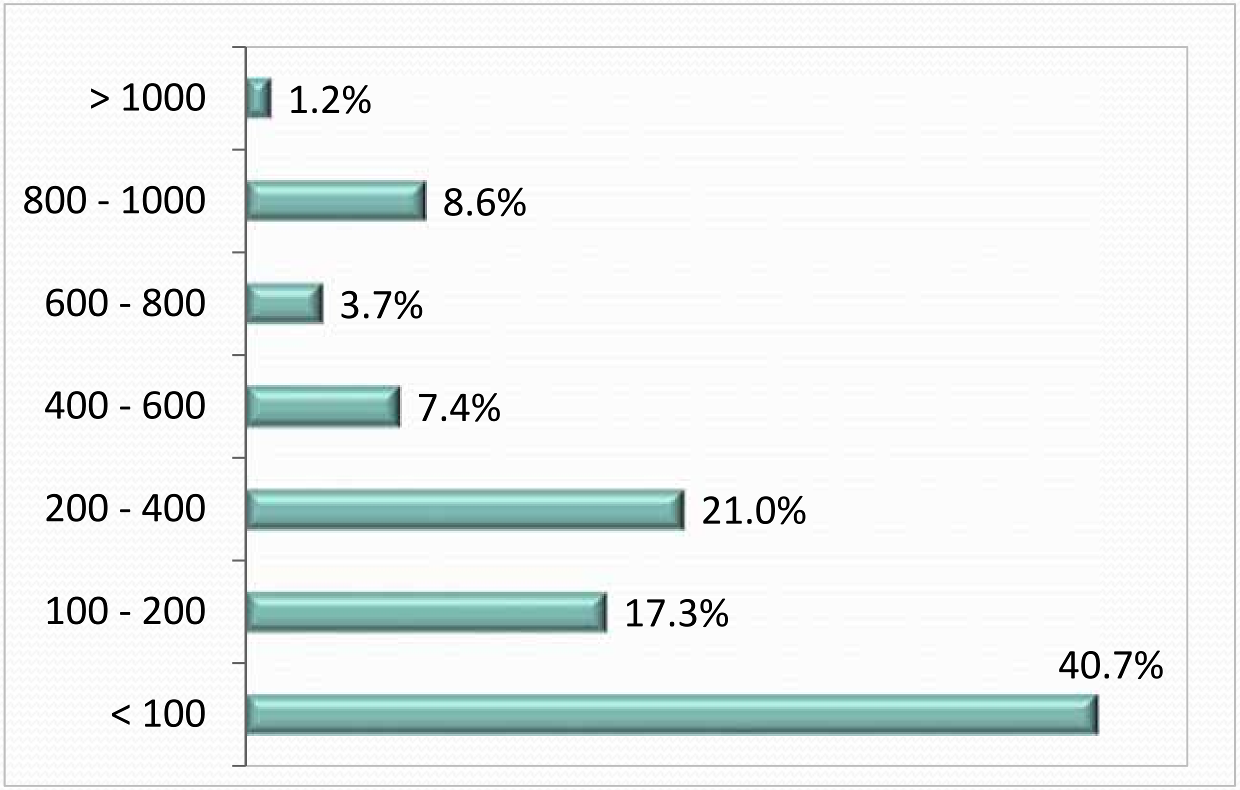


Typical Sample Burn Times



Installation, Maintenance and Cleaning Issues

- 2-1200 samples per year-average=285
- 90 degree elbows avoided, average slightly less than 1
- 13% hooked multiple furnace to same ductwork



Number of Samples Tested per Year

Areas of Concern with Test Procedure

- Only 56/106 respondents answered question; 26 provided comments that range from no problems (majority) to issues with dolomites →Missouri→ no constant mass even at lower temperature

Experimental Plan

Objective: *Determine significant influences affecting variability of asphalt correction factors*

Three studies:

- Sensitivity Study at NCAT Lab
- Round Robin Study(RRS)
- Troubleshooting Outliers from RRS

Sensitivity Study at NCAT Lab

Objective: *Examine different factors to determine which factors influence ignition test results*

- Identify materials
- Identify factors and levels
- Display of treatment combination
- Conduct tests and statistical analysis
    - Linear regression analysis
    - If p-value$\leq$0.10 regression coefficient is statistically significant -factor has an effect on test results

Aggregates/Mixes

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

Aggregate/ Mix	Aggregate Description	Source	Expected CF Range
1	Limestone and Granite	Calera, AL – Vulcan Materials	0.0 - 0.5
2	Limestone and Granite with 1% Lime	Calera, AL – Vulcan Materials	0.0 - 0.5
3	Limestone	Barbeau, MI – Payne and Dolan	0.5 - 1.0
4	Dolomite	Delphi, IN ---USA Aggregates	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%
Burning Profile (Troxler Only)	Default, Option 1, Option 2

Sensitivity Study Results

Factors Affecting Asphalt CF-Mix 1 and 2

Mix #	Variable	Levels	Average CF	Statistically Significant (Y/N)	Practically Significant (Y/N)
Mix 1	Ignition Unit	Thermolyne	0.07	Y	Y
		Troxler	0.12		
		Gilson	-0.03		
	Temperature	800°F	-0.02	Y	Y
		1000°F	0.12		
	AC Content	Opt. AC -1%	0.10	Y	N
		Opt. AC +1%	0.00		
	Air Flow, Sample Weight			N	-
Mix 2	Ignition Unit	Thermolyne	-0.26	Y	N
		Troxler	-0.21		
		Gilson	-0.36		
	Temperature	800°F	-0.33	Y	N
		1000°F	-0.23		
	Air Flow, AC Content, Sample Weight			N	-

Factors Affecting Asphalt CF

- Test Temperature:

✓ Affects AC CF for 7/12 combinations

✓ Effect more significant for convection units

✓ Decreasing test temperature decreases aggregate mass loss for all mixes

- Air Flow (Damper Opening):

✓ Affects AC CF for 4/12 combinations

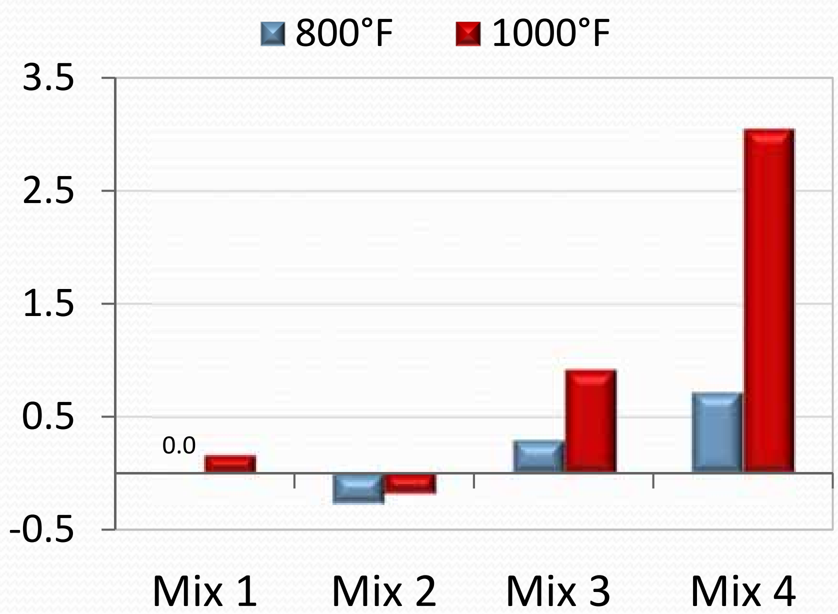
✓ Restriction in air flow may cause an increase of asphalt CF

✓ Effect more significant for Troxler

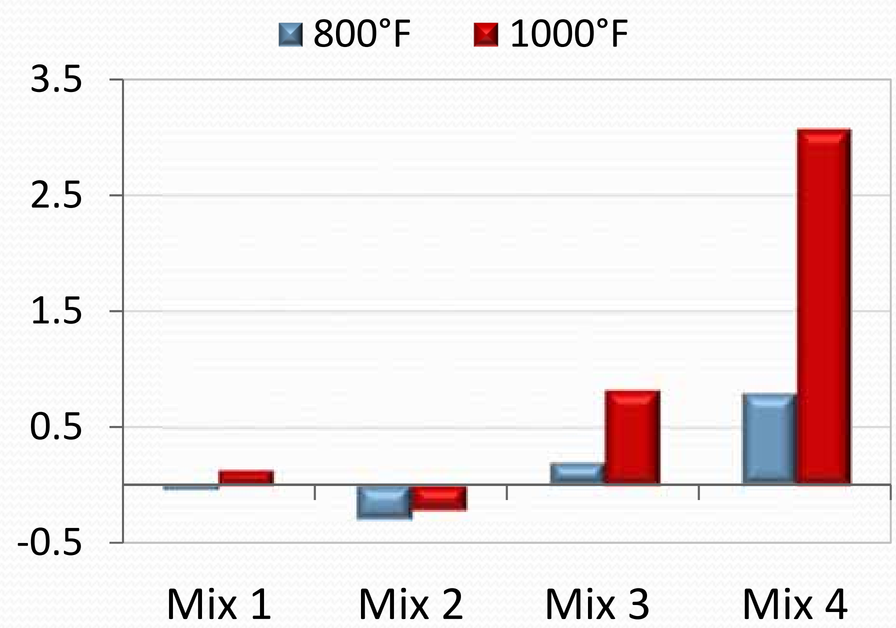
Factors Affecting Asphalt CF

- Asphalt Content:
  - ✓Affects AC CF for 3/12 combinations(Mix 3 and 4)
  - ✓Both combinations with Troxler unit
- Sample Weight:
  - ✓Not significant

Temperature Effect by Mix Type



AC content =Optimum - 1%



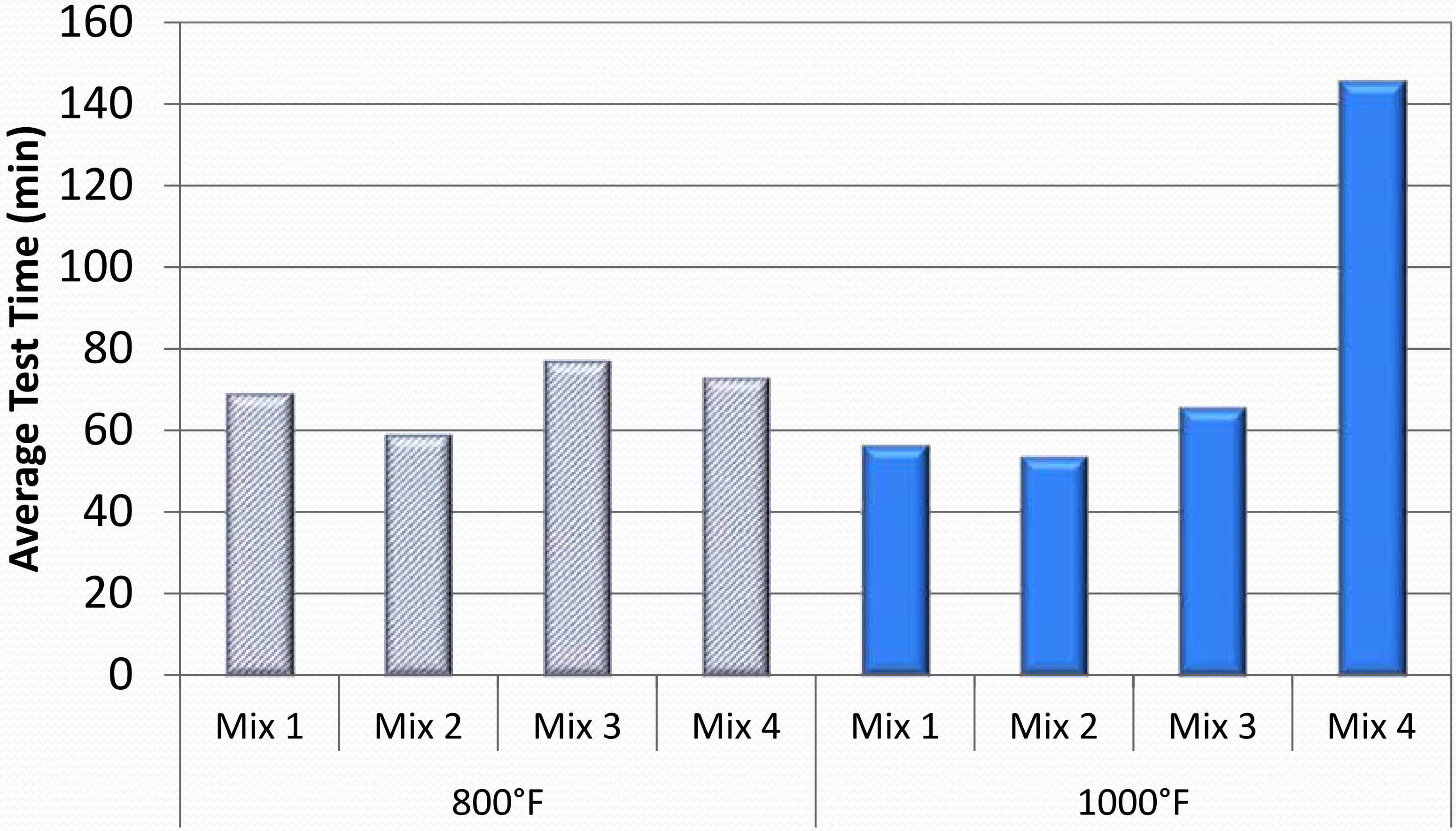
AC content =Optimum +1%

Troxler Only-Burning Profiles

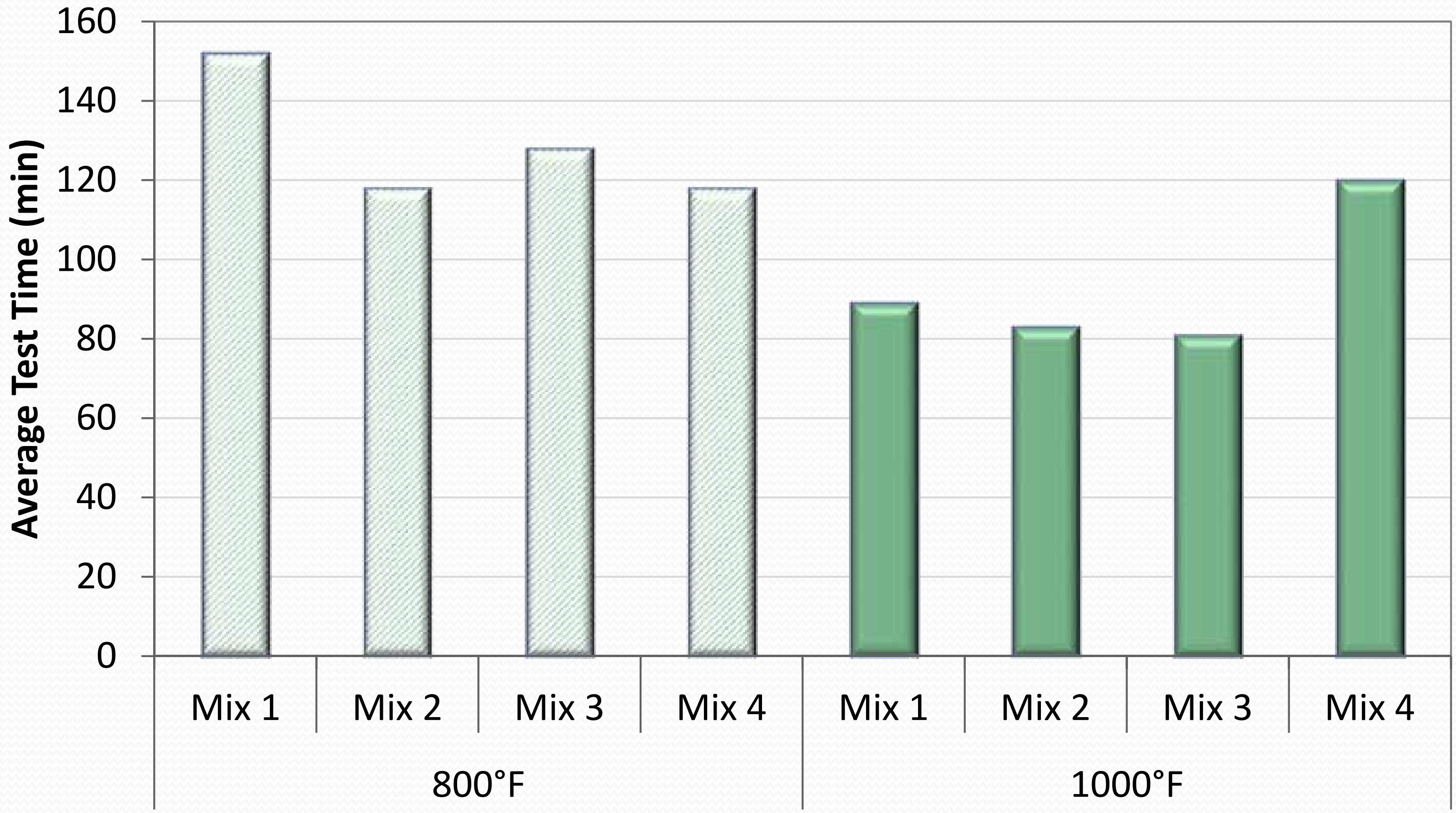
Mix #	Variable	Levels	Average CF	Statistically Significant (Y/N)	Practically Significant (Y/N)
Mix 1	Profile	Default, Option 1, Option 2	0.11, -0.04, 0.17	Y	**Y**
Mix 2	Burning Profile, AC Content, Sample Weight			N	---
Mix 3	Profile	Default, Option 1, Option 2	0.70, 0.64, 0.92	Y	Y
Mix 4	Profile	Default, Option 1, Option 2	1.59, 1.27, 2.15	Y	Y

- For mixes 1, 3 and 4, Option 2 yielded highest asphalt CF
- For mixes 1, 3 and 4 Option 1 resulted in lowest asphalt CF
- Change in asphalt CF caused by changing burning profiles was more pronounced for mix 4

Average Test Time by Mix Type and Test Temperature -Thermolyne



Average Test Time by Mix Type and Test Temperature -Gilson



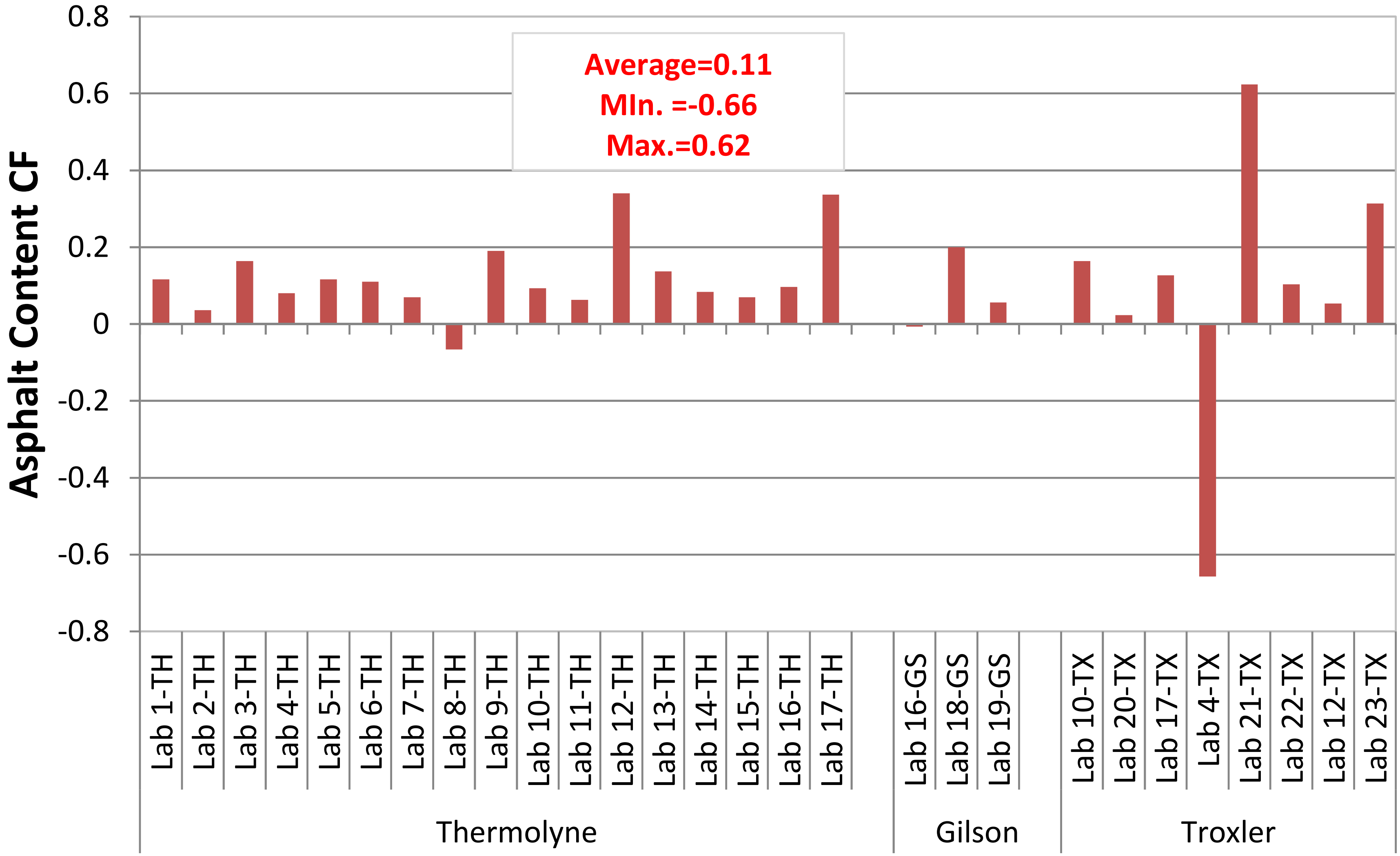
RRS Experimental Plan

Objective: *Identify CF outliers for further investigation*

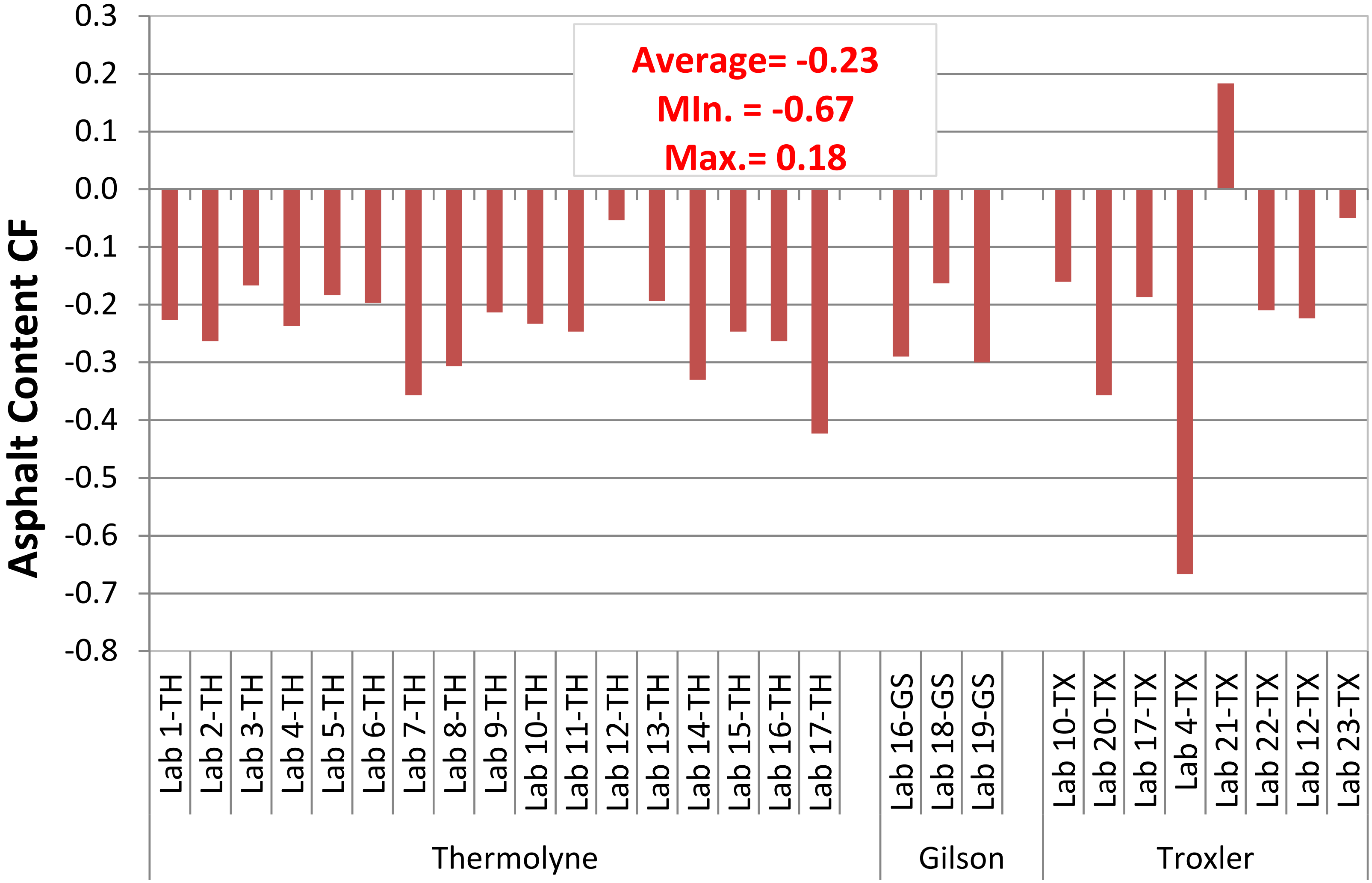
Labs	18 DOT agencies; 5 Contractors/Research
Oven brand	17 Thermolyne, 8 Troxler, 3 Gilson
Multi-labs	5 labs with two different oven brands
Number of Mixes	Four mixes at their optimum asphalt content
***Test* temperature**	538°C (mixes 1-3) and 482°C (mix 4) for convection units (Thermolyne, Gilson); default and option 1 for infrared unit(Troxler)
Total Number of Specimens	4 samples x 4 mixes x (28 units) = 448 samples; 1500 grams each
Replicates	3 per mix

RRS Results

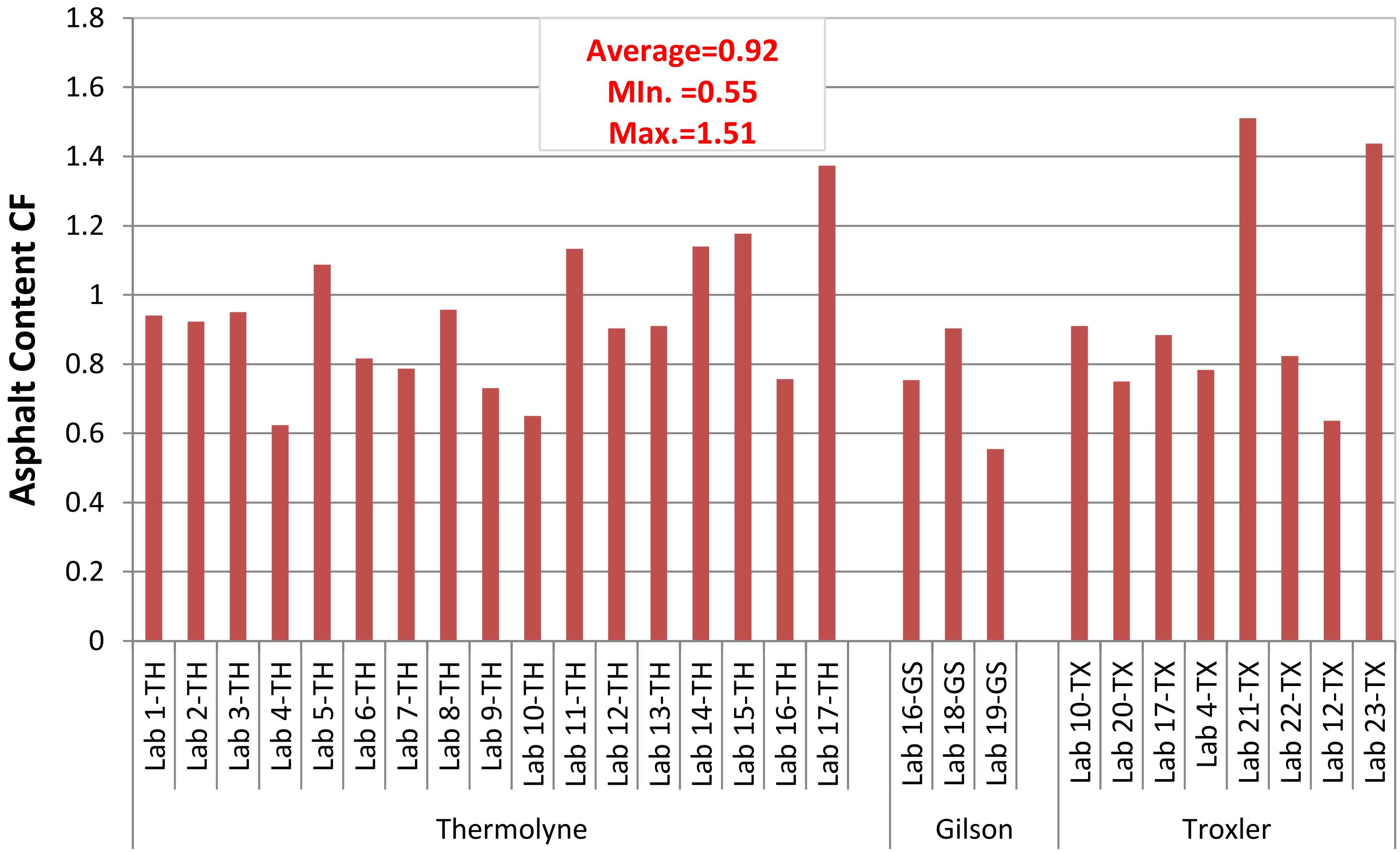
Asphalt Content CF RRS -Mix 1



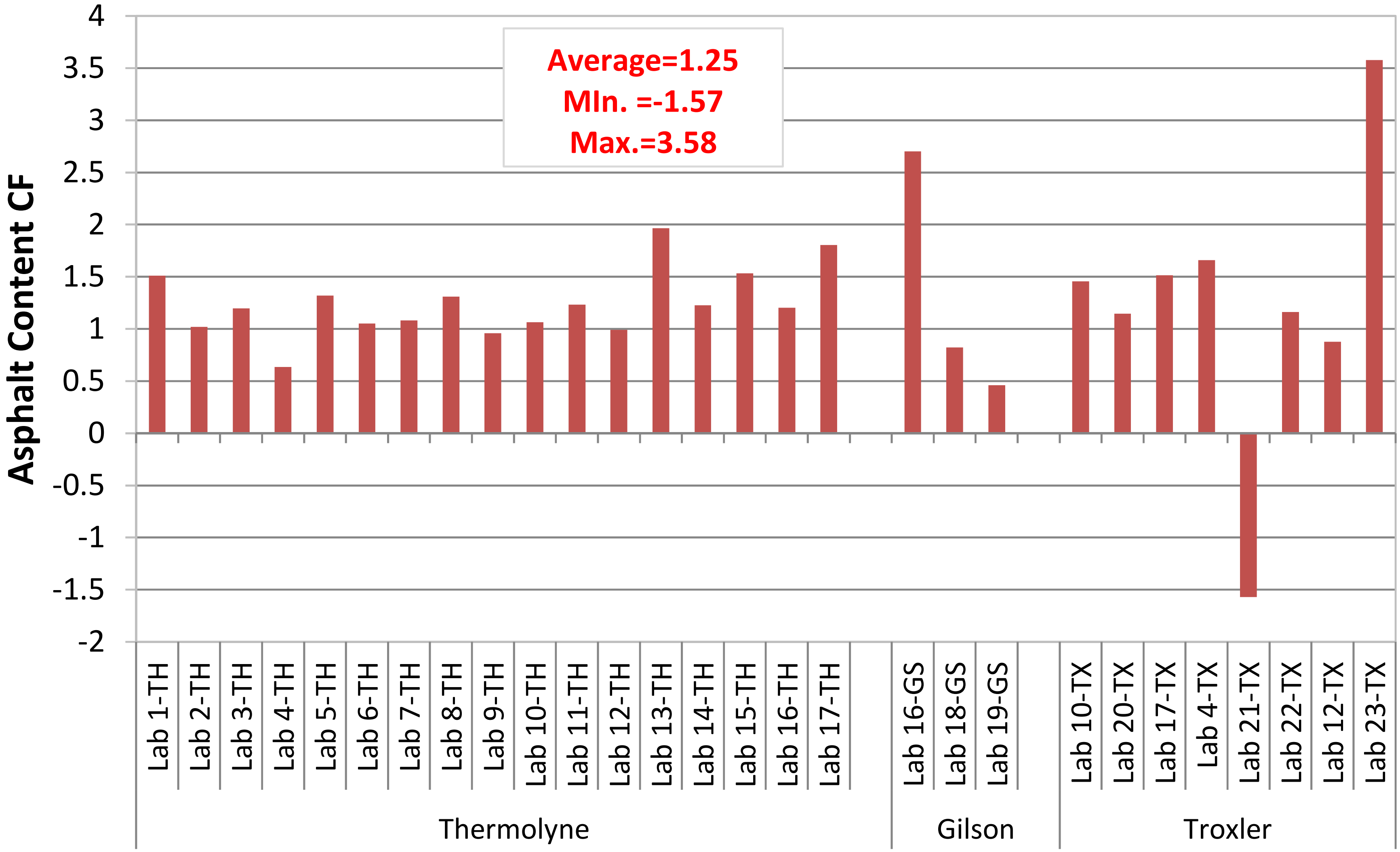
Asphalt Content CF RRS -Mix 2



Asphalt Content CF RRS -Mix 3



Asphalt Content CF RRS -Mix 4



Precision Statistics-RRS

Mix #	Actual AC%	Average Measured AC%	Average AC CF	Standard Deviation	
				W/L	B/L
1	5.2	5.32	0.12	0.097	0.117
2	5.2	4.97	-0.23	0.086	0.102
3	6.2	7.08	0.88	0.197	0.212
4	6.1	7.31	1.21	0.345	0.370
AASHTO T 308				**0.069**	**0.117**

Troubleshooting Outliers from Round Robin 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**

APPENDIX G

Checklist for Troubleshooting Laboratory Visits

Checklist for Visiting RRS Labs

General – All Furnaces

- Check cleanliness of furnaces.
  - Is there a lot of build-up in chamber?
  - How often is the chamber cleaned?
- Check default criteria to see if they have changed anything.
- Check exhaust setup, length of ducts, elbows.
- Do they check the internal scale before each test? Total mass should be within 5 g of external mass.
- Check resistance of heating elements.
- Check how often they have furnace calibrated.
- How long do they generally wait before weighing the sample after completion of the test? Do they have an in-house rule for this, or just weigh whenever they get a chance?
- Do they generally use 538°C, or do they use lower temperature? (Burn profile for Troxler?).
- Check baskets. How clean are they? Are they heavily worn?

Thermolyne Furnaces Only

- Check filter set point.
- Check their cut-off limit (0.01%?).
- Perform lift test. Do they do this regularly?
- To check criteria, hold down "Enter" while turning unit on.

Troxler Furnaces Only

- When they do the furnace cleaning, do they also physically vacuum out the side as stated in owner's manual? Though this may be omitted.
- What burn profile do they generally use?
- Look at burn profiles. Have they altered them at all?

Gilson Furnaces Only

- How do they determine how long to burn the sample the first time? Do they use experience from previous mixes, or do they have a set time? Do they determine this during design/correction factor determination before mixes are actually produced?
- How many times do they generally have to put the sample back in before it's determined to be complete? Do they go by visual clues only, or weight?
- How long do they let the sample sit out of the furnace before checking the weight to see if the mass has not changed?

Lab 4 -Troxler

- Results significantly different for Mix 1 and 2
- CF from oven tickets were significantly different from external weighing
- Results obtained from external weighing were found to be similar to results for other labs

Mix #	Average Lab AC from RRS	Average AC from RRS for Lab 4	AC Average (Manually weighing on scales outside the furnace) by NCAT
1	5.32	4.54	5.52
2	4.97	4.53	4.92

Lab 21-Troxler

- CF results higher for Mix 3 and 4 than for average of all labs
- After results submitted, this lab decided to replace the unit due to malfunction
- NCAT tests using new Troxler unit more in line with results for average of all labs

Mix #	Average Lab AC from RRS	Average AC from RRS for Lab 21	Average AC Measured During Lab Visit
3	7.08	7.71	7.12
4	7.31	4.53	7.55

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 round robin testing

Installation, Operation, and Maintenance of Ignition Furnace

NCHRP Report 847

APPENDIX I

Proposed Standard Practice for Installation, Operation, and Maintenance of Ignition Furnaces with Commentary

AASHTO Designation: R X-16

1. SCOPE

1.1. This standard practice is for the initial installation, operation, and maintenance of an ignition furnace for measuring the asphalt content of an asphalt mixture according to T 308. The aggregate recovered after ignition can be used for gradation analysis according to T 30.

1.2. Failure to properly install, operate, or maintain the ignition furnace may result in erroneous measurements and/or additional hazards.

1.3. The values stated in SI units are to be regarded as the standard.

1.4. *This standard practice does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish safety and health practices along with determining the applicability of regulatory limitations prior to use.*

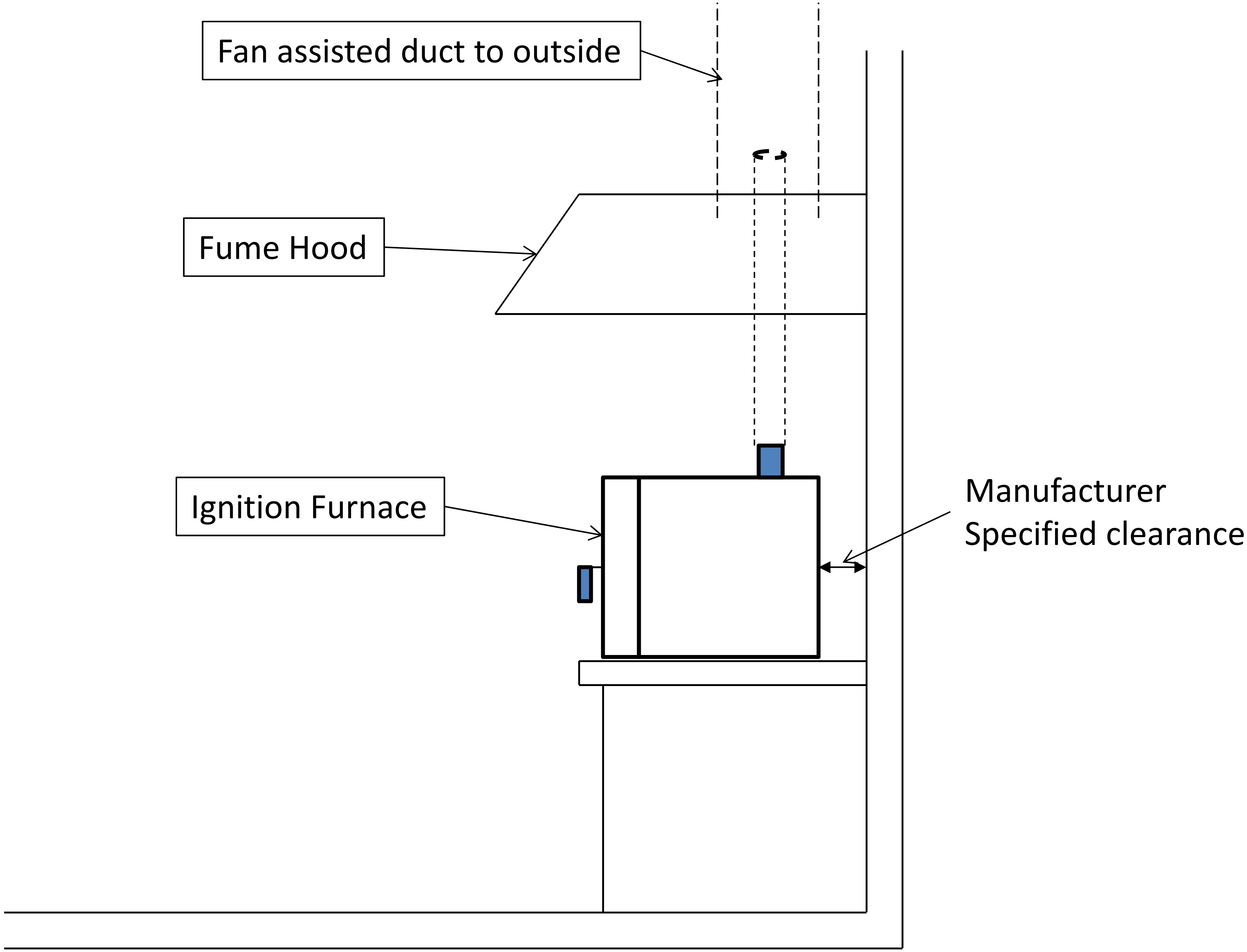
2. REFERENCED DOCUMENTS

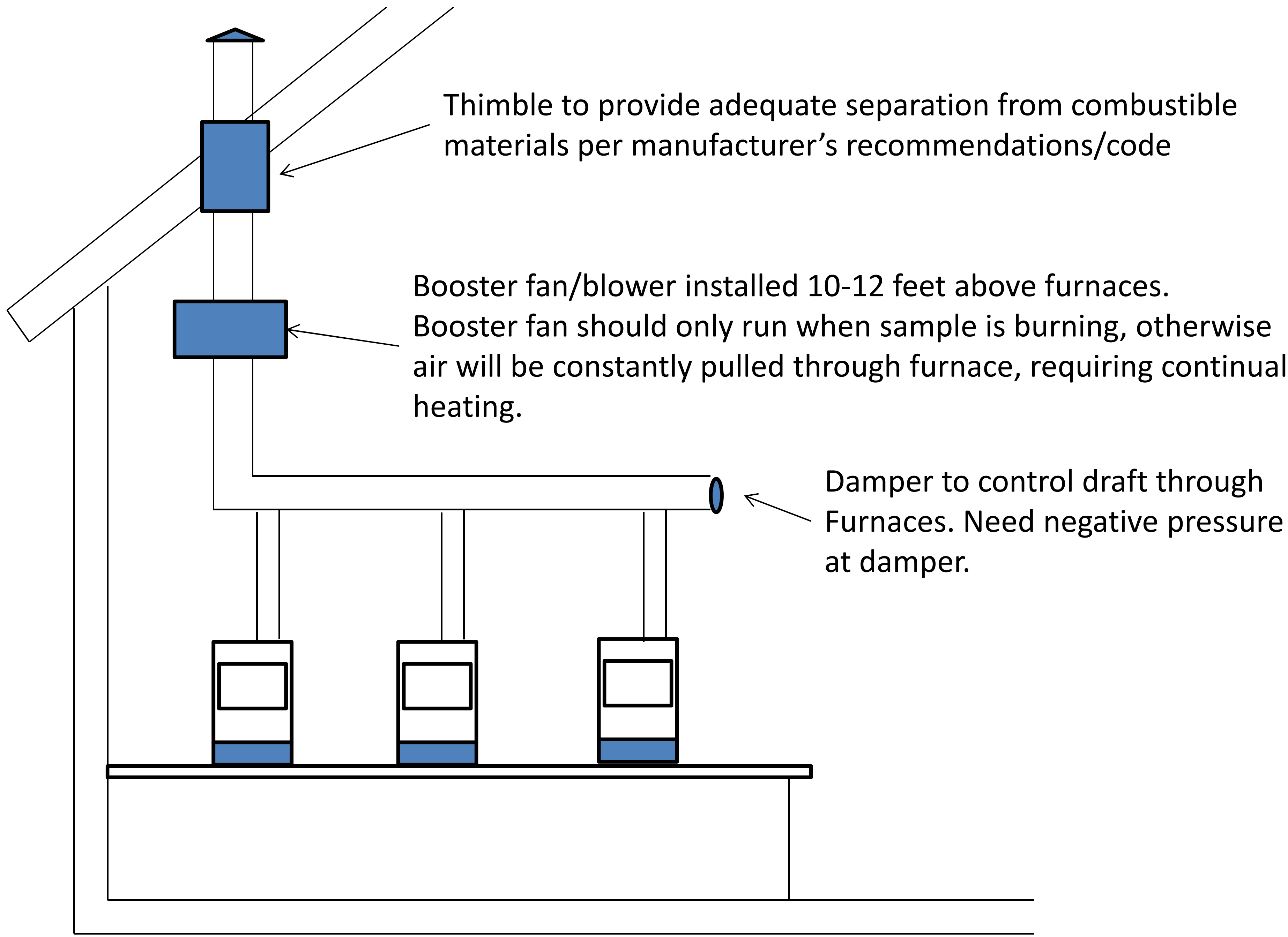
2.1. *AASHTO Standards:*

- T 30, Mechanical Analysis of Extracted Aggregates
- T 168, Standard Method of Test for Sampling Bituminous Paving Mixtures
- T 308, Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method
- T 329, Standard Method of Test for Moisture Content of Hot-Mix Asphalt (HMA) by Oven Method
- R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
- R 47, Standard Practice for Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size

Installation, Operation, and Maintenance of Ignition Furnace

- Follow Manufacturer's recommendations for installation, operation, and maintenance
- Situate furnace so that adequate space for hot baskets
- Minimize length of vent (less than 10 feet if possible)
- Leaking smoke can be caused by improper seals, negative pressure in room (caused by hoods), etc
- Moisture in mix affects measured asphalt content


Fan assisted duct to outside
Fume Hood
Ignition Furnace
Manufacturer
Specified clearance


Thimble to provide adequate separation from combustible materials per manufacturer’s recommendations/code
Booster fan/blower installed 10-12 feet above furnaces. Booster fan should only run when sample is burning, otherwise air will be constantly pulled through furnace, requiring continual heating.
Damper to control draft through Furnaces. Need negative pressure at damper.

Installation, Operation, and Maintenance of Ignition Furnace (Cont'd)

- Allow sample to cool before measuring weight externally
- Lime affects the correction factor
- Be careful with high AC content mixes such as fine RAP, RAS, etc. Sample size will likely need to be reduced to prevent overheating furnace once burn begins
- Perform round robin testing to ensure accuracy of measured AC content. This can be done within one lab with multiple pieces of equipment or between multiple labs. Accurately measuring the CF is a bigger problem with high mass loss aggregates

Conclusions

- Although not recommended, sharing CF may be possible when low CF aggregates (say 0.1 to 0.2% or less) are used
- Amount of lime has to be closely controlled during production otherwise this will affect the CF and result in incorrect measurement of AC content
- For mixes that do not contain lime, test conducted at 800°F significantly reduced asphalt CF, particularly for high mass loss aggregates

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
- Causes of differences in CF from troubleshooting study were primarily related to wrong equipment settings or other equipment issues

Recommendations/Further Work

- Conducting ignition test for RAP materials at 800°F, will allow more accurate determination of the RAP asphalt content which can be difficult since the CF is not known
- Key product of this research is a Proposed Standard Practice for Installation, Operation, and Maintenance of Ignition Furnaces
- Additional work currently in progress to evaluate effect of reducing test temperature including mixes that contain recycled materials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Thank you!

Courtesy of Timothy Ramirez