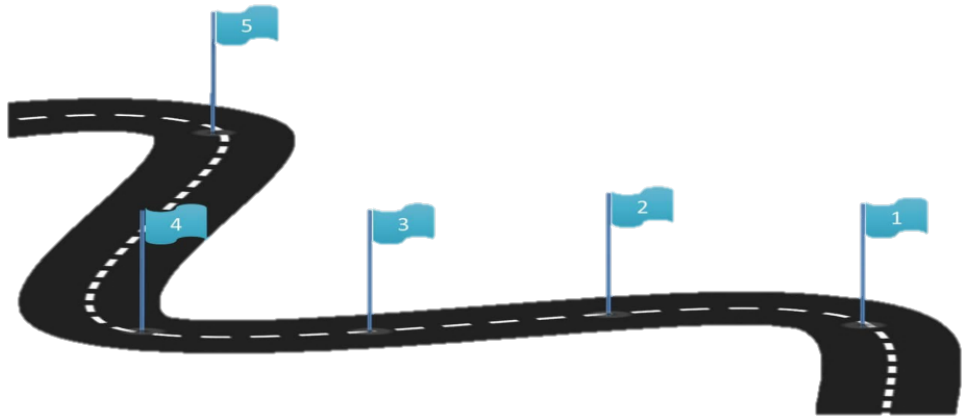
Balanced Mix Design in Missouri

Why Balanced Mix Design?

- Agency not creating specifications for mix components & additives
- Allows innovation and flexibility for contractors

BMD History in Missouri

- 2017 - 2019 – Started Performance Testing and Developed Benchmarks
  - DCT, I-FIT, SCB, CT_{Index}
  - Hamburg
- 2019 – Selected Final BMD Tests, Developed JSP, and Started Shadow Projects
  - CT_{Index}
  - Hamburg
- 2020 - 2022 – 45 Pilot/Shadow Projects – Revised JSP
  - No Reheating of Material
  - QC/QA made fabricated at the plant
- 2023 – 34 Pilot/Shadow Projects
  - Need for a Final Draft Specification
  - Move to RT_{Index} instead of Hamburg



Research Review

https://spexternal.modot.mo.gov/sites/cm/CORDT/Forms/By%20Year.aspx

Support for Balanced Asphalt Mixture Design Specification Development in Missouri

September 2020 Final Report	Project number TR201811 MoDOT Research Report number cmr 20-010

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Criticality	DC(T) [J/m^2]	FI	IDEAL-CT
H	600	14	150
M	500	8	100
L	400	4	55

Setting BMD Thresholds

Table 5-1. Field sections with significant time in service

	Section #	Constr. Year	Virgin Binder Grade	Asphalt Content (%)	ABR (%)	ABR by RAP (%)	ABR by RAS (%)
Phase I	MO52_1	2010	PG64-22	4.8	33.5	0	33.5
	US 54_8	2006	PG70-22	5.6	8.6	8.6	0
	US50_1	2011	PG64-22	5.0	24.6	24.6	0
	US63_2	2008	PG64-22	5.6	29.9	19.9	10
	US54_7	2003	PG64-22	6.2	0	0	0
Phase II	MO 151	2010	PG64-22	4.7	30.6	15.9	14.7
	US 36 E	2011	PG64-22	5.1	24.7	24.7	0
	US 54 E	2010	PG70-22	5.7	11.8	11.8	0
	MO 94	2005	PG64-22	5.6	0	0	0
	MO 6 W	2015	PG58-28	5.9	29.6	29.6	0
	US 61 N	2013	PG64-22H	5.3	29.6	29.6	0

Flexibility Index	Ideal CT	Percent of Contract Price
NMAS <190	NMAS <190	
< 2.0	< 32	98%
2.0 – 3.9	32 – 60	100%
4.0 – 7.9	60 - 97	102%
>8.0	> 97	103%

- US 50 – Good Performance ~ FI = 7.84; CT = 96.0
- US 36 – Poor Performance ~ FI = 1.12; CT = 20.2

Future Changes in Performance Tests

CRACKING ⟵ ⟶ **RUTTING**

DURABILITY ↓

CT-Index

SIP Parameter on Hamburg (HWTT)

TSR

RT-Index

Future Performance Specifications

CT-Index		
SuperPave CT_{Index}	SMA CT_{Index}	PWL
< 50	< 135	PWL (Modified)
50 – 100	135 – 240	
> 100	> 240	

Tensile Strength Ratio (TSR)	
TSR	% Pay
85 % or Above	Use PWL or Full Incentive
84 – 75 %	100
70 – 74 %	98
< 70 %	Remove

RT-Index	
PG High Temp. Grade	Minimum RT_{Index}
58H & 64S	50
64H	65
64V	80

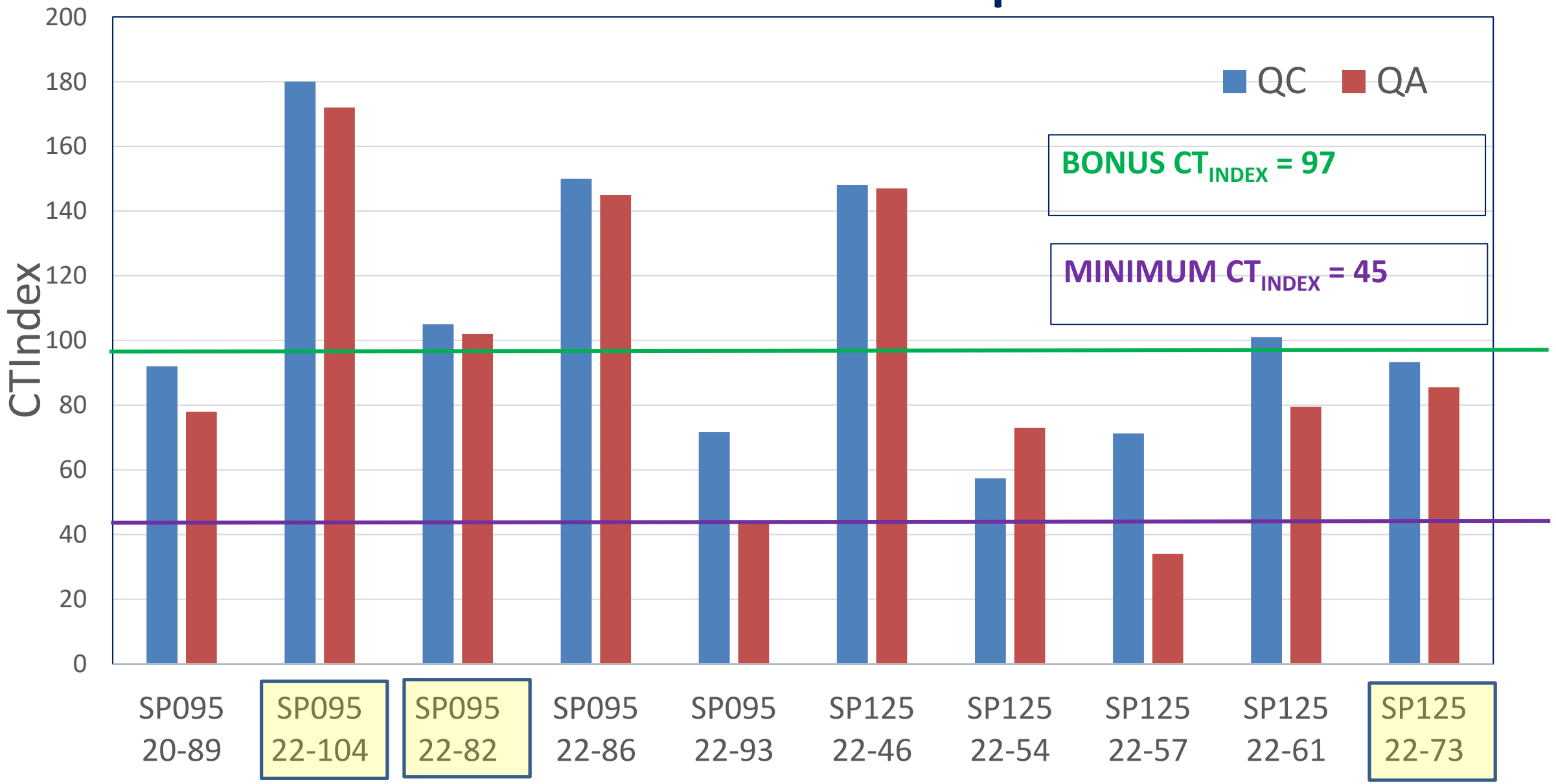
Hamburg Wheel Track		
PG High Temp. Grade	Minimum Wheel Passes	Maximum Rut Depth (mm)
58S	5,000	12.5
64S	7,500	12.5
64H	15,000	12.5
64V	20,000	12.5

Construction Year 2022

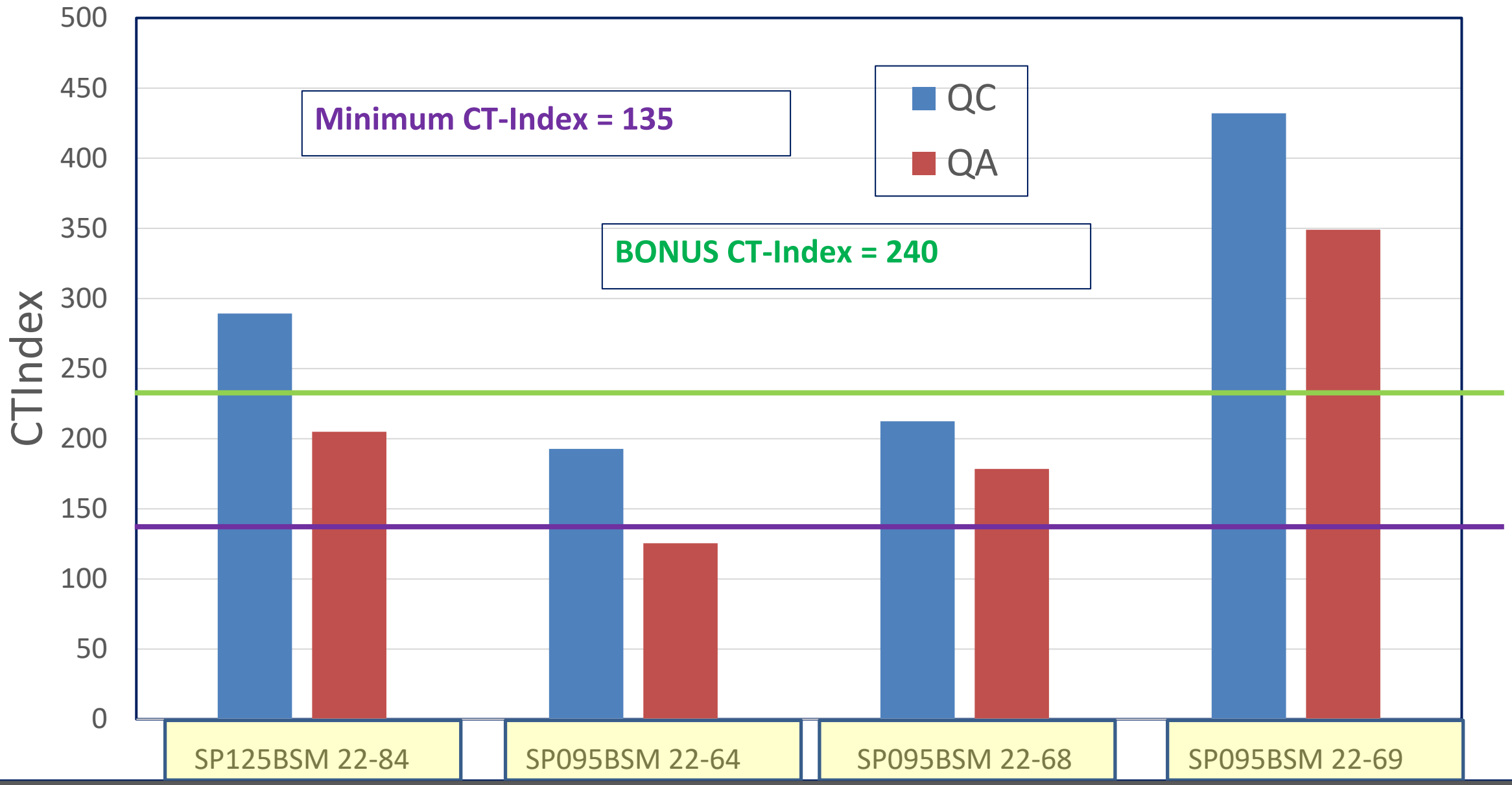
- 16 Projects Selected
- 8 Projects with BMD QC/QA production sampling and testing
- 8 Projects with BMD testing for Job Mix Approval Only
- 1 QC Set / 10,000 tons
- 1 QA Set / 20,000 tons

Dist	County	Route	Job Number
NW	Atchison	IS 29	1I3231
NW	Daviess	IS 35	1I3232
NW	Livingston	US 36	1P3277
NE	Audrain	US 54	2P3258
NE	Lincoln	US 61	2P3259
		MO 79	2P3241
KC	Platte	IS 635	4I3331
KC	Cass	IS 49	4I3332
CD	Cooper	IS 70	5I3252
CD	Boone	US 63	5P3409
SL	St. Charles	US 61	6P3307
SL	Franklin	US 50	6P3560
SL	St. Louis	US 61	6S3281
SW	Bates	IS 49	7I3258
SW	Christian	US 65	7P3210
SE	Pemiscot	IS 155	9I3597
SE	Wayne	US 67	9P3705

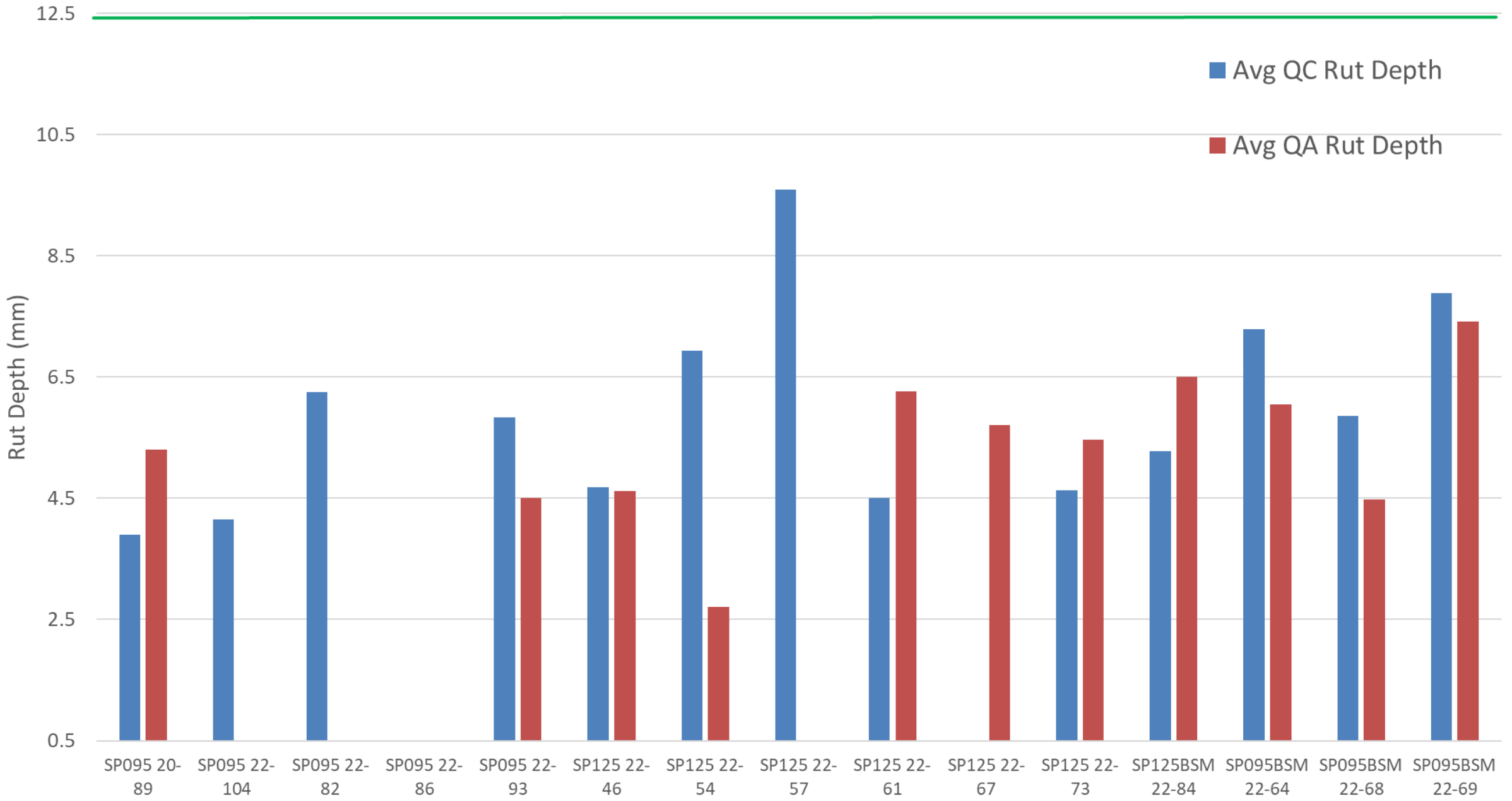
2022 CT-Index Test Results for SuperPave Mixes



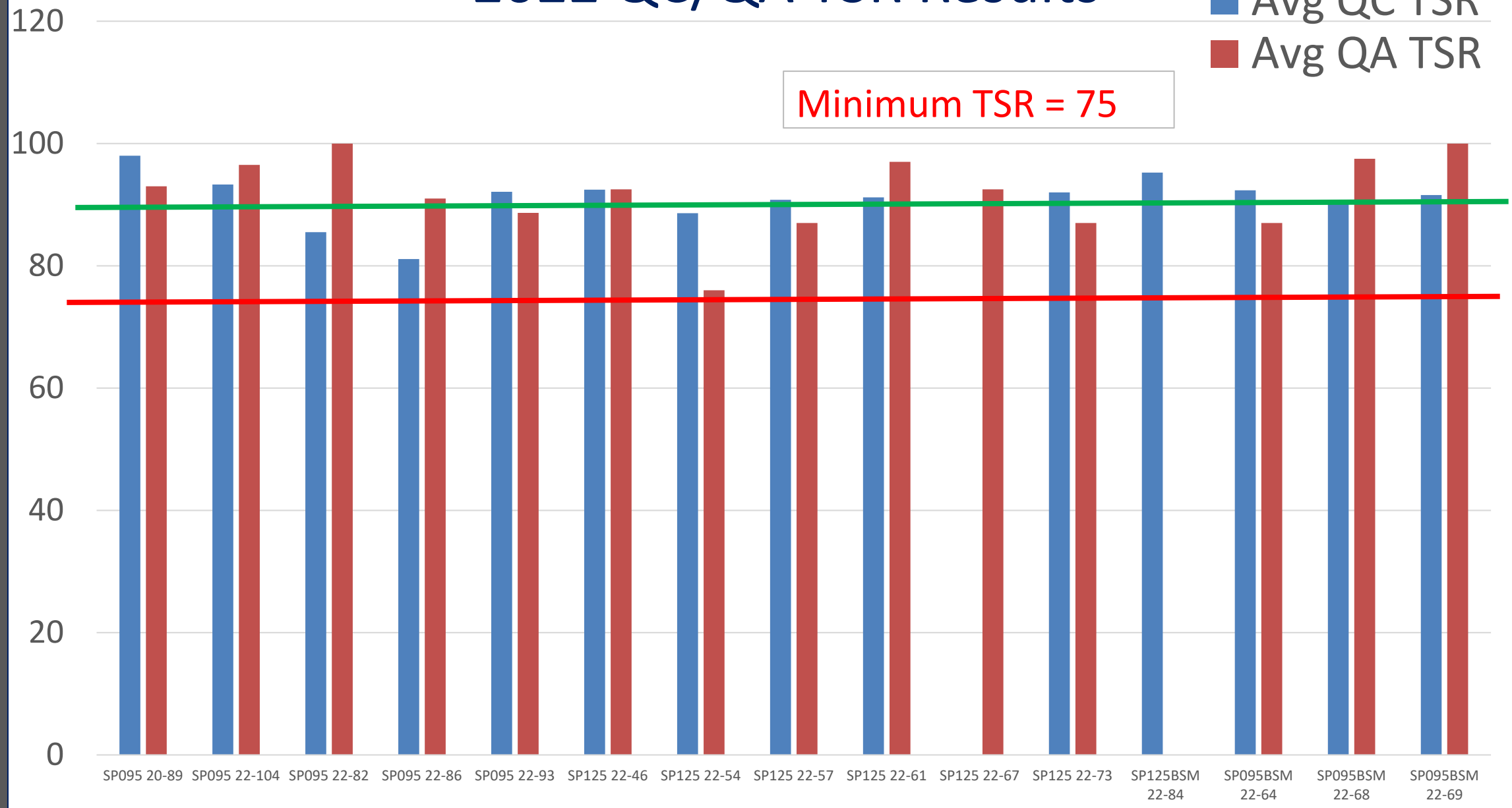
2022 CT-Index Test Results for SMA Mixes

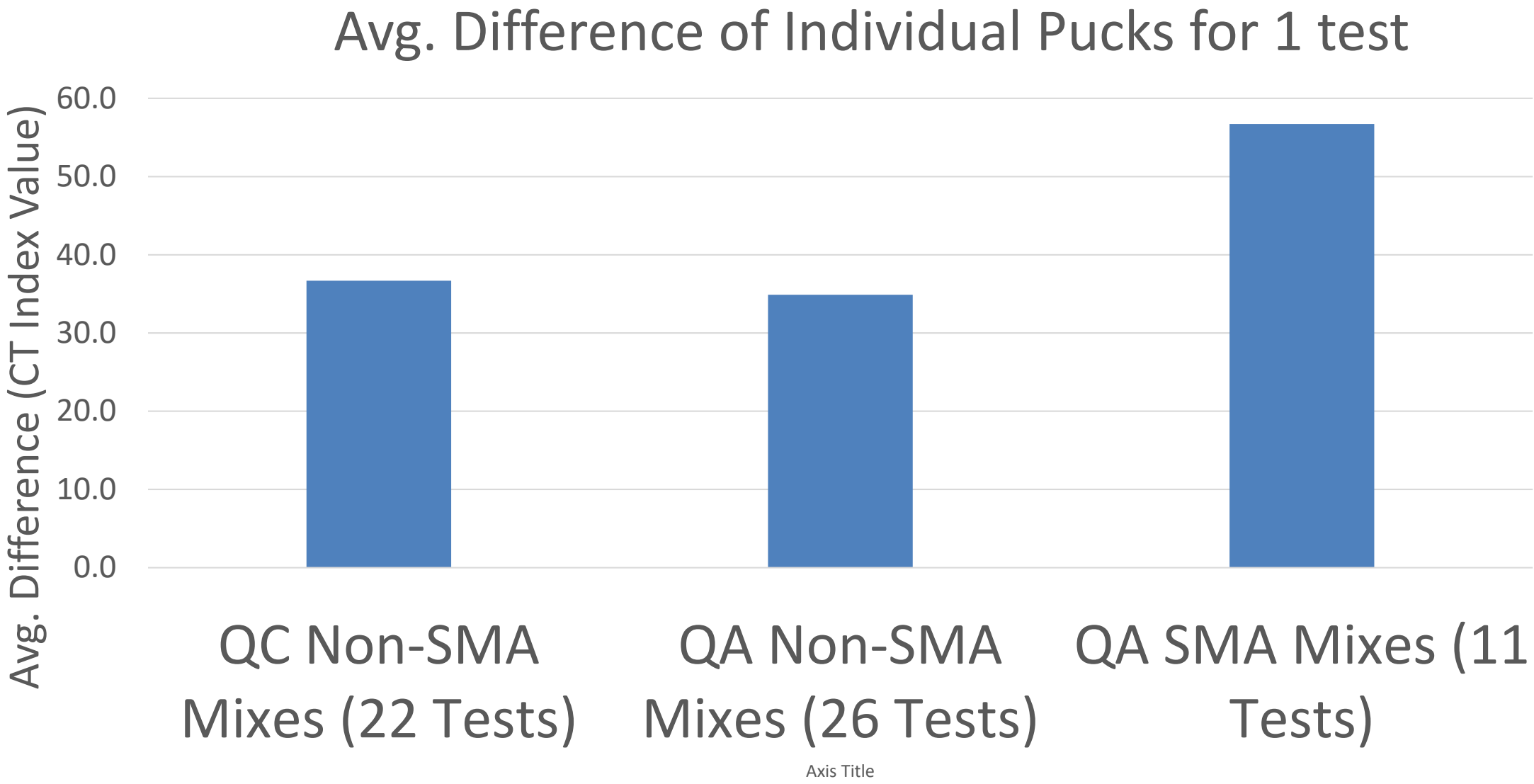


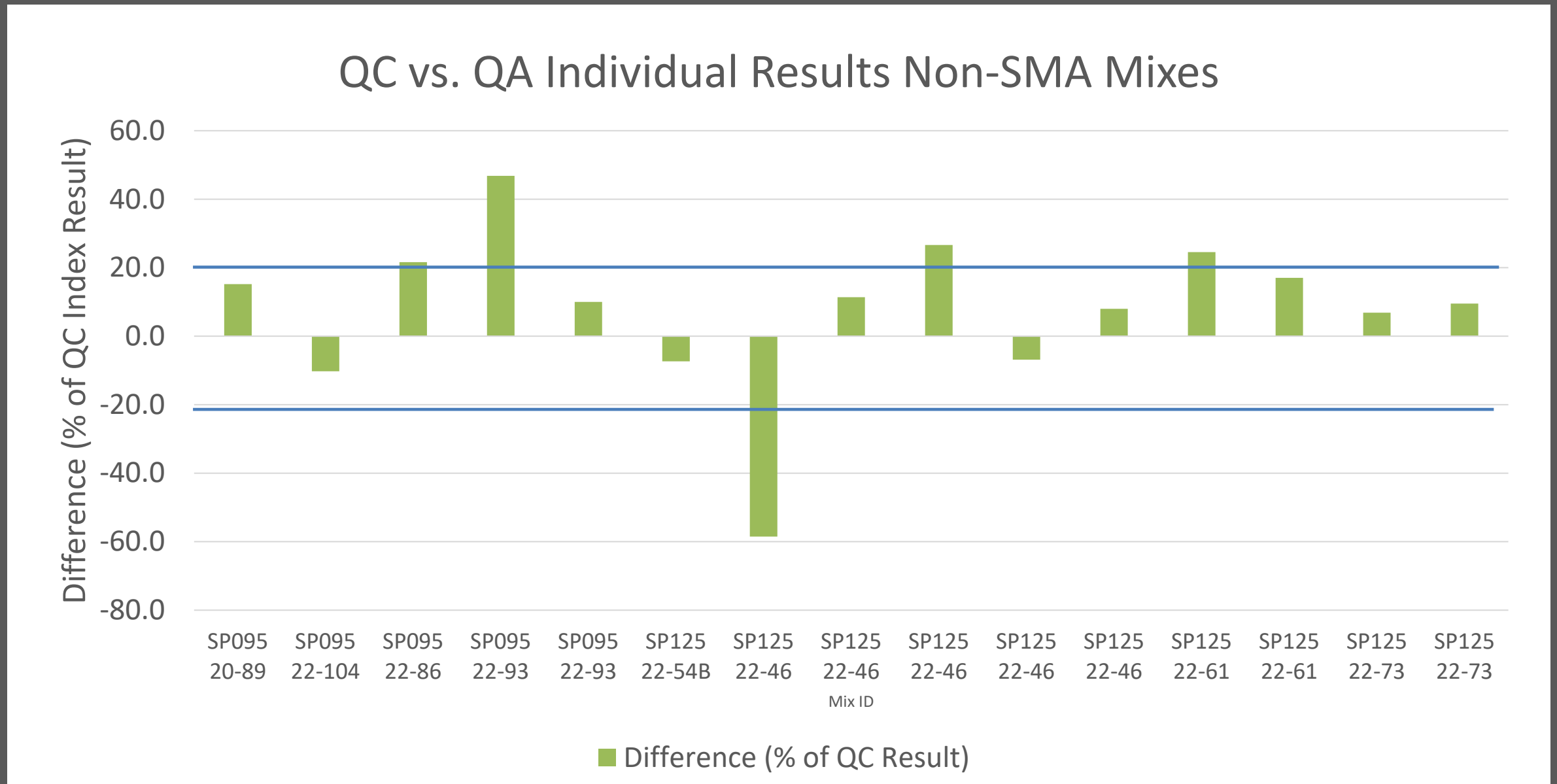
2022 Hamburg Test Results (All Mixtures)

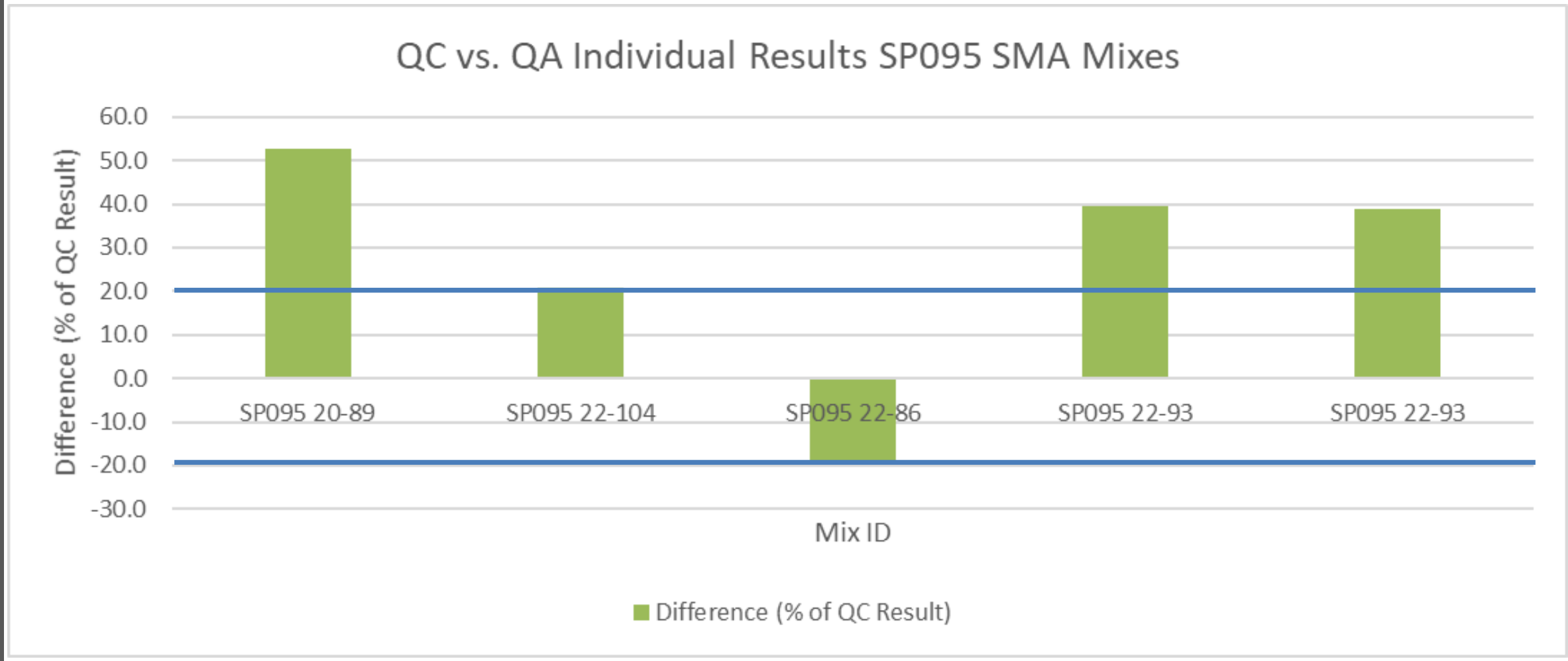


2022 QC/QA TSR Results

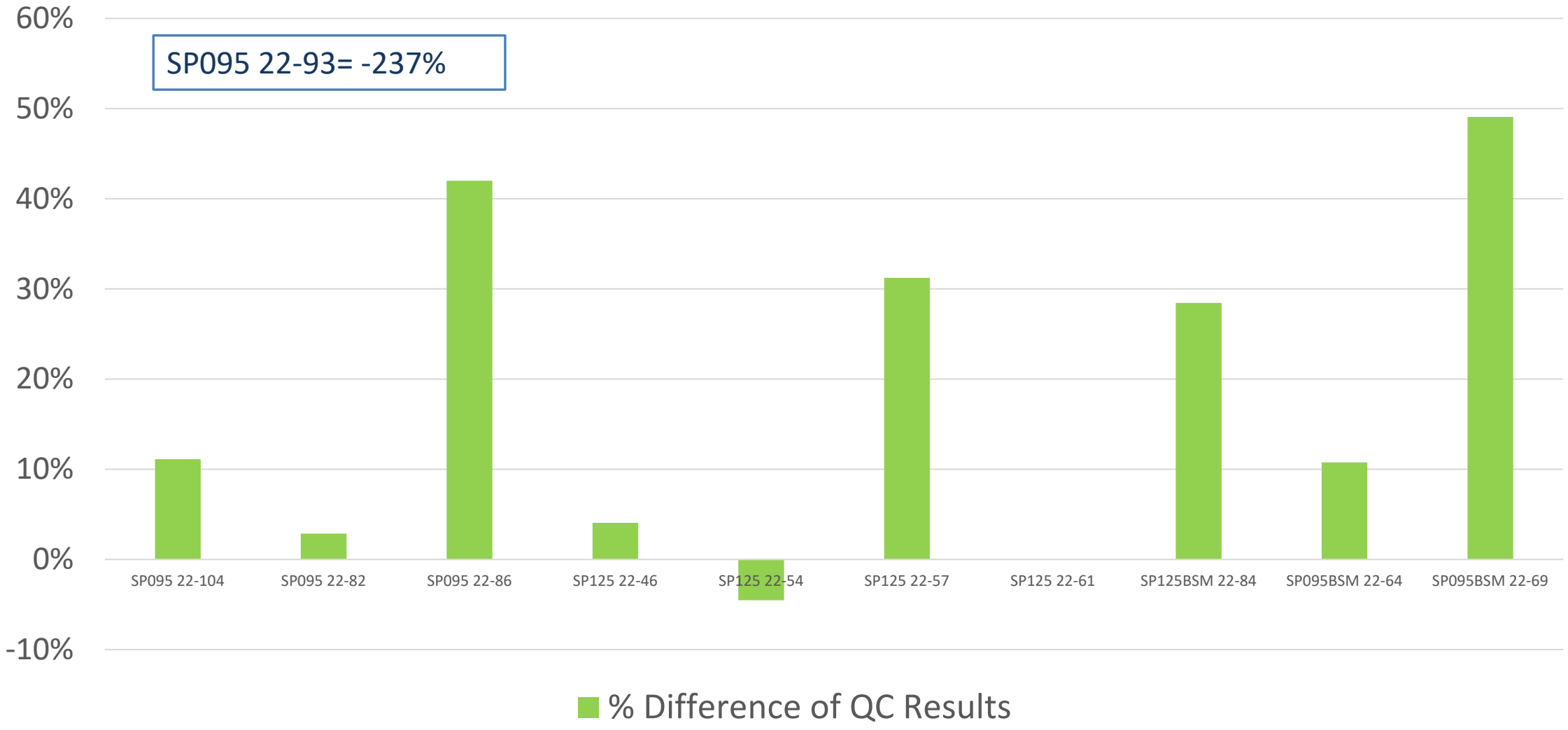



Avg. Difference of Individual Pucks for 1 test
Avg. Difference (CT Index Value)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
QC Non-SMA Mixes (22 Tests)
QA Non-SMA Mixes (26 Tests)
QA SMA Mixes (11 Tests)
Axis Title

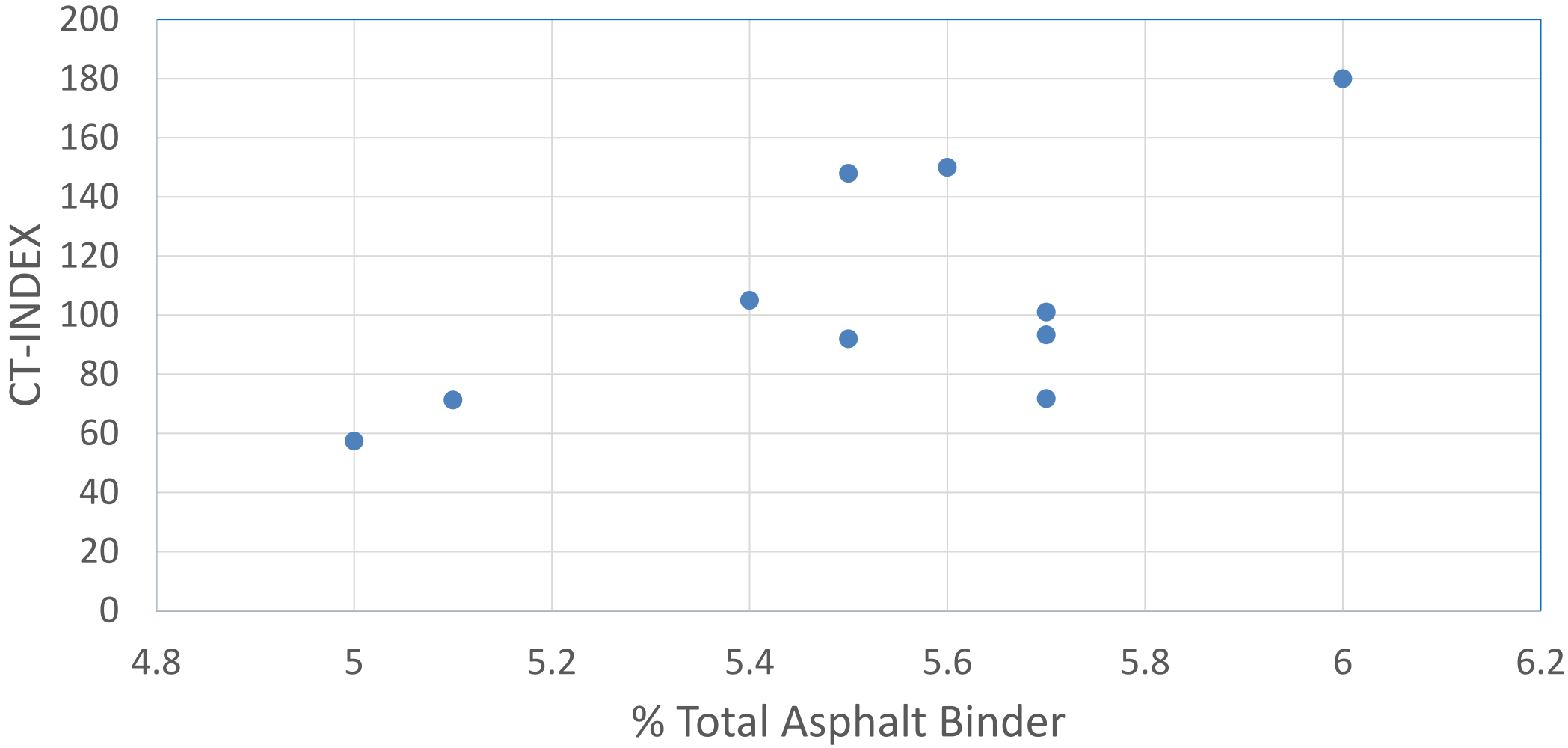

QC vs. QA Individual Results Non-SMA Mixes
Difference (% of QC Index Result)
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
-80.0
SP095 20-89
SP095 22-104
SP095 22-86
SP095 22-93
SP095 22-93
SP125 22-54B
SP125 22-46
SP125 22-46
SP125 22-46
SP125 22-46
SP125 22-46
SP125 22-46
SP125 22-61
SP125 22-61
SP125 22-73
SP125 22-73
Mix ID
Difference (% of QC Result)

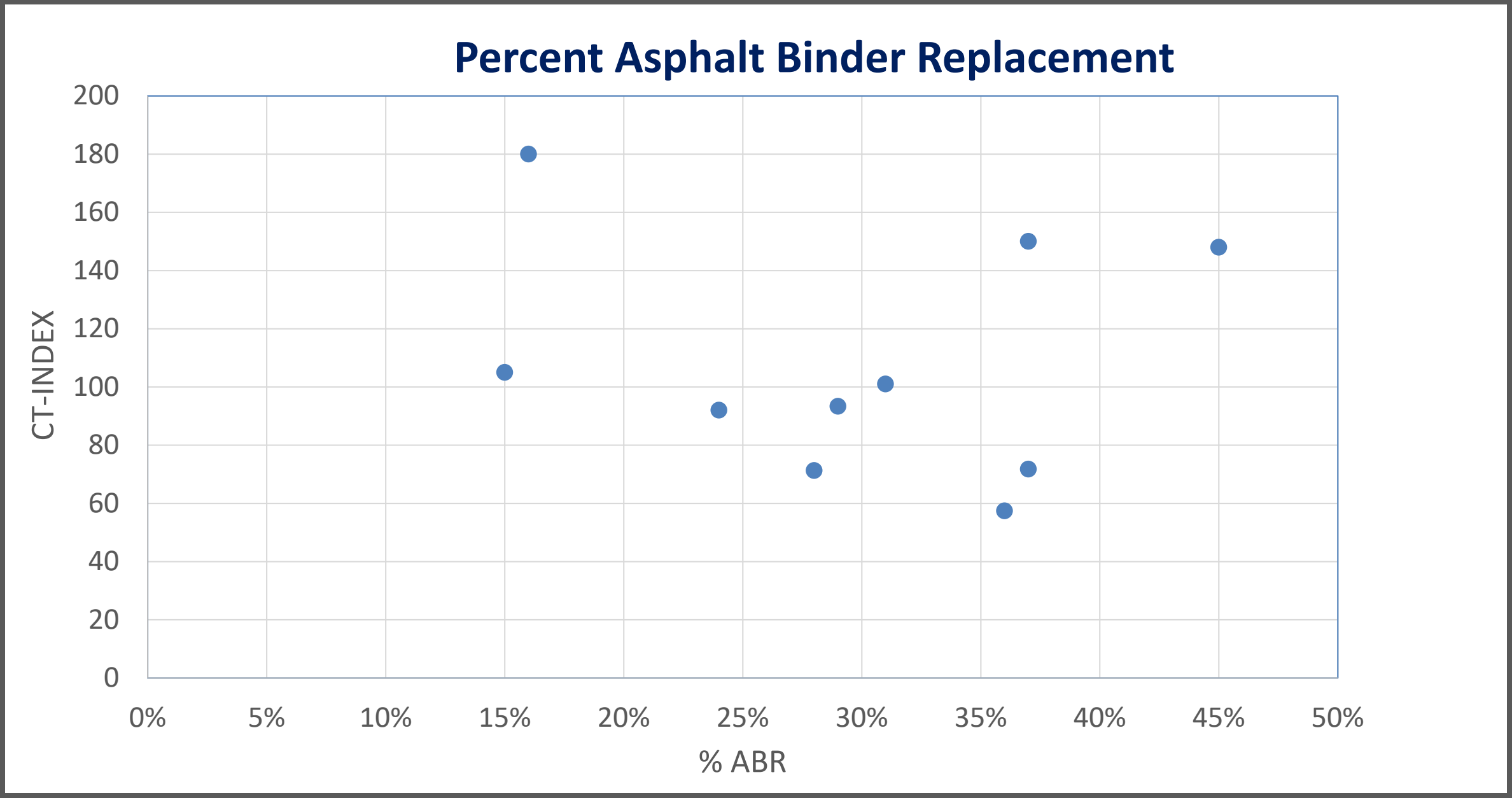

QC vs. QA Individual Results SP095 SMA Mixes
60.0
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
Difference (% of QC Result)
SP095 20-89
SP095 22-104
SP095 22-86
SP095 22-93
SP095 22-93
Mix ID
Difference (% of QC Result)

CT_{Index} - JMF vs QC Field Comparison



% Asphalt Binder vs CT-INDEX




Percent Asphalt Binder Replacement
CT-INDEX
200
180
160
140
120
100
80
60
40
20
0
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
% ABR

BMD LESSONS LEARNED

- Reheating significantly affects CT_{Index}
  - QC and QA specimens fabricated by the contractor at the plant
- Dwell Time can affect CT_{Index}
  - Specimens need to be tested within a week
- Rejuvenators/Warm Mix additives can affect CT_{Index} and Hamburg results
  - 30 minute wait time before specimen fabrication.
- Variability in CT_{Index} results
  - Fabricate 5 CT_{Index} specimens, throw out high and low value, average remaining three

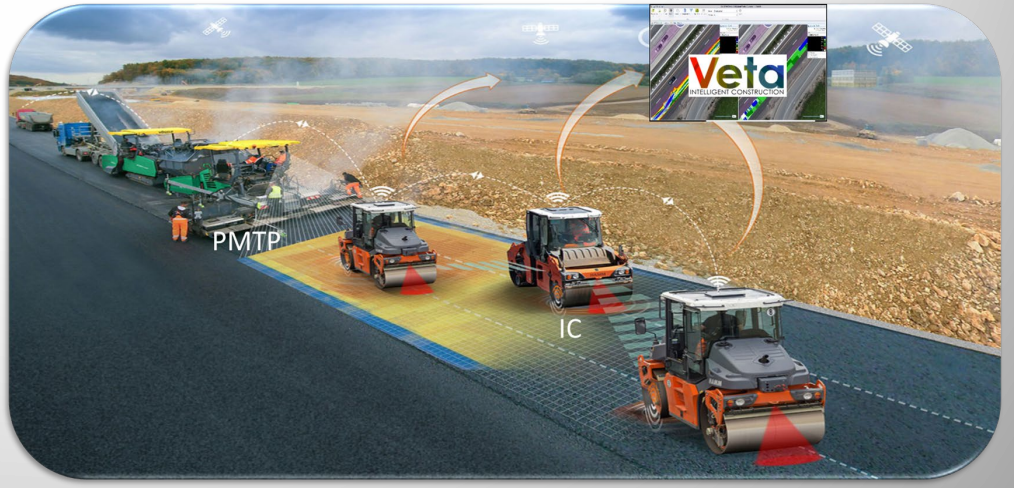
Industry/Agency/ Academia Partnership

- MAPA Quarterly Meetings
- Bituminous Technical Team Meetings
- BMD Group

1 Challenge - Incorporating BMD & IC into Specifications for Pay Factors

Performance Pay Factors

- CT-Index
- Hamburg / RT Index
- Paver Mounted Profiler
- Intelligent Compaction



Source: modified from Wirtgen, GSSI

Proposed New Pay Factors

Density

- Cores or Nuclear Gage
- Intelligent Compaction

CT_{Index}

- RT_{Index}
- TSR

% AC

New Pay Factors Cont……

PMTP

Smoothness

IRI

New Pay Factors Formulas

403.23.2 Pay Factors. The total pay factor (PF_T) for each lot will be equal to the weighted sum of the pay factors (PF) for each pay factor item for each lot, and is determined as follows:

$$PF_T = + (0.5)\ PF_{Density} + (0.25)\ PF_{CTindex} + (0.25)\ PF_{AC}$$

The PF_T for each lot, on the shoulder or otherwise when the density pay factor is not directly included, will be equal to the weighted sum of the PF for each pay factor item for each lot, and will be determined as follows:

$$PF_T = (0.5)\ PF_{CTindex} + (0.5)\ PF_{AC}$$

Getting the CT_{Index} into PWL_t Calculations

The PF for each pay factor item for each lot will be based on the PWL_t of each pay factor item of each lot and will be determined as follows:

When PWL_t is greater than or equal to 90: $PF = 0.6\ PWL_t + 46$;

When PWL_t is greater than or equal to 70 and PWL_t is less than 90: $PF = 0.5\ PWL_t + 55$;

When PWL_t is less than 70: $PF = 2\ PWL_t - 50$;

When all CT_{Index} results are above 100 for SuperPave mixes and above 240 for SMA mixes; maximum CT_{Index} incentives shall be given regardless of PWL.

When all CT_{Index} results are above 80 for SuperPave mixes and above 190 for SMA mixes; a minimum of 100 percent pay for CT_{Index} shall be provided regardless of PWL.

INCENTIVES/DISINCENTIVES

- 6 % PWL
  - Density, CT_{Index}, %AC
- 2% - PMTP
- 3 – 5% - Smoothness
- **TOTAL – 11 – 13 %**

- Sublot – 1 Day Production/Paving Shift
- Lot Size – 5 Days Production/Paving Shifts
- Random Numbering Discussion
  - Field Density by Tonnage
  - Plant Sampling by Time Frame
- Increased Time and Effort in Performance Testing
  - 10 Specimens vs 2 Specimens

Tested Property	Test Method	Contractor Frequency (Minimum)	Engineer Frequency (Minimum)
Pay Factors			
Mat Density (% of theoretical maximum density)[a]	MoDOT TM 41, AASHTO T 166 or AASHTO T 331	1 Sample / 1000 tons	1 Sample / Lot
CT_{Index}	ASTM D 8225	1 Sample /Sublot	1 Sample / Lot
Asphalt content	AASHTO T 164, or MoDOT Test Method TM-54, or AASHTO T 287, or AASHTO T 308	1 Sample / Sublot	1 Sample / Lot
Pay Factor Adjustments			

Performance Test	Minimum Number of Specimens	Molded Specimen Height (mm)
Cracking Tolerance Index (CT_{Index})	5	62
Rutting Tolerance Index (RT_{Index})	3	62
Volumetrics	2	N_{Design}
% Asphalt Content	Loose Mix as needed	N/A
Retained Loose Mix [a]	2 boxes to retain	N/A

(a) Loose mix sampling is for Hamburg verification of mixture not meeting minimum RT_{index} thresholds, volumetric, or % asphalt content testing.

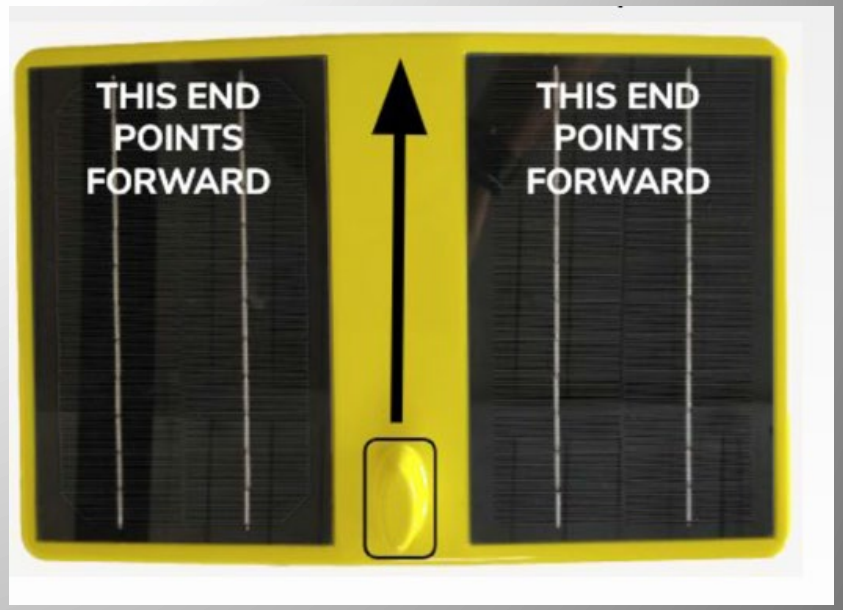
Equipment and Training

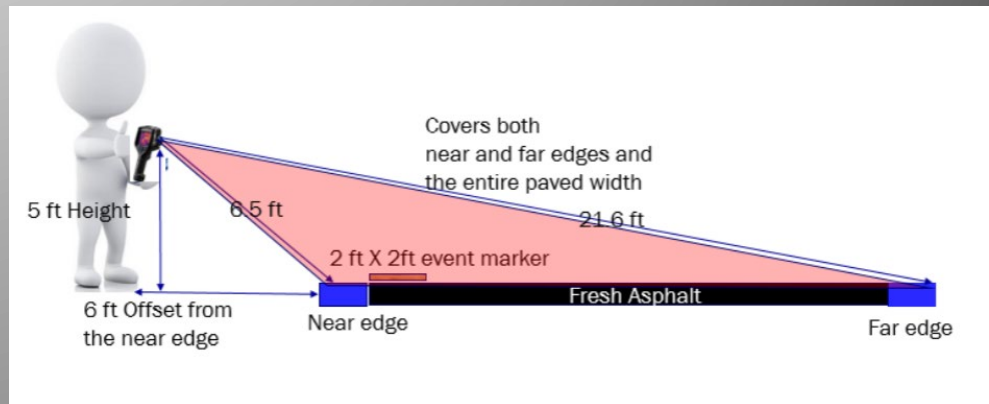
CT-Index & RT-Index

- Total Equipment needed - $300,000
- 3 Load Frames and 6 Water Baths on Order
  - SL, KC, and SW Districts
  - Central Laboratory
- Arrange State-Wide Training at each District when equipment arrives
  - Part of the Contract
  - Working with Linn State to incorporate into SuperPave Training

Intelligent Compaction/Paver Mounted Thermal Profiler

- PMTP/Intelligent Compaction – Continuation of ~ 14 projects/yr
  - Recognize the need of on-site technical support and training.
    - Proposal of Hiring a Consultant
  - Continue with annual IC/PMTP Trainings
    - MoDOT IC/PMTP 101 Training
    - MoDOT IC/PMTP Advanced Training





Implementation Goals

- Finishing a Final “Draft” BMD Specification for Pilot Projects
  - 7 – 14 Pilot Projects per Year
  - No Spec Changes for 2024 Construction Season; but working toward final “Draft” Specification for 2025 Construction Season
- Working on Interim BMD Specification
  - Allow Contractors to select BMD Spec or Regular SuperPave Spec
  - Interim Spec will NOT have IC; but will have PMTP requirement
- Starting Research on BMD Validation

BMD Validation

- Missouri Supplemental Test Sections
  - MO 740 (Stadium Project) in Central Missouri
  - NRRA Reflective Cracking Challenge on I-155, SE Missouri
- More Test Sections Needed
  - BMD Validation Guide

Appendix A: Plant Modified Plant Compacted Mixture Results

Mix Name	CT-Index	RT-Index	Hamburg at 20k passes (mm)
SP-Control	111.0	100	2.2
SP+PPA	113.6	63.6	5.6
SP-MDPE	90.5	94.8	2.8
SP-LDPE	136.4	76.3	3.5
SP-ECR	151.6	62.3	4.3
SP+SBS	75.6	90.7	3.7
SMA-ECR	232.1	44.6	5.3
SMA-LDPE	371.3	42.3	5.2
SMA-Control	274.1	34.4	14.1

QUESTIONS