Impacts of Ignition Furnace Correction Factors in Quality Assurance

U.S. Department of Transportation
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- Dennis Dvorak from FHWA-Resource Center

Abbreviations and Acronyms

- AASHTO – American Association of State Highway and Transportation Officials
- CF – Correction factor
- JMF – Job mix formula
- LCP – Light capital pavement
- NMAS – Nominal maximum aggregate size
- PWL – percent within limits
- UTB – Ultra-thin bonded

Why do you care?

What are you going to get out of this?

Give context for the **significant impact of errors** in correction factors for ignition furnaces

- Impacts accurate and fair **acceptance** by agencies
- Impacts **quality control** assessments by contractors
- Impacts proper and fair payment for asphalt mixtures

Why do you care?

What are you going to get out of this?

Topics for discussion:

- Background
  - AASHTO T 308
  - MaineDOT practice
- Results
  - All CF
  - CF comparisons
  - Impact on QA
    - Simulations
    - Real Lot data

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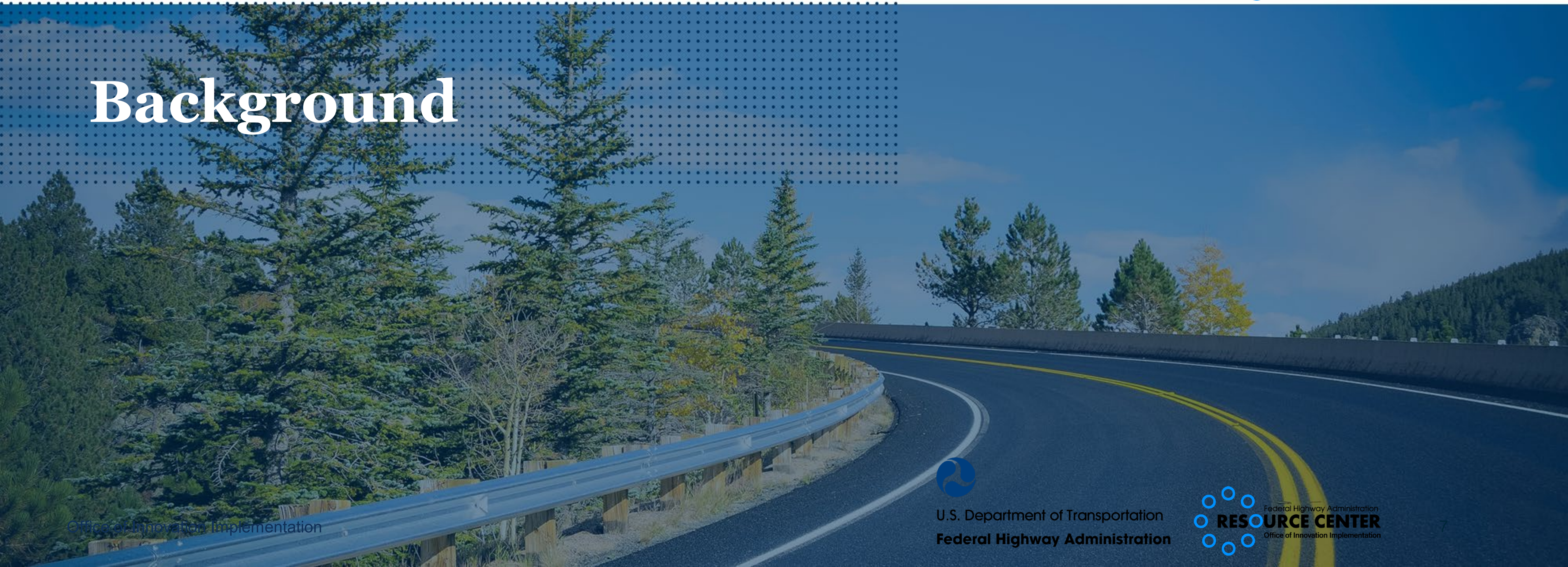
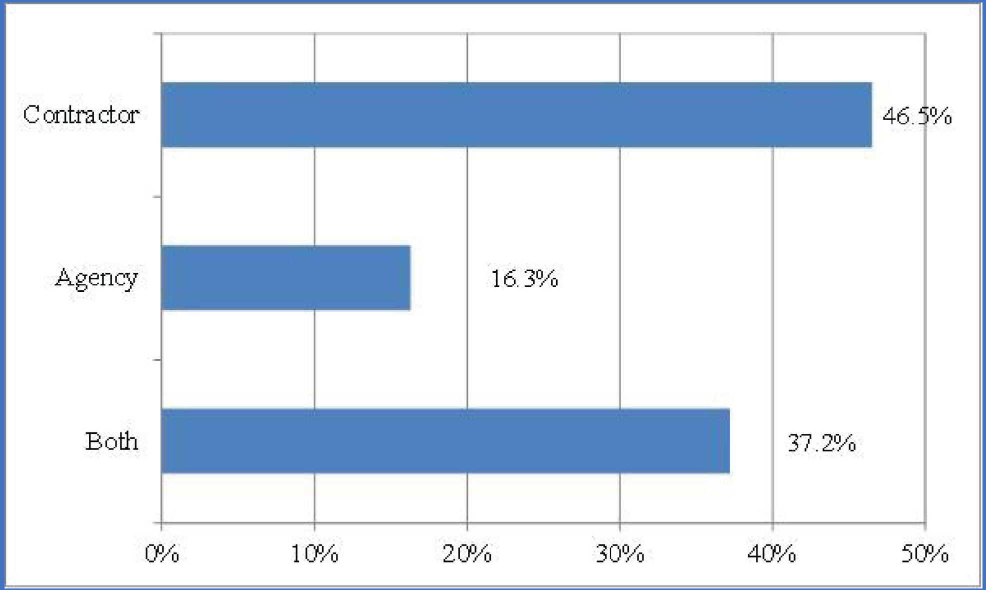
Background



AASHTO T 308 – Ignition Furnace

- Used by most agencies and contractors to determine asphalt content
- Correction factor key to adjust for aggregate burn off and breakdown at high temperatures

Entity preparing ignition furnace correction factors (Source: NCHRP 09-56)



AASHTO T 308 – Correction Factors

- "A1.1. Asphalt binder content results may be affected by the type of aggregate in the mixture and the ignition furnace. **Therefore, asphalt binder and aggregate correction factors must be established by testing a set of correction specimens for each job mix formula (JMF) mix design**. Correction factor(s) must be determined before any acceptance testing is completed and repeated each time a change in the mix ingredients or design occurs. **Any changes greater than 5 percent in stockpiled aggregate proportions should require a new correction factor**."

- NCHRP 09-56 Variability of Ignition Furnace Correction Factors
  - "Although not recommended in the AASHTO T 308 standard, sharing correction factors between different furnaces should not be a significant problem when low correction factor aggregates (of 0.1% or less) are used. For higher mass loss aggregates (1.0% and larger), **sharing correction factors should not be allowed**. As the CF increases from 0.1% to 1.0%, the errors caused by sharing CFs will certainly increase."

Background: Acceptance Sampling Practice

Sampling from the paver hopper onsite

Secured by agency personnel.

Lab #1 (Central Lab)

Lab #2 (Regional Lab)

Transported by contractor to one of two MaineDOT labs

Background: Correction Factor Practice

- Correction factor generated by MaineDOT for each ‘base’ JMF for each oven per AASHTO T 308
  - ‘Base’ considered to be aggregate and RAP skeleton and binder aim – can vary binder grade, additives, etc.
- Lab batches two samples for design using component aggregate, virgin binder content, and RAP
  - Actual binder mass added is recorded and used.
- One sample is split into four AASHTO T308 tests and correction factor generated from average of four samples
- Second sample is shipped to second lab for their potential use in dispute process – split and tested a similar way in another oven.

Unique Data Analysis Opportunity

- Database containing the following:
  - Mix design
  - Date correction factor performed
  - Laboratory
  - Oven ID
  - Correction factor
- Opportunity to:
  - Analyze distribution of correction factors
  - Compare CF between labs and oven generated using same process

Comparison ID	REF ID	Furnace 1	Furnace 1 Date	Furnace Loss 1	Furnace 2	Furnace 2 Date	Furnace Loss 2
001	16018	FRPT-NCAT1.1	31-Aug-18	0.80	BGR-NCAT3.1	17-Jun-19	0.70
002	17079	BGR-NCAT2	12-Sep-19	0.35	FRPT-NCAT1.1	09-Oct-19	0.53
003	17085	BGR-NCAT1	18-Sep-19	0.52	FRPT-NCAT2	03-Sep-19	0.68
004	17105	FRPT-NCAT2	04-Sep-19	0.35	BGR-NCAT1	22-Jun-19	0.31
005	17907	BGR-NCAT2	03-Sep-19	0.4	FRPT-NCAT1.1	18-Jun-19	0.44
006	18007	BGR-NCAT3.1	15-Jun-19	1.13	FRPT-NCAT2	18-Jun-19	1.12
007	18060	FRPT-NCAT2	31-Aug-18	0.43	BGR-NCAT3.1	17-Jun-19	0.5
008	18066	BGR-NCAT4	16-Aug-18	0.47	FRPT-NCAT3	10-Oct-18	0.37
009	19001	BGR-NCAT4	17-Jun-19	0.32	FRPT-NCAT3	03-May-19	0.29
010	19001	FRPT-NCAT3	03-May-19	0.29	FRPT-NCAT2	07-Aug-20	0.27
011	19001	BGR-NCAT4	17-Jun-19	0.32	FRPT-NCAT2	07-Aug-20	0.27
012	19003	BGR-NCAT2	17-Sep-20	0.44	FRPT-NCAT3	02-Jul-19	0.42
013	19003	FRPT-NCAT3	02-Jul-19	0.42	FRPT-NCAT1.1	13-May-19	0.38
014	19003	BGR-NCAT2	17-Sep-20	0.44	FRPT-NCAT1.1	13-May-19	0.38
015	19019	BGR-NCAT3.1	19-Jun-19	0.24	FRPT-NCAT2	22-Oct-20	0.14
016	19020	FRPT-NCAT3	12-Jul-19	0.34	BGR-NCAT1	28-Jun-19	0.3
017	19024	BGR-NCAT3.1	01-Aug-19	0.3	FRPT-NCAT2	30-Apr-19	0.27
018	19025	FRPT-NCAT2	27-Apr-19	0.33	BGR-NCAT1	22-Oct-19	0.29
019	19029	BGR-NCAT3.1	23-Nov-20	0.33	FRPT-NCAT1.1	12-Jul-19	0.33

Unique Data Analysis Opportunity

This study:

Mix Design	*Same*	
CF generation procedure	*Same*	
Oven manufacturer	*Same*	
Staff training	*Same*	
Oven		**Different**
Laboratory		**Different**

Real life:

Mix Design	*Same*	
CF generation procedure		**Different**
Oven manufacturer		**Different**
Staff training		**Different**
Oven		**Different**
Laboratory		**Different**

This is a best-case scenario for CF differences….

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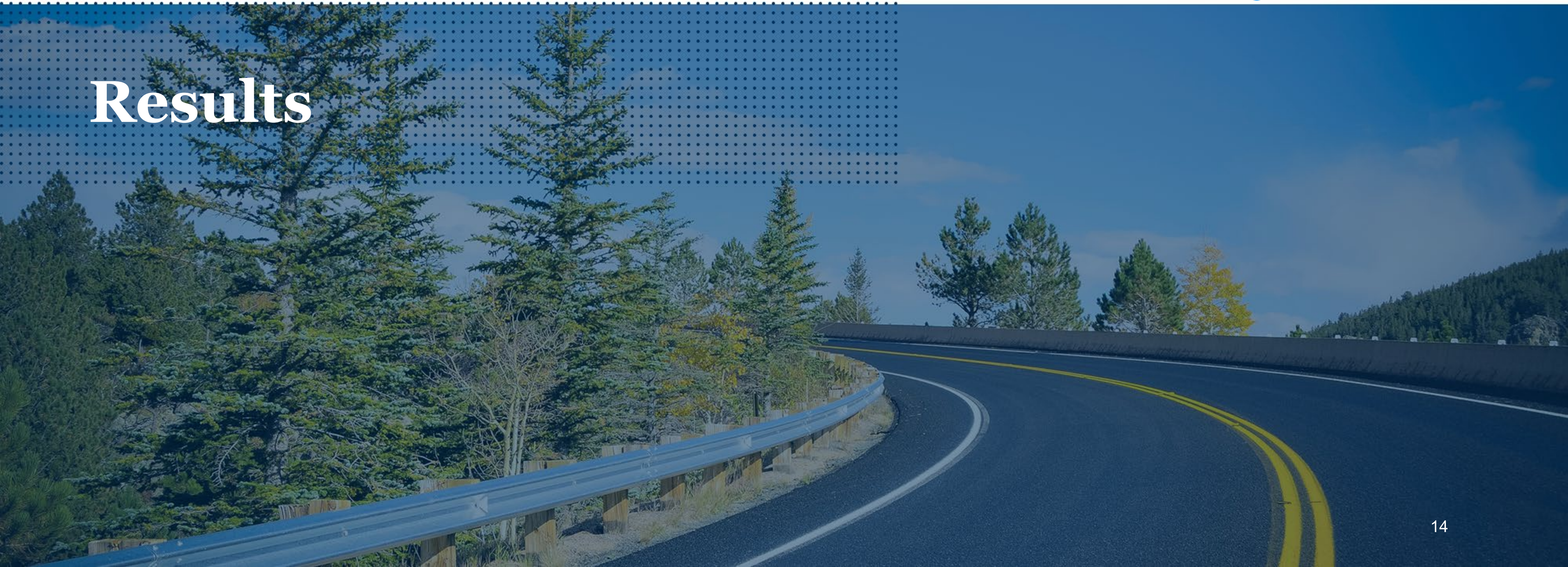
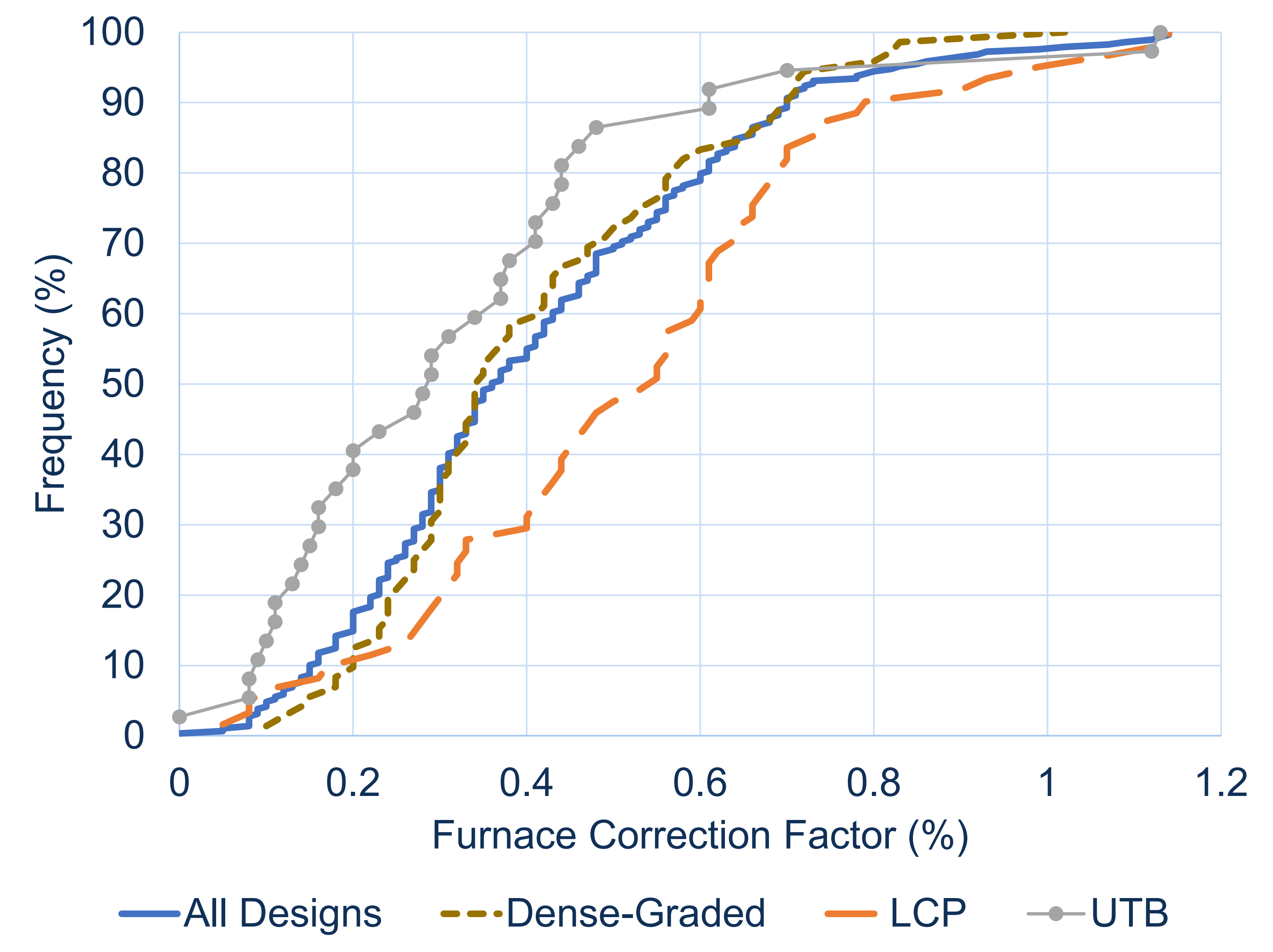
Results



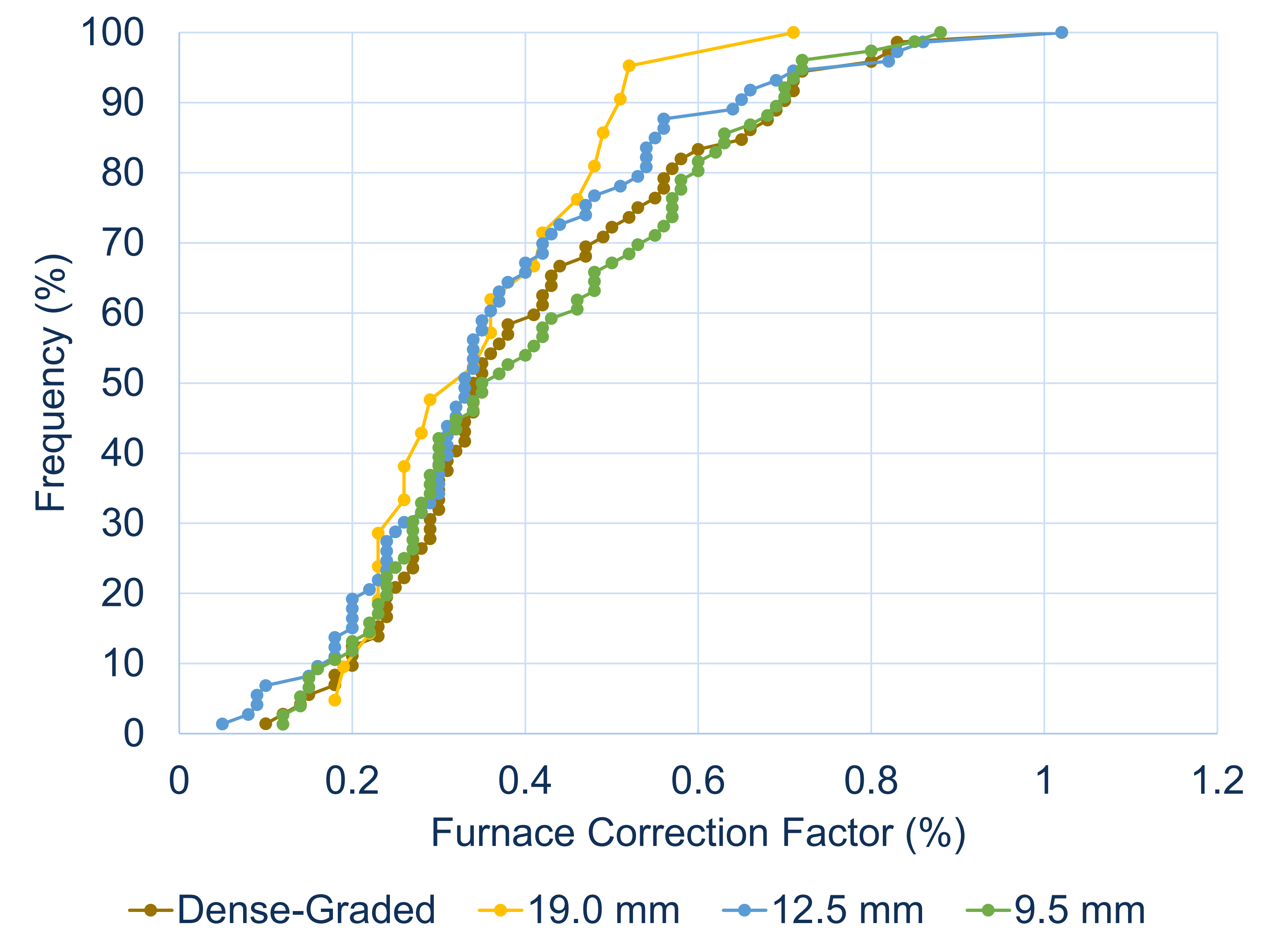
Correction Factor Distribution

- 2018-2022
- Typical factors between 0.3% – 0.5%
- Clear difference between LCP and UTB
  - Impact of recycled materials, aggregate types, and fines



Correction Factor Distribution

- 2018-2022
- No clear impact of NMAS



Correction Factor Comparisons

- 75 comparisons between different furnaces for the same mixture design.
  - 13 from the same lab / 62 from different labs
- Absolute differences

Comparison ID	REF ID	Furnace 1	Furnace 1 Date	Furnace Loss 1	Furnace 2	Furnace 2 Date	Furnace Loss 2
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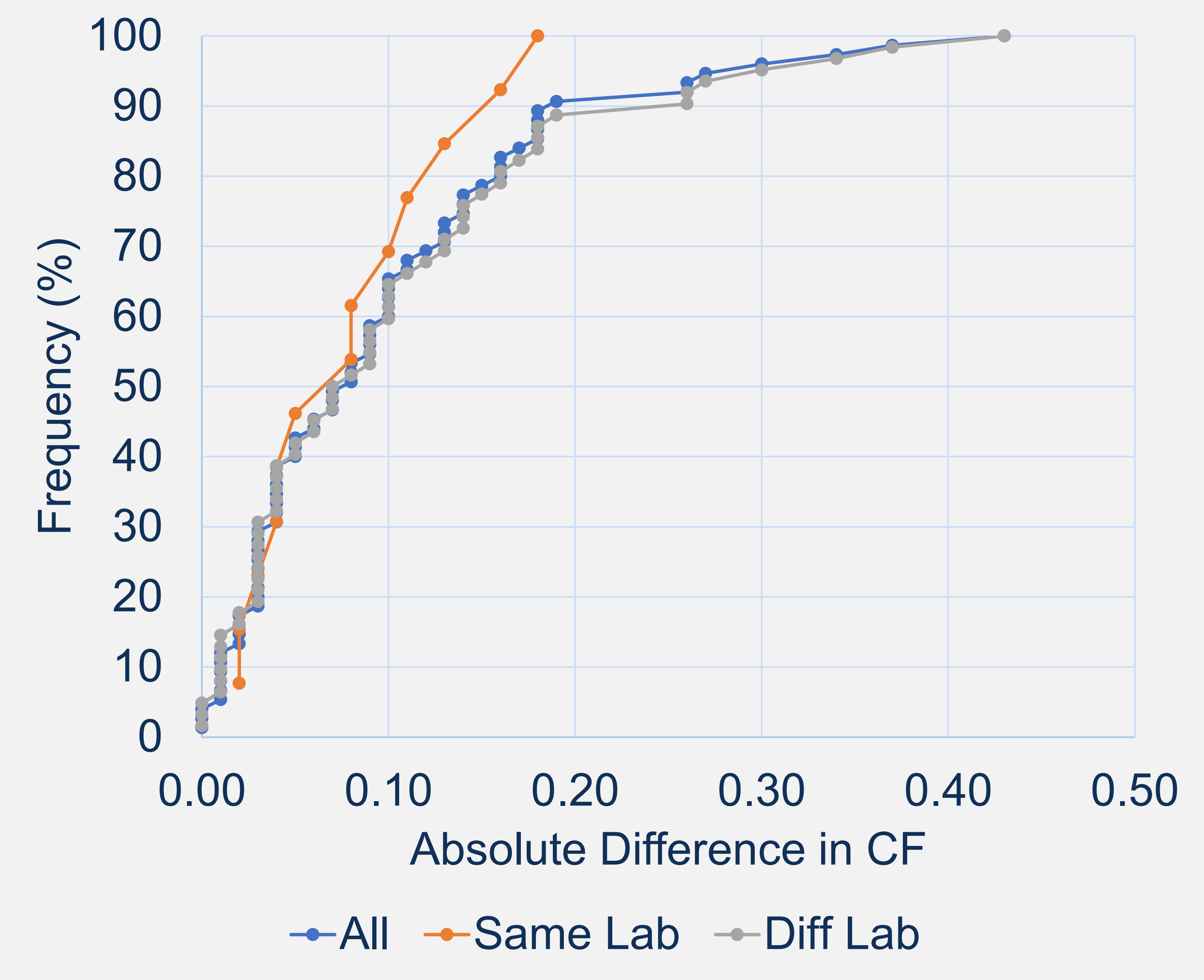
020	19031	FRPT-NCAT2	14-Jun-19	0.33	BGR-NCAT4	20-Nov-20	[illegible]

Difference in CF – Cumulative Distribution

- Avg. Difference = 0.10
- Median Difference = 0.07
- 75th percentile = 0.14

- Different labs saw the highest differences



Background: MaineDOT PWL Acceptance

- MaineDOT uses PWL and AASHTO pay equation (90 PWL = 1.0 pay)
- Agency-only results
- Asphalt content equals 25% of composite payfactor
- Typical lot (6 sublots) of 4500 tons at $100/ton used for cost analysis
- Asphalt content tolerance of 0.4% from mix design aim as LSL and USL

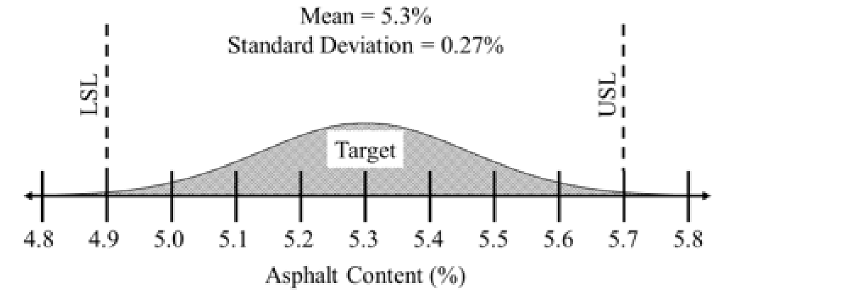
QA Impacts based upon three CF error values:

- 0.07 (Median)
- 0.10 (Average)
- 0.14 (75th percentile)

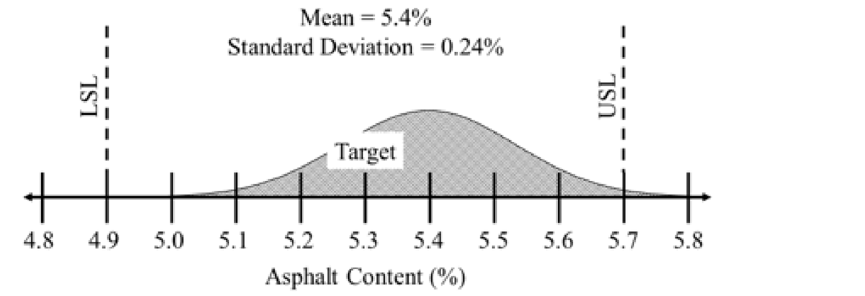
Scenarios to Simulate CF Impact

Run for positive bias and negative bias, positive shown only as example

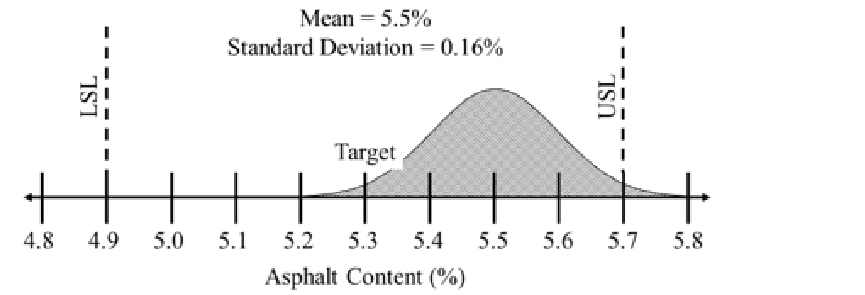
Scenario 1:
Lot on aim with typical standard deviation (90 PWL).



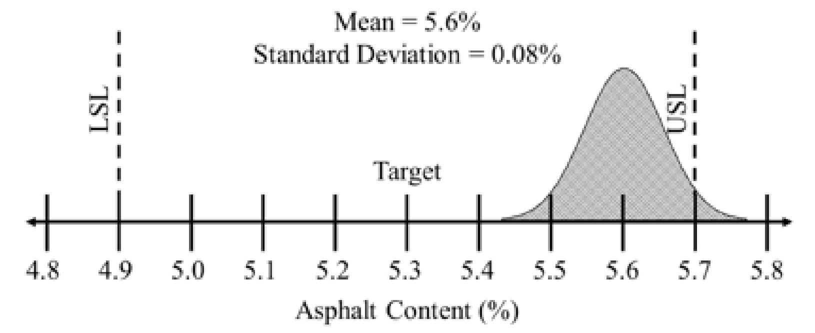
Scenario 2:
Lot average 0.1% higher than target with tighter standard deviation to achieve 90 PWL.



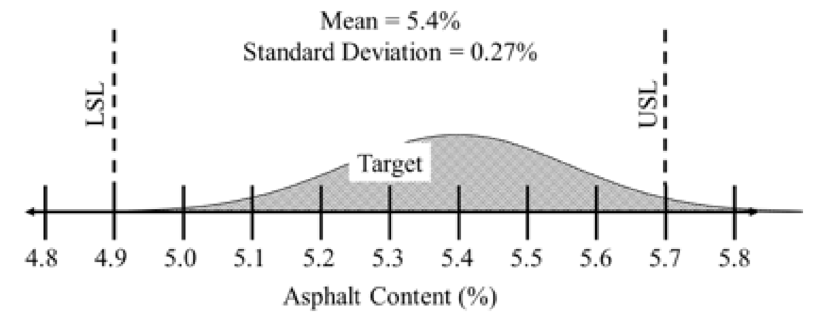
Scenario 3:
Lot average 0.2% higher than target with tighter standard deviation to achieve 90 PWL.



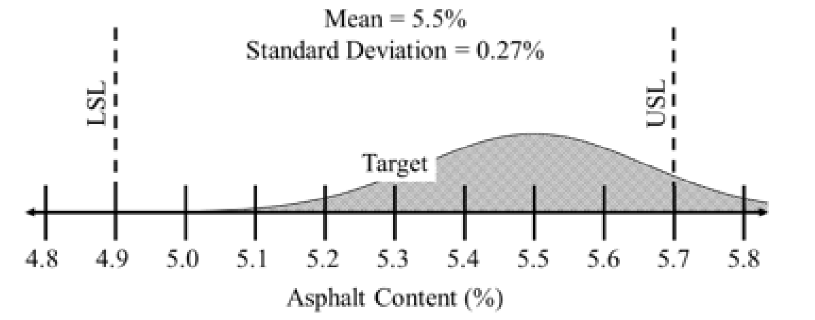
Scenario 4:
Lot average 0.3% higher than target with tighter standard deviation to achieve 90 PWL.



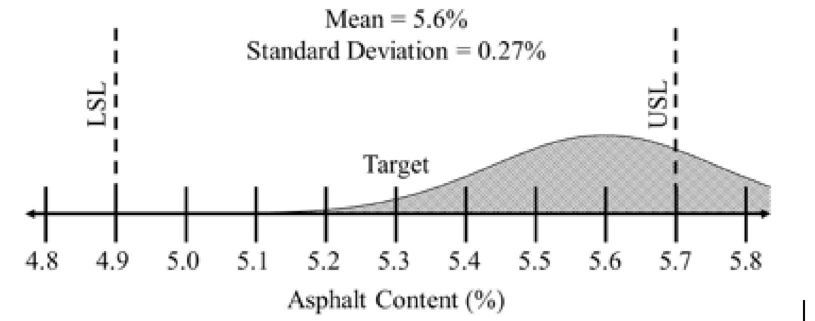
Scenario 5:
Lot average 0.1% high with typical standard deviation.



Scenario 6:
Lot average 0.2% high with typical standard deviation.



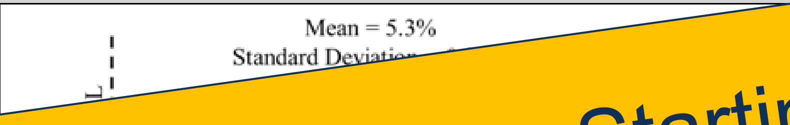
Scenario 7:
Lot average 0.3% high with typical standard deviation.



Scenarios to Simulate CF Impact

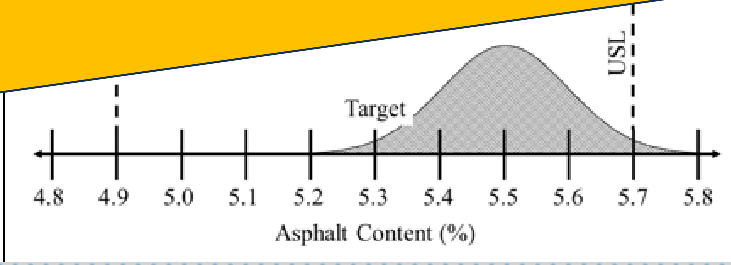
Run for positive bias and negative bias, positive shown only as example

Scenario 1:
Lot on aim with typical standard deviation (90 PWL).

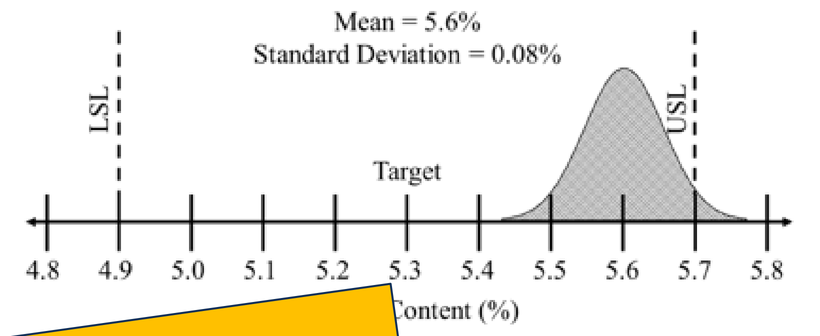


Scenario 2:
Lot average 0.1% higher t
target with tighter stand
deviation to achieve
PWL.

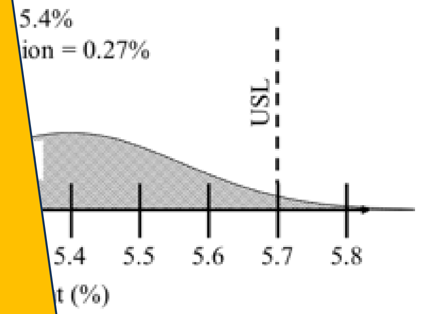
Scenario 3:
Lot average 0.2% higher than
target with tighter standard
deviation to achieve 90
PWL.

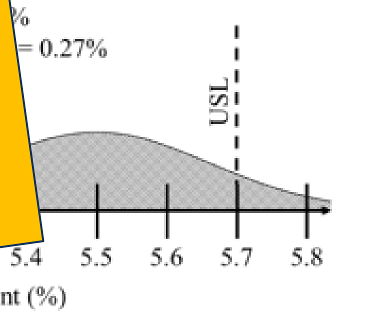


Scenario 4:
Lot average 0.3% higher than target with tighter standard deviation to achieve 90 PWL.

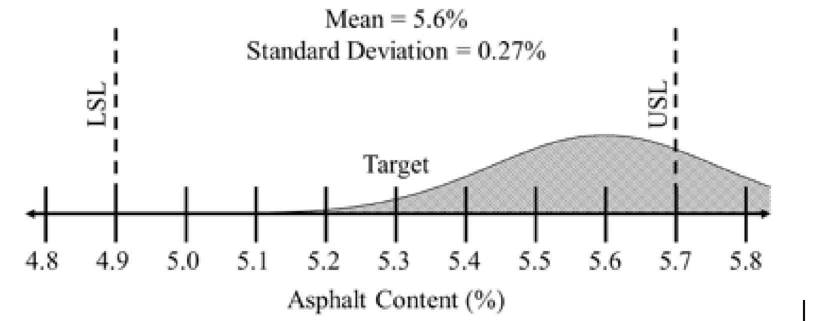


Scenario 5:





Lot average 0.3% high with typical standard deviation.



Scenarios 1-4 = Starting PWL held constant at 90 with different averages

Scenarios 5-7 = Lot standard deviation held constant with different averages

PWL Error
(Positive Bias)

- Assumes no adjustment by the contractor to Acceptance results as that cannot be simulated
- Significant effects, especially when the original average value is off the stated aim

ΔPWL Based Per Condition		Scenarios 1-4 Average Lot Asphalt Content				Scenarios 5-7 Average Lot Asphalt Content		
		On Aim	Aim + 0.1%	Aim + 0.2%	Aim + 0.3%	Aim + 0.1%	Aim + 0.2%	Aim + 0.3%
Change in CF	-0.07	-1.8	-7.5	-11.8	-26.4	-6.7	-8.7	-12.6
	+0.07	-1.8	4.5	7.8	10.1	3.3	7.7	-31.6
	-0.10	-3.6	-12.5	-19.9	-44.5	-11.4	-13.9	-22.0
	+0.10	-3.6	4.9	9.8	10.1	3.6	10.9	-3.6
	-0.14	-7.1	-16.5	-26.4	-57.8	-15.1	-17.9	-27.5
	+0.14	-7.1	4.2	10.1	10.1	3.0	12.5	1.2

ΔPayment
(Positive Bias)

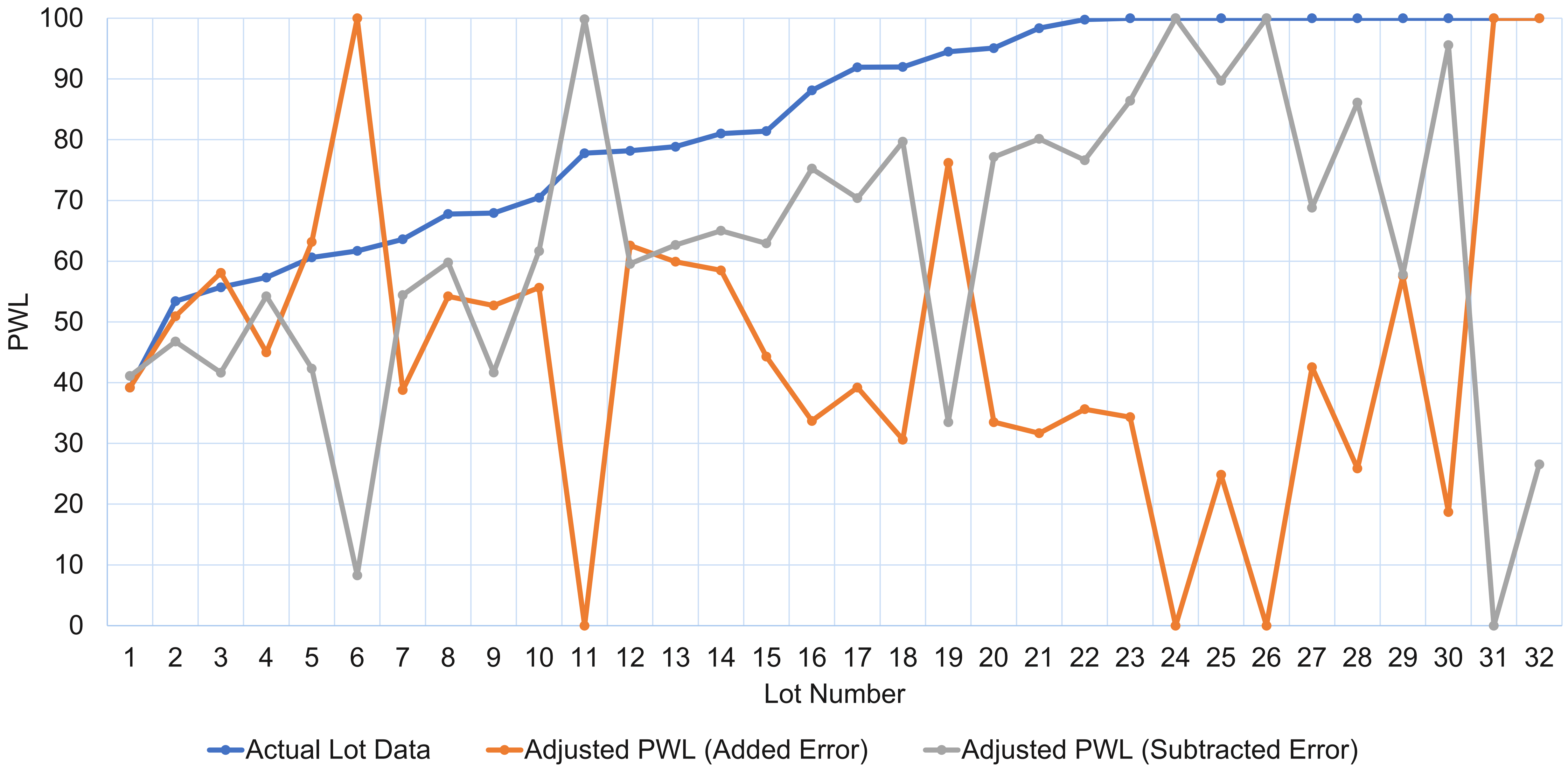
- Assumes no adjustment by the contractor to Acceptance results as that cannot be simulated
- 1% = $4500 in scenario

Change in Overall Lot Payment Per Condition		Scenarios 1-4 Average Lot Asphalt Content				Scenarios 5-7 Average Lot Asphalt Content		
		On Aim	Aim + 0.1%	Aim + 0.2%	Aim + 0.3%	Aim + 0.1%	Aim + 0.2%	Aim + 0.3%
Change in CF	+0.07	-0.2%	-1.0%	-1.5%	-3.3%	-0.8%	-1.1%	-1.2%
	-0.07	-0.2%	0.6%	1.0%	1.3%	0.4%	1.0%	1.1%
	+0.10	-0.5%	-1.6%	-2.5%	-5.6%	-1.4%	-1.7%	-1.9%
	-0.10	-0.5%	0.6%	1.2%	1.3%	0.4%	1.4%	1.7%
	+0.14	-0.9%	-2.1%	-3.3%	-7.2%	-1.9%	-2.2%	-2.4%
	-0.14	-0.9%	0.5%	1.3%	1.3%	0.4%	1.6%	2.1%

Actual Lot Analysis

- Three major designs evaluated with larger CF differences – 32 total lots
  - Design A (9.5mm Fine-Graded w/ RAP) – CF difference = 0.30
  - Design B (12.5 mm Coarse-Graded w/RAP) – CF difference = 0.37
  - Design C (12.5 mm Coarse-Graded w/RAP) – CF difference = 0.43

Design	Average Original PWL	Average Altered PWL (subtract error)	Average Altered PWL (add error)	Average PWL Error
A	70.6	66.9	43.0	19.4
B	93.1	31.9	77.5	39.7
C	65.8	45.8	48.1	18.9


100
90
80
70
60
50
40
30
20
10
0
PWL
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
Lot Number
Actual Lot Data
Adjusted PWL (Added Error)
Adjusted PWL (Subtracted Error)

Findings

- Effect of mixture type evident in CF's for MaineDOT mixtures
- Bias observed between CF generated for different ovens if the same design
  - Range in values for Maine aggregates (0.07 – 0.14 range)
  - Differences smaller than observed than in national studies (typically with higher loss and absorptive aggregates)
- Differences in CF can cause significant impacts to Acceptance and Quality Control functions if accurate CF not generated
  - Observed in statistical acceptance program depending on the conditions
  - Effect can be made worse when production is off the aim

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Questions?

Thank you for your attention!

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