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MDOT SHA's BMD Study

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Background Information

- MDOT SHA places about ~1.3 to 1.5 M tons of asphalt every year
  - ~85% of it is dense graded mix
  - ~15% is gap-graded mix
- Maryland do not have problems with rutting
- We do have some premature cracking problems
  - We suspect that some of our mixes could be on dry side
- Our goal is to address the cracking and rutting issues with new balanced mix design approach

Recycled materials

	2017	2018	2019	2020	2021
RAP Tons	312025	294768	337473	231823	304097
RAS Tons	996	1502	1470	800	930
Total Mix Tons	1492624	1297822	1451227	1063718	1358966

MSMT 412

Recommended virgin asphalt grade	Minimum Allowable % Binder Replacement	
	RAP or RAP/RAS	RAS Only
No change	<=30	<=20
Blending charts	>30	>20

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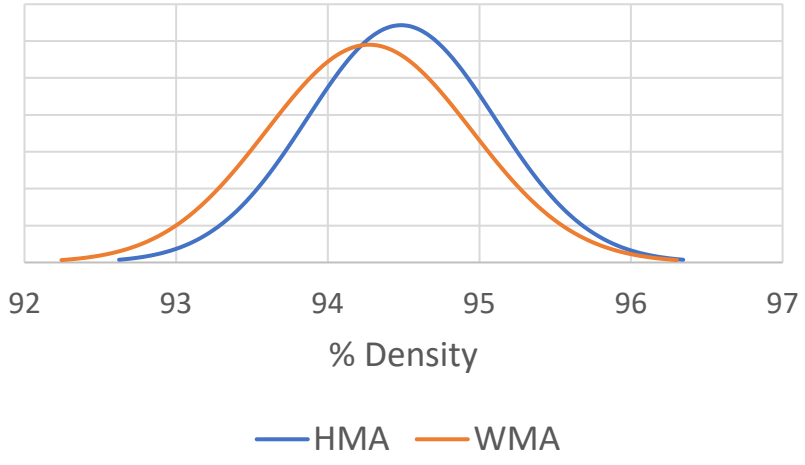
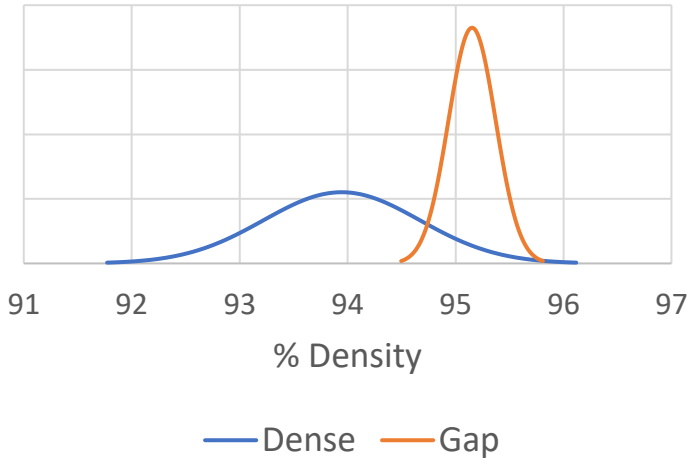
Historical Density





10,000 cores from last 10 years were analyzed to obtain above data

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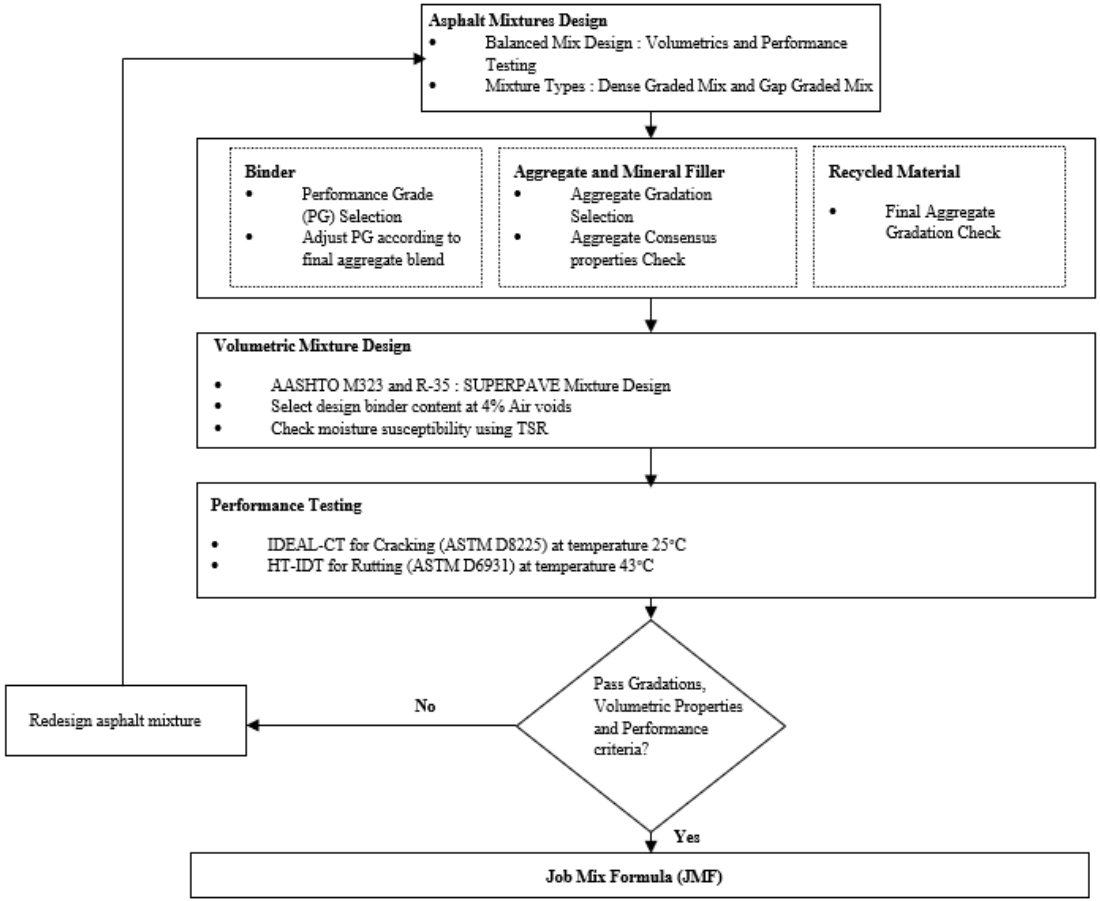
BMD Research Project

- Maryland sponsored a two-years research project
  - We chose to go with surrogate testing methods for this study
  - University of Maryland completed research as of 12/31/2021
- Project objectives were:
  - To study the effects of recycled materials and other key mix components in mix performance
  - Set up thresholds for IDT and Ideal CT index
  - Study the effects of different equipment and its impact on test results between multiple laboratories

(AASHTO MP46-20 Approach A-Volumetric Design with Performance Verification)



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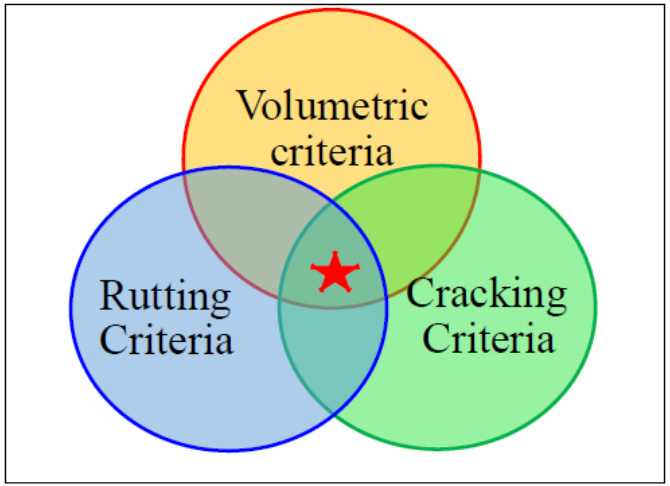
Framework for the Proposed Balanced Mix Design Approach

- AASHTO MP46-20 Approach A-Volumetric Design with Performance Verification



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Fatigue cracking: IDEAL CT (ASTM D8225-19 @25oF)

CT_{index} (G_f =fracture energy), m_{75} = slope = $\left|\frac{P_{85}-P_{65}}{l_{85}-l_{65}}\right|$, D= specimen diameter (mm)

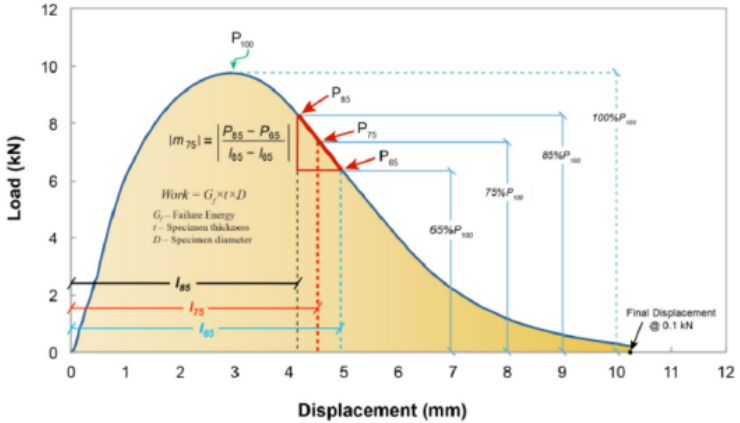

FIGURE 21 Recorded load (P) versus load-line displacement (l) curve.

D= 62mm

$$CT_{Index} = \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right)$$

t = specimen thickness (mm)

$$CT_{Index} = \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right) \times \left(\frac{t}{62}\right)$$

Rutting: HT-IDT @44°C, (Christensen and Bonaquist, 2007)

Note: temperature of 10 °C below than the yearly 7-day average maximum temperature 20 mm below the pavement surface with 98% reliability as determined by the Long-Term Pavement Performance Bind (LTPPBind) at 50 mm/min loading rate.

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Fatigue cracking: IDEAL CT (ASTM D8225-19 @25°F)

- constant deformation rate of 50 mm/min.
- TSR IDT frame, Lottman's head;
- 150±2 mm diameter and 62±1 mm height;
- Compacted at 7±0.5% air void;
- Cured in water bath for 2 hours @25°C
- Testing at @25°F
- Load vs. displacement curve

CT Index Values from Past Studies

Reference Study	Mixture Type	Recommended Values
Bennert et al., 2018	High RAP Surface Course	>150
	High RAP inter/Base Course	>120
Newcomb et.al., 2018	Dense graded mix	≥80
Diefenderfer et.al., 2019	Dense graded mix	≥80
Zhou et al., 2020	Superpave mix	≥90
	TxDOT dense graded mix	≥55
	Stone Matrix Mix	≥135
	Thin Overlay Mix	≥180
	Crack Attenuating mix	≥400

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Why Surrogate Testing?

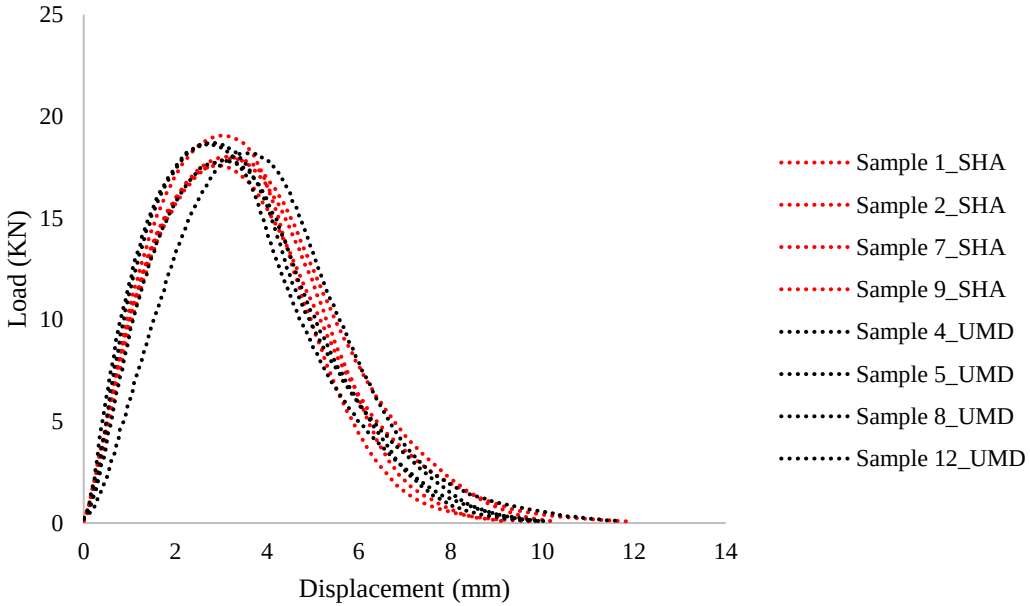
- Less expensive equipment compared to AMPT, Hamburg, APA, and Texas Overlay tester etc.
- Test results can be obtained quickly
- Simplicity (instrumentation, sample preparation)
- Low equipment cost
- Minimum training
- Efficiency (speed of testing)
- Repeatability (COV <25%)
- Sensitivity (Binder Content, Volumetric, Binder Type, Aging)
- Correlated to field

Mix Selection and Test Criteria

- 17 mixes (12 dense and 5 gap) were provided by DOT and testing was completed by UMD
  - We chose the following variety in mix selection:
    - RAP content
    - ESALS
    - Nominal Maximum Size of Aggregate
- Specimens were prepared at 7+/-0.5% air voids
- Ideal-CT (ASTM D8225):
  - 150 mm diameter and 62 mm thick specimens tested at 25C
- IDT (ASTM D6931)
  - 150 mm diameter and 95 mm thick specimens tested at 43 C

Round Robin Testing

- 3 round robin testing
- 2 lab comparisons (MD SHA & UMD)
- 3 lab comparisons (MD SHA, Producer Lab, UMD)
- Good Agreement between MD SHA and Producer Lab (screw-type of testing system)
- UMD used closed loop servo hydraulic testing system



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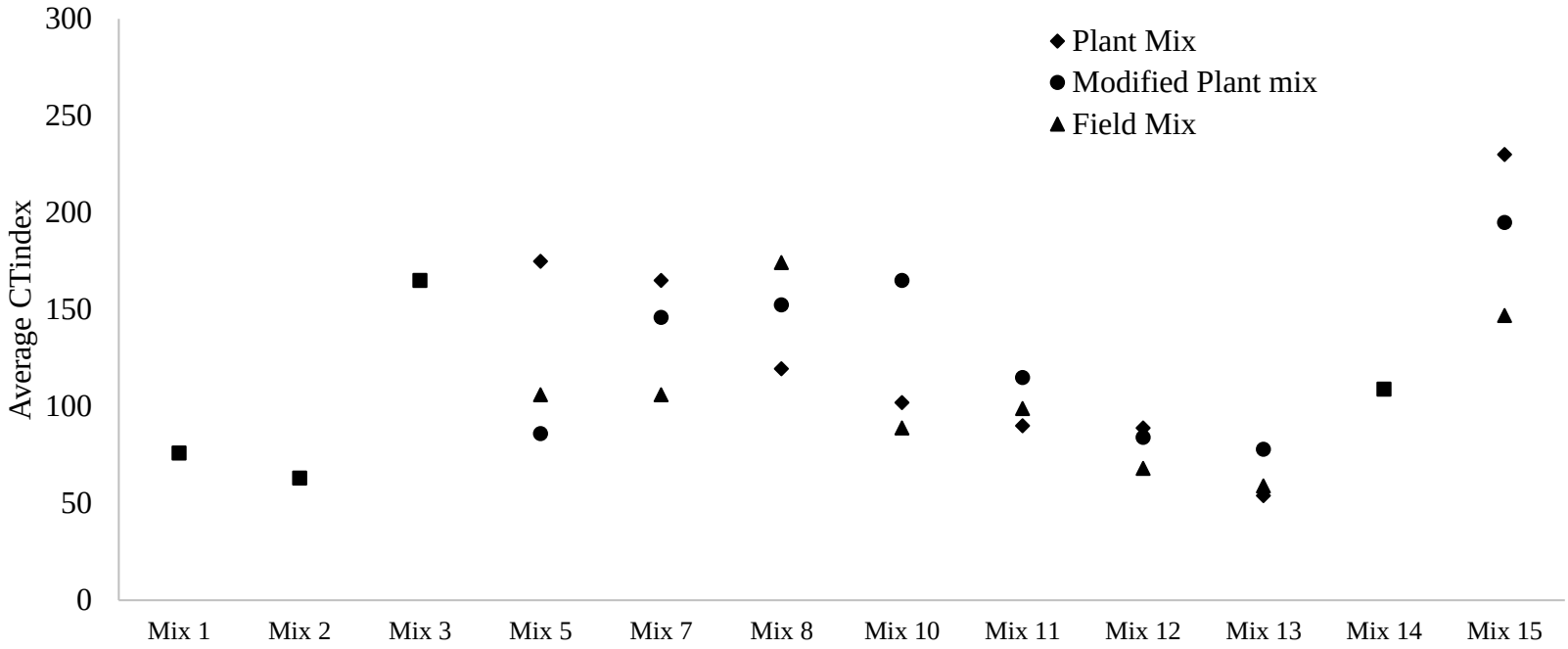
CT Index-Dense Mixtures



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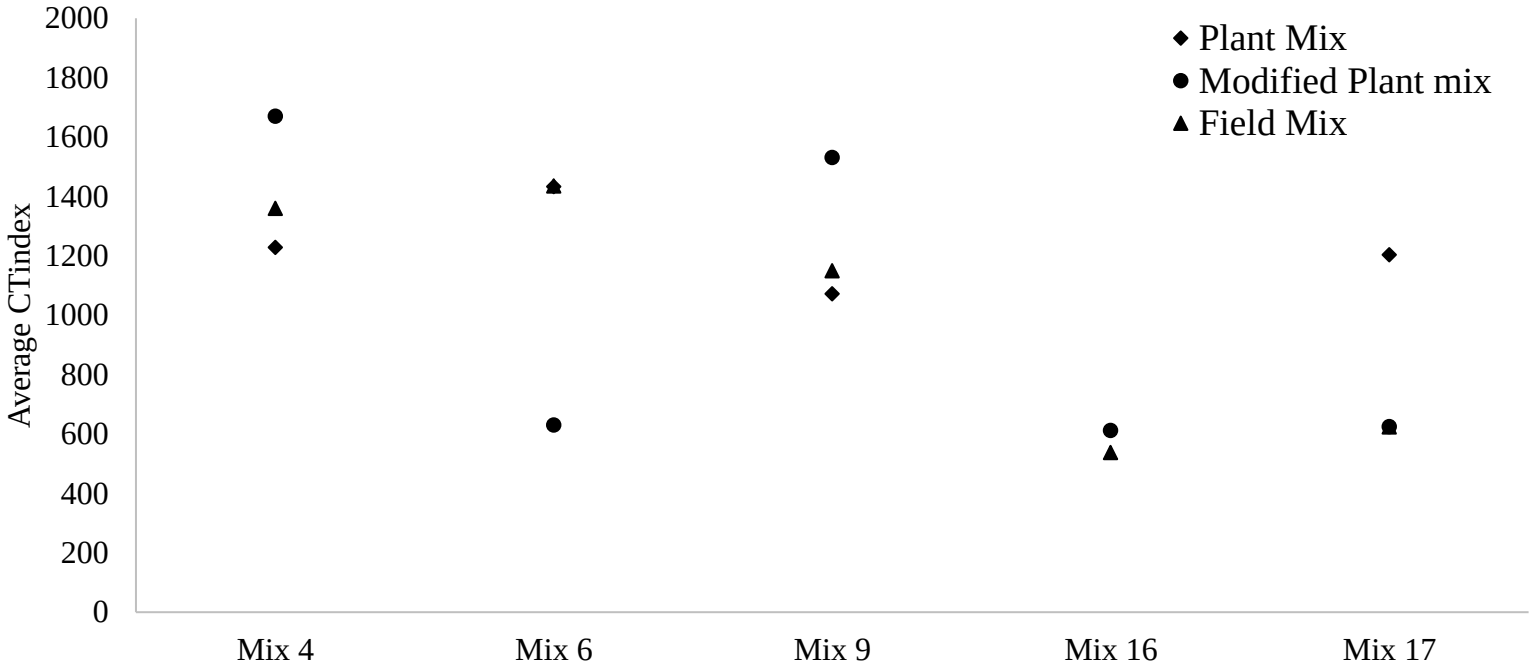
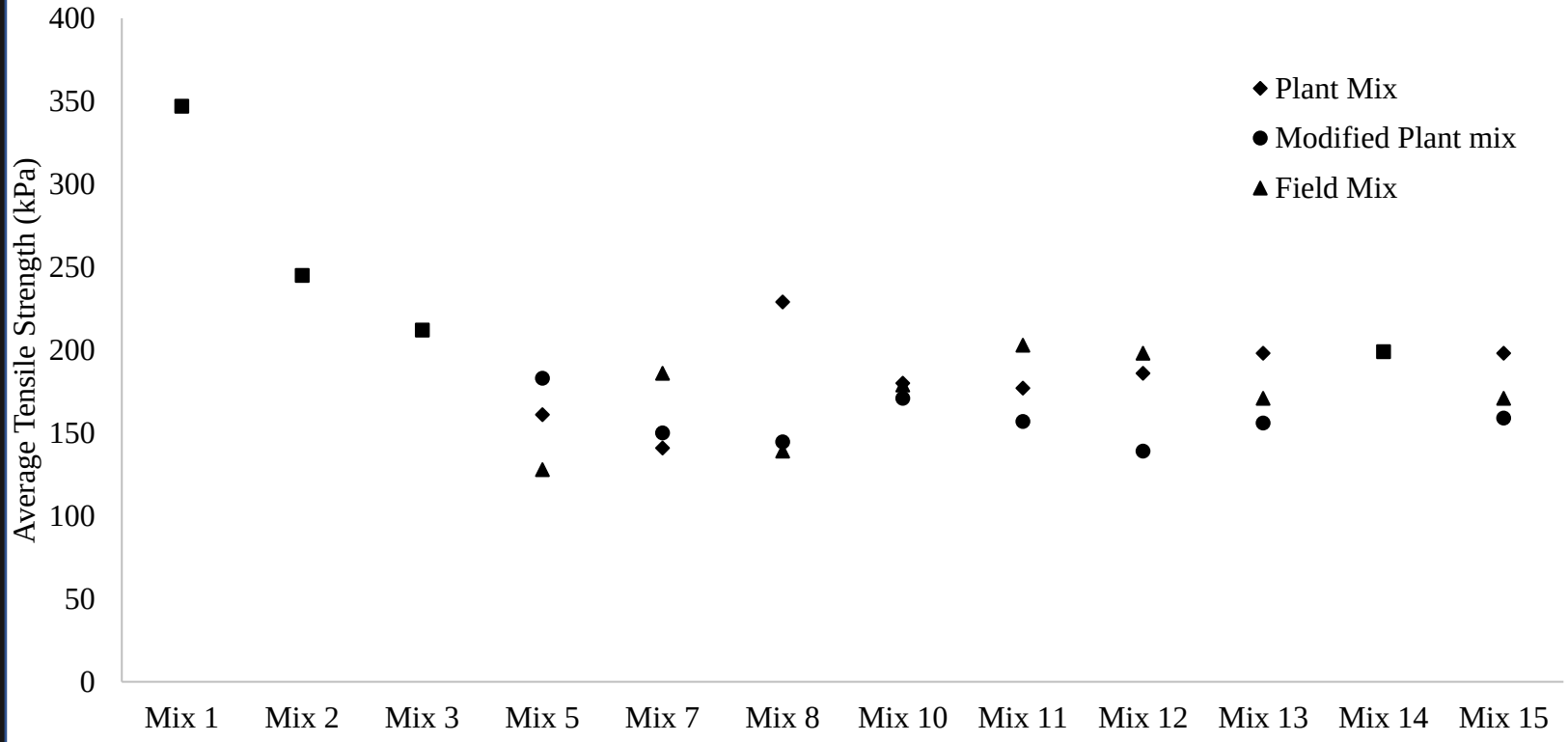
CT Index-Gap Mixtures



HT-IDT, Dense Mixtures



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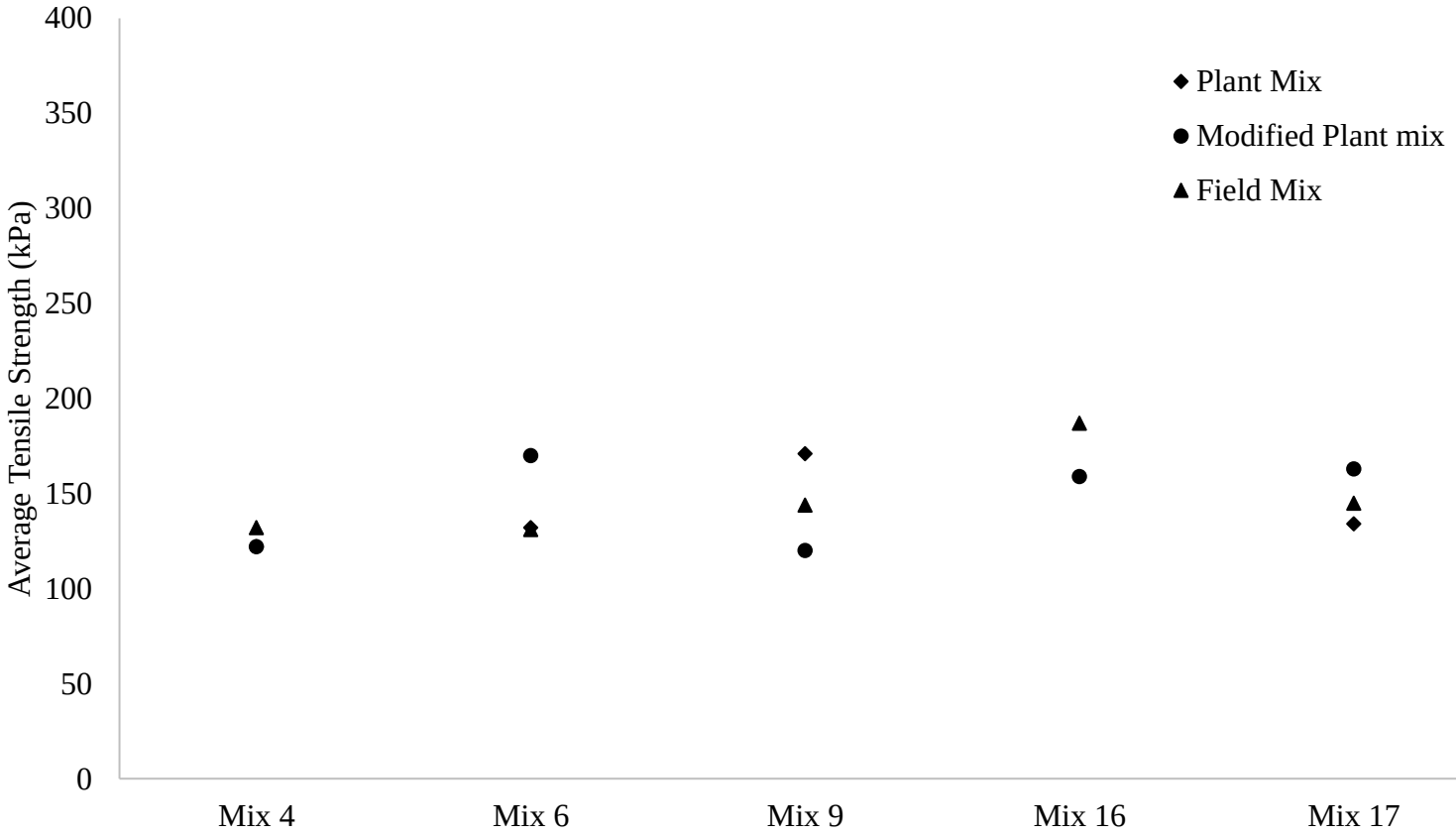
HT-IDT, Gap Mixtures



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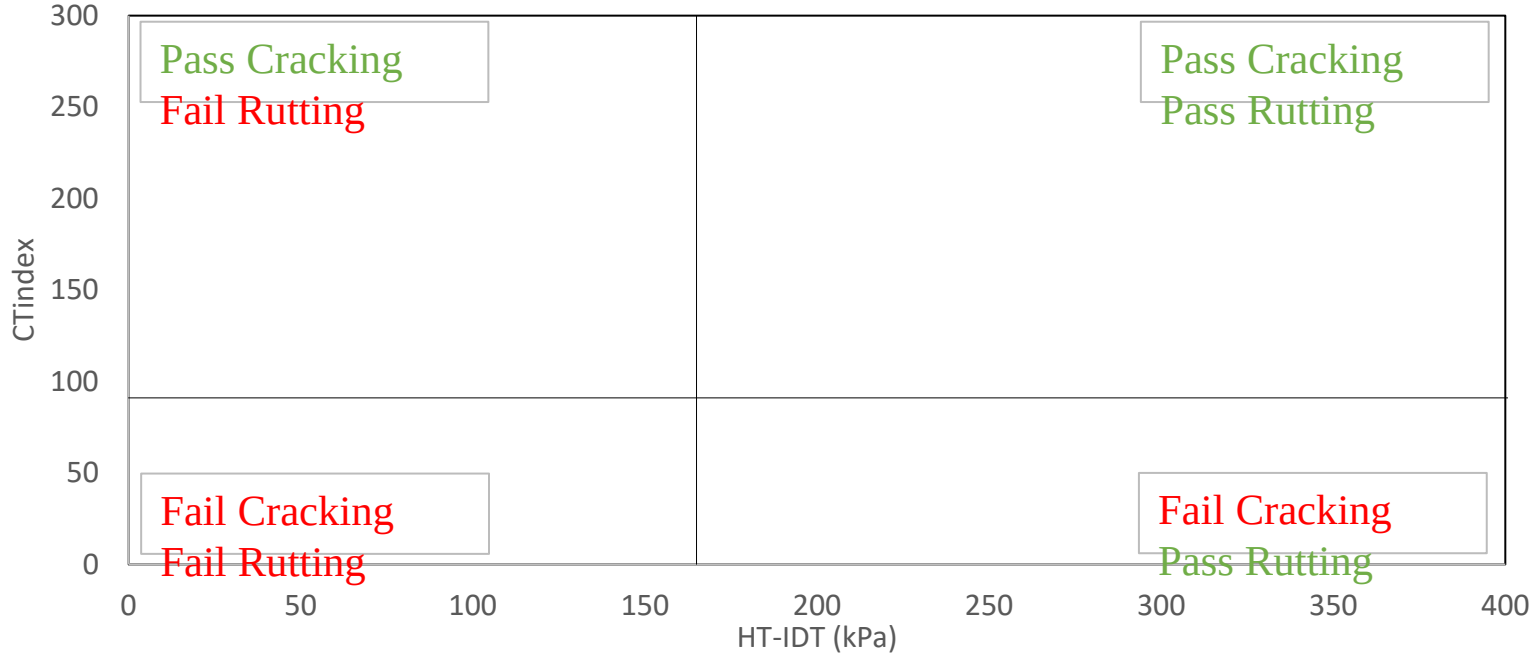
Thresholds Set for Dense Mixes



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Maryland Draft Spec

	IDT (plant mix)	IDT (field mix)	CT index (plant)	CT index (field)
Dense graded mix	171 kpa or 25 psi	165 kpa or 24 psi	96	91
Gap graded mix	131 kpa or 19 psi	135 kpa or 20 psi	1049	812

Threshold values based on 90% confidence interval and from trimmed average.
(trimmed average-1.645*SD)

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Next Steps

- Pilot Project:
  - Bidding with new performance testing requirements
  - Perform round-robin tests between QC and SHA lab
    - Eliminate between lab variability in test results

- Validation:
  - Study the performance of oven aged mixture for long-term aging
  - Aging will be selected to reflect the actual crack initiation as part of validation
  - Collect field performance data
  - Building a database of test results

- Base line criteria could be adjusted based on future data from industry!!

Cracking Data

MIX TYPE	FLEXIBLE		COMPOSITE	
	SCD	FCD	SCD	FCD
RAP/HIGH POLISH	1.514	2.037	1.276	2.031
RAP/HIGH DFV	0.709	1.056	0.738	1.266
RAP/GAP	0.483	0.923	0.492	0.99
RAP/SHINGLES	0.835	1.13	1.267	2.542
SHINGLES/HIGH POLISH	13.143	21.182		
RAP/SHINGLES/ HIGH DFV	22.3	4.657	5.474	3.191
GAP GRADED	0.658	2.334	0.705	2.647
HIGH POLISH	3.268	4.347	3.141	3.821
HIGH DFV	0.971	1.353	1.538	2.819
RAP	1.054	1.464	1.15	1.813
SHINGLES	3.337	5.309	0.174	3.006
VIRGIN	4.084	5.779	1.256	3.378

SCD - Structural Cracking Density Avg Increase Rate

FCD - Function Cracking Density Avg Increase Rate

- Cracking density is measured on pavements 10 to 15 years old
- This is only one of the parameters in pavement rehab criteria
- Average crack initiation was found at ~7 years

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Shadow Testing

- Using AMPT for following tests:
  - *Dynamic modulus*: measures *stiffness* at various weather and traffic conditions
    - Tests conducted at 4, 20, 40^0 C
    - 0.1, 1 and 10 Hz (represents traffic)
  - *Stress sweep recovery*: measures *rutting* parameter
    - Tests will be conducted at high and low temps using LTTP bind
  - *Cyclic fatigue*: measures *fatigue cracking* property
    - Test conducted at max of 21^0 C (intermediate)

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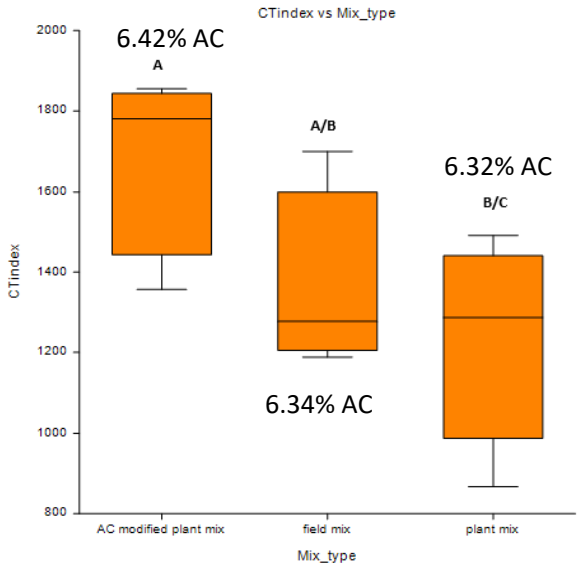
Common Concerns

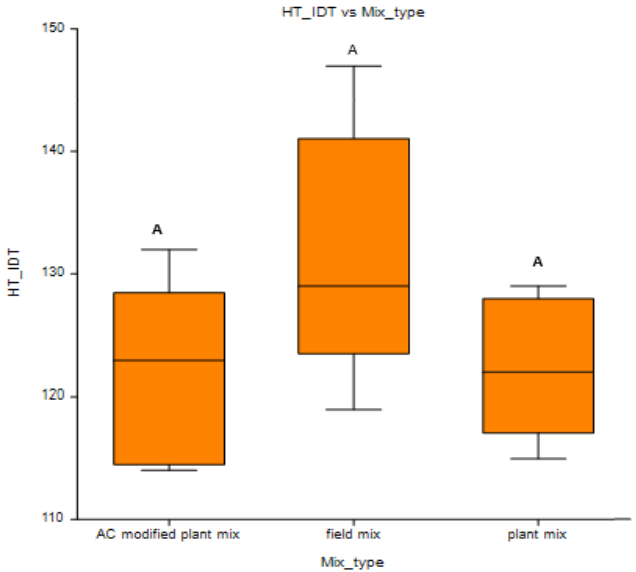
- Pay factors:
  - We will continue follow the same volumetric mix approach for pay
  - The method we are implementing is volumetric performance testing method
- Frequency of performance testing:
  - Once at round-robin study between labs (Not mandatory but beneficial)
  - During mix design
  - Not decided yet on QC/QA frequency
- Questionable sample size:
  - Statistical analysis was done to rule out bias of sample type
  - Not possible to cover all aggregate types for study
  - Existing criteria could be revised based on more info, lab and field performances

Additional Analysis

H186B12B5F09 – gap mix – CT Index



H186B12B5F09 – gap mix - IDT



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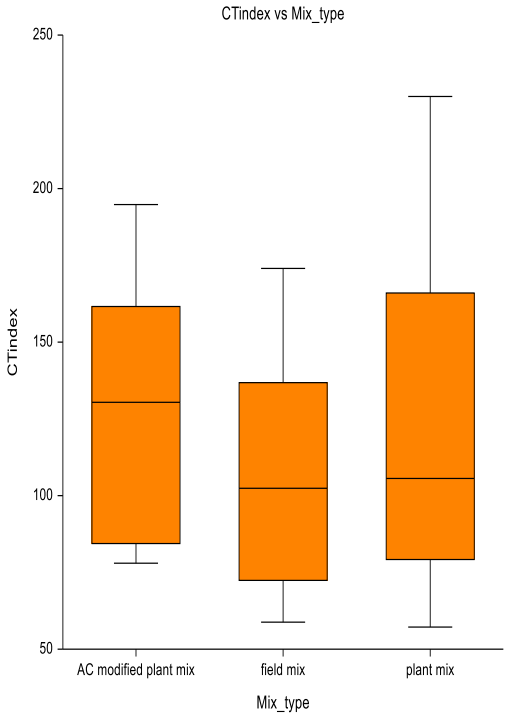
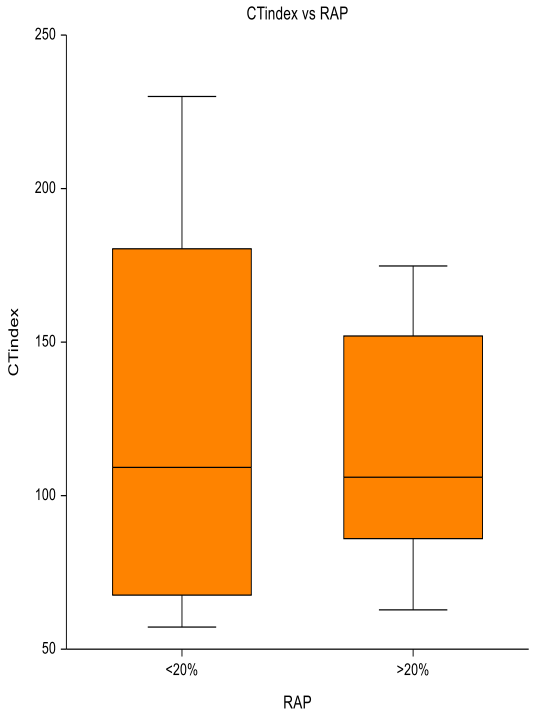
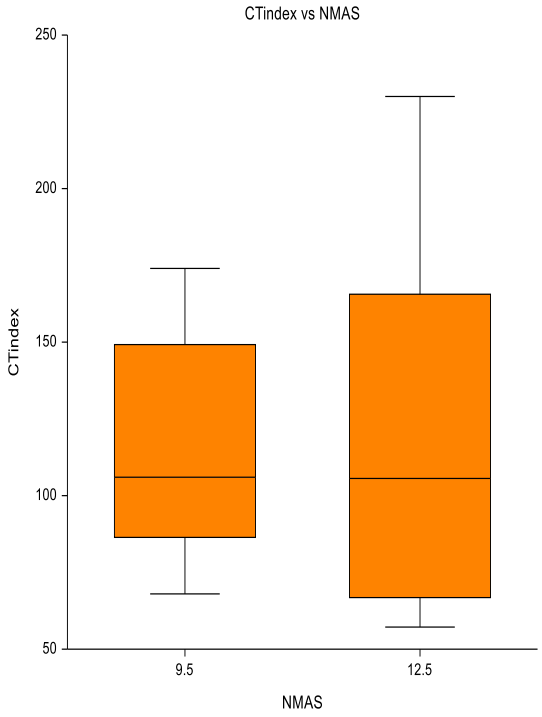
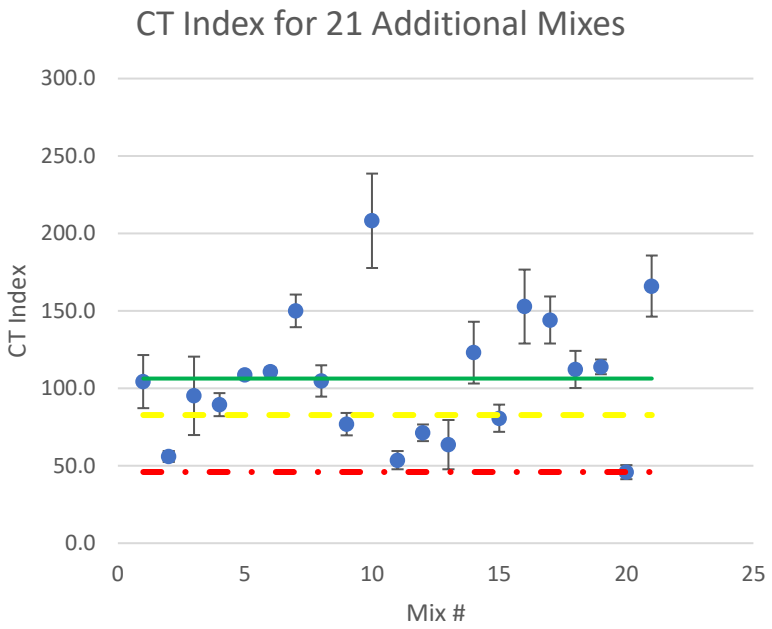
Dense Mixes Combined

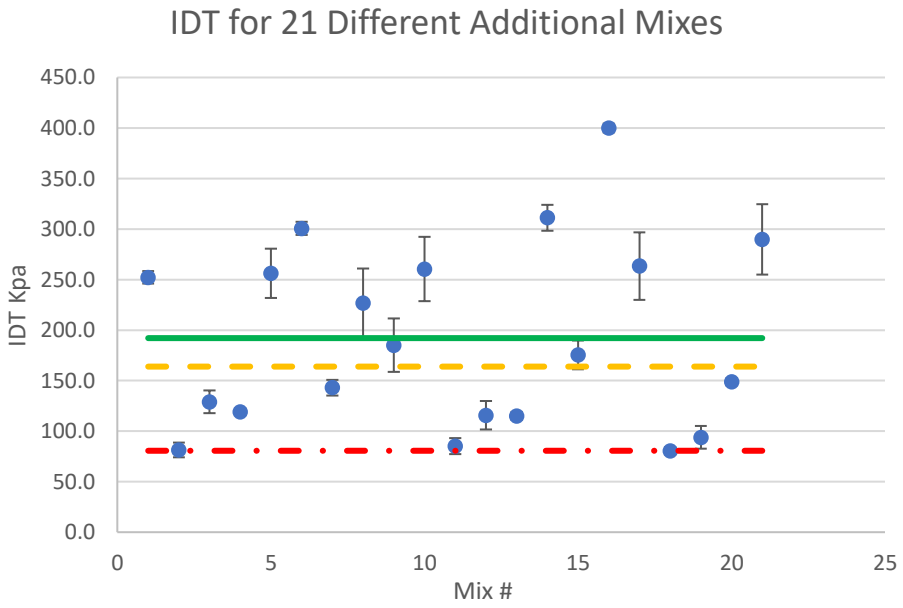




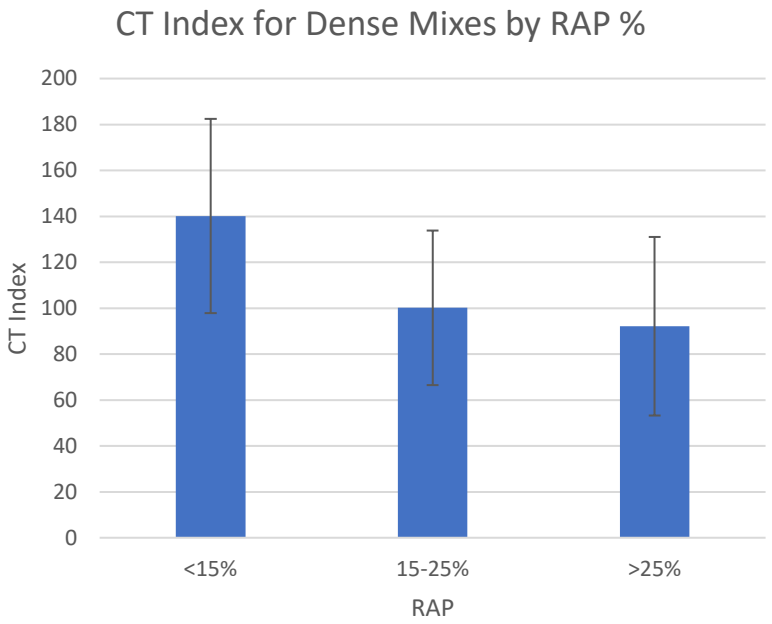


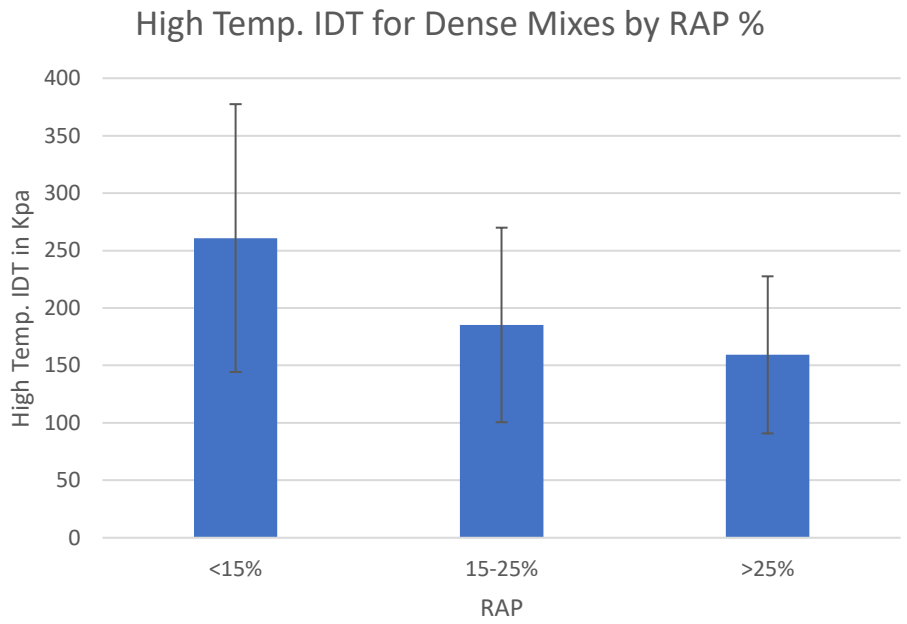
Benchmark Revision



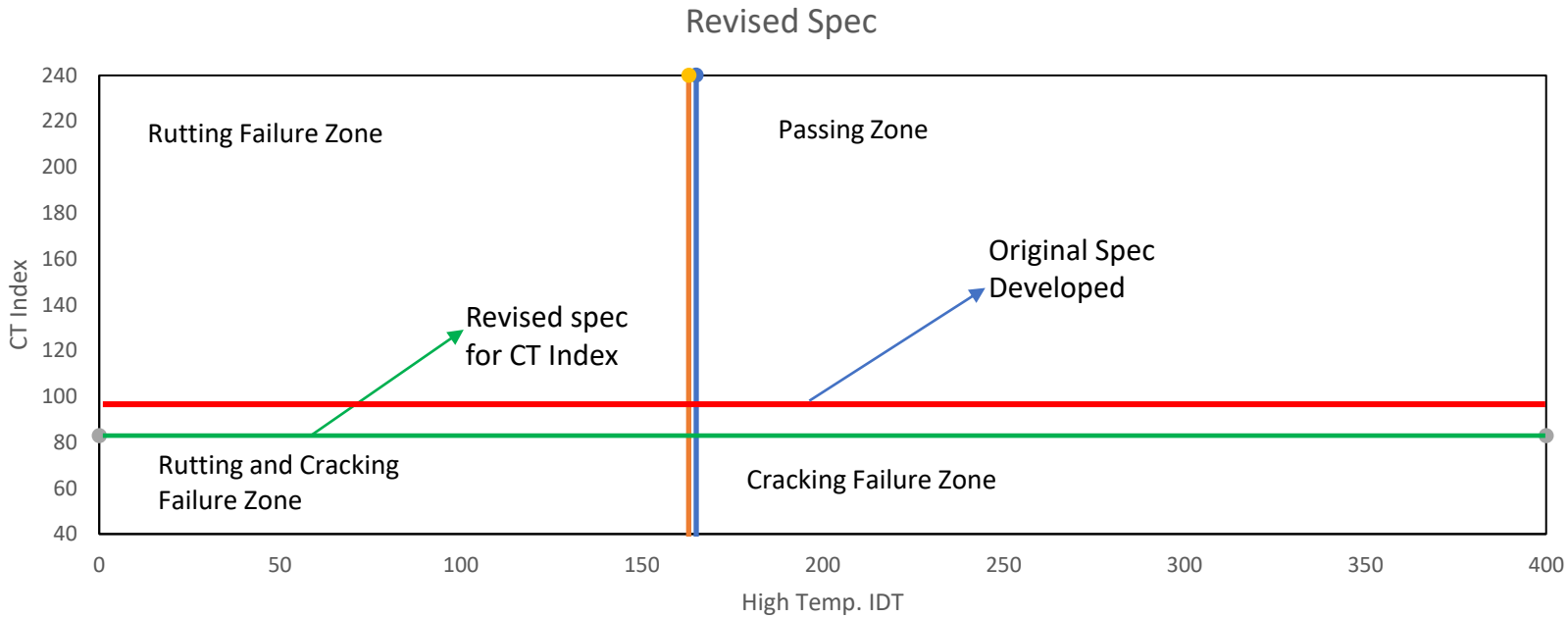


Effect of RAP on Index Properties





Revised Thresholds Set for Dense Mixes



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Ongoing & Future Direction

- ***Transition from Benchmarking study to Validation***
  - Expand “benchmark” study to include additional Maryland Mixtures
  - Relate Index Tests to predicted performance (AMPT, APA, other)
  - Relate Index test results to field performance – shadow and pilot projects

- ***Develop performance spec for asphalt mixtures***
  - Consider PWL instead of average values for acceptance
  - Assess acceptance risks
  - Develop PF rewarding quality

- ***Implementation Plan:*** pilot projects for fine-tuning acceptance thresholds

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Thank You!!

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