



# **Percent within Limits (PWL), AASHTOWARE and Balanced Mix Design (BMD):**

**An Update on WisDOT's Current Practice and Future Plans**

December 5-6<sup>th</sup>, 2024

WAPA Annual Conference

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**Dan Kopacz, PE**

Bureau of Technical Services, WisDOT

# BTS HMA Materials Personnel

- Casey Wierzchowski – HMA Materials Supervisor
- Dan Kopacz – Statewide HMA Pavement Engineer
- Jeffery Anderson – HMA Mix Design Specialist
- Matthew Andreini – HMA Performance Testing Specialist
- Meg Olson – HMA Binder Lab Coordinator
- Brian Jandrin – Nuclear Program Specialist
- Albert Kilger – HMA Engineer





**PWL:**

**An Update on WisDOT's Current Practice and Future Plans**

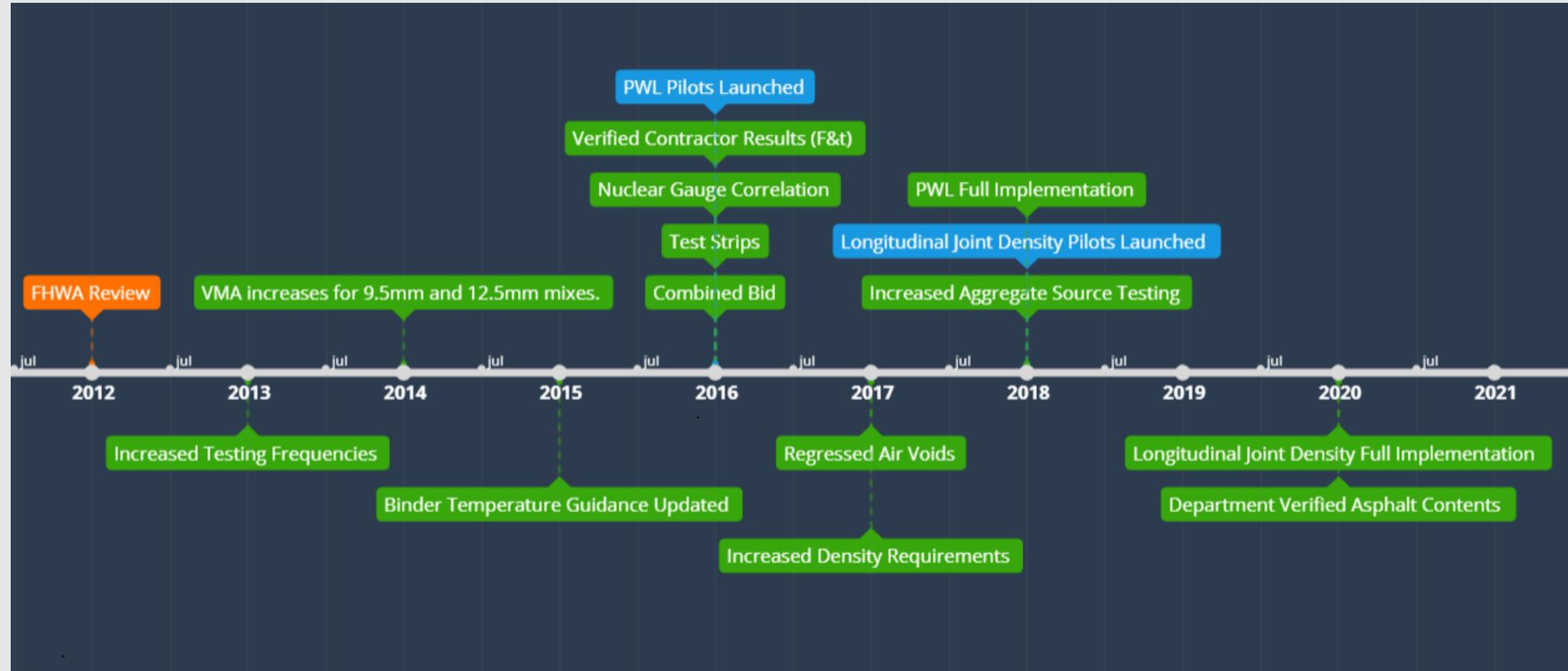
**Dan Kopacz, PE**

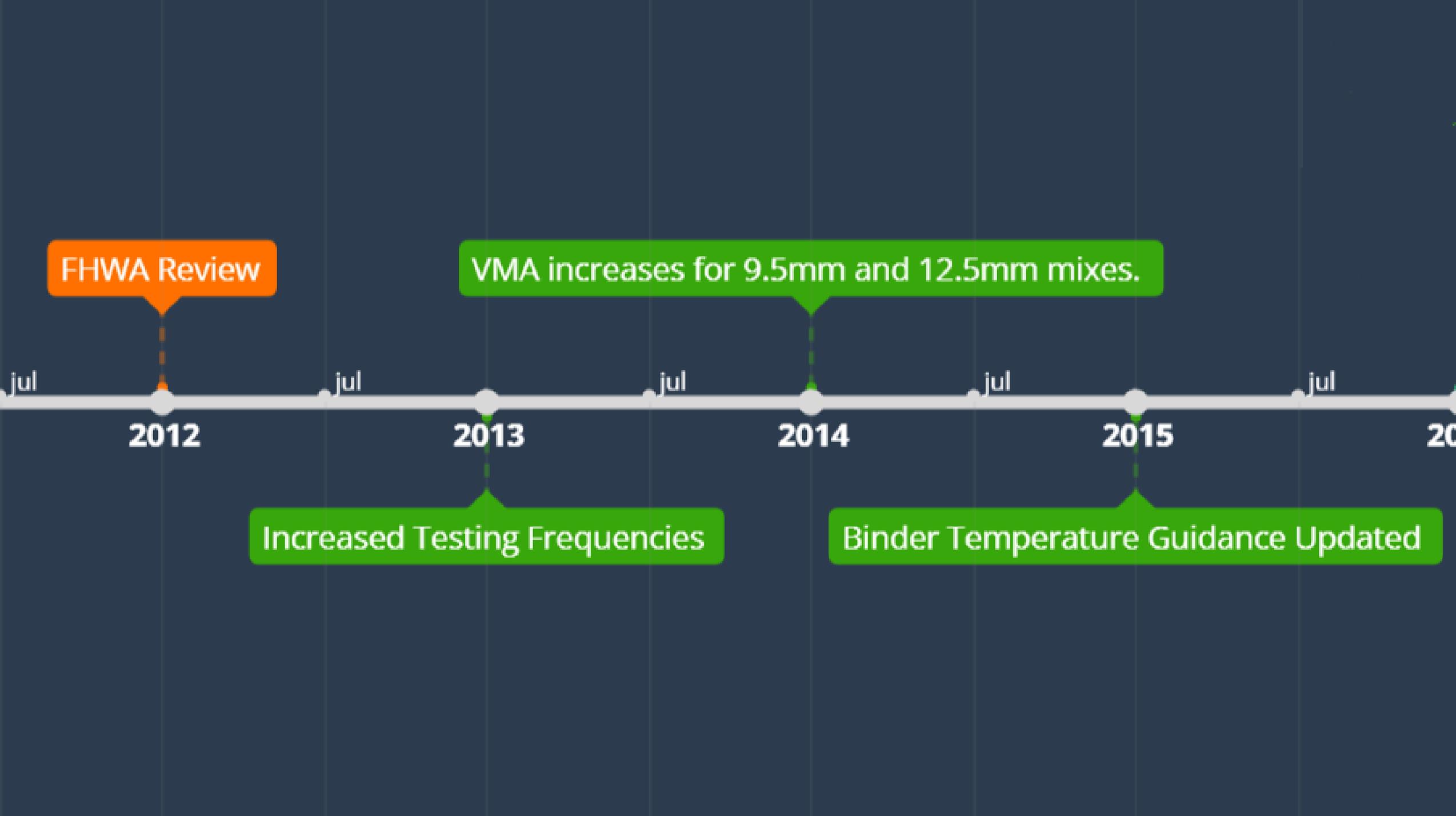
# Quality Assurance Goals

- Remain FHWA Compliant
  - Code of Federal Regulations (CFR)
- Verify Contractor Data
  - F&t is used to verify contractor data
- Increase Consistency Near the Target
  - Percent Within Limits (PWL)
- Ensure Adequate Performance
  - Set appropriate specification limits



# Where we were





FHWA Review

VMA increases for 9.5mm and 12.5mm mixes.

Increased Testing Frequencies

Binder Temperature Guidance Updated

2012

2013

2014

2015

2016

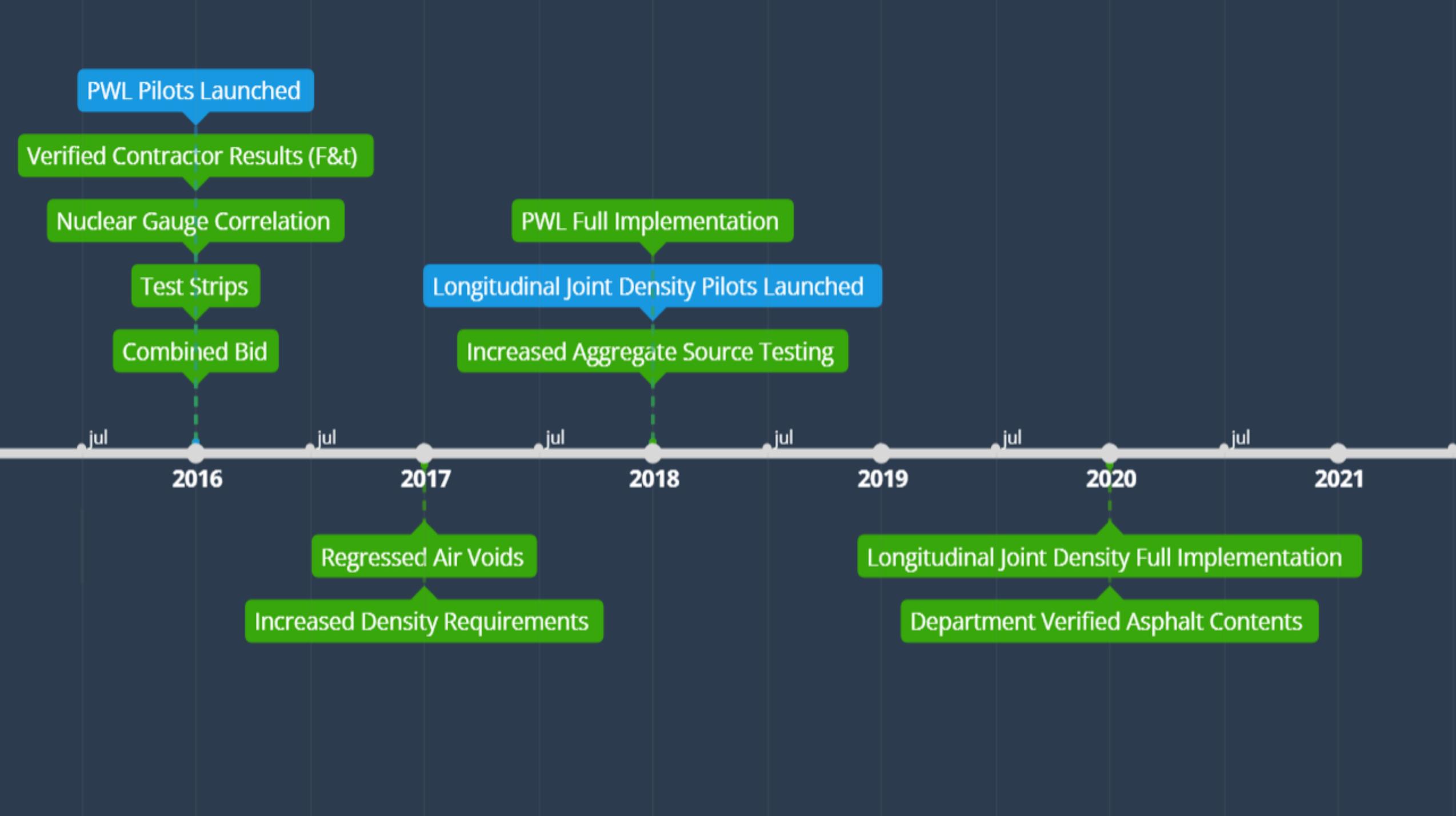
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PWL Pilots Launched

Verified Contractor Results (F&t)

Nuclear Gauge Correlation

Test Strips

Combined Bid

2016

2017

2018

2019

2020

2021

jul

jul

jul

jul

jul

jul

Longitudinal Joint Density Pilots Launched

Increased Aggregate Source Testing

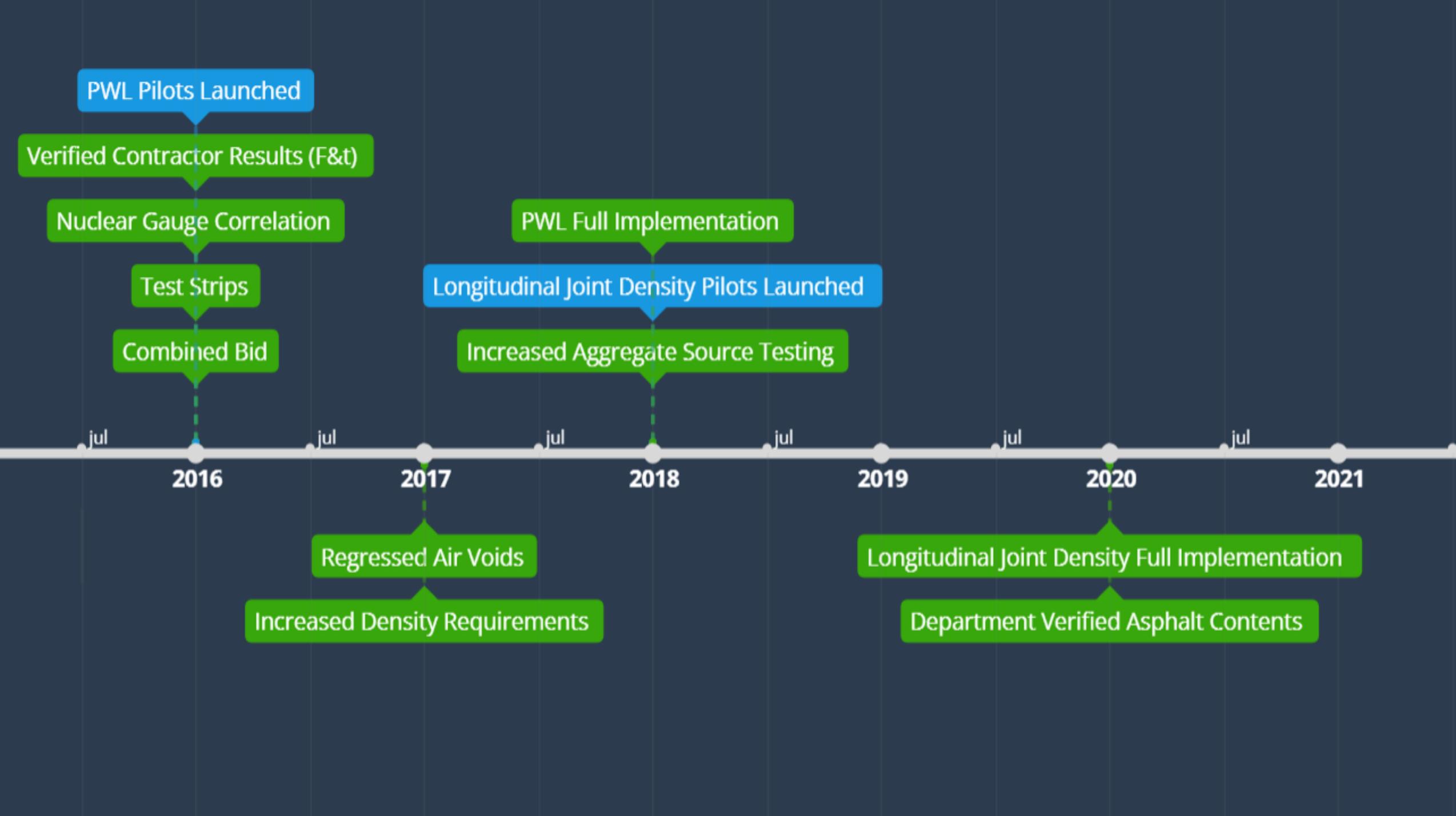
Regressed Air Voids

Increased Density Requirements

PWL Full Implementation

Longitudinal Joint Density Full Implementation

Department Verified Asphalt Contents



PWL Pilots Launched

Verified Contractor Results (F&t)

Nuclear Gauge Correlation

Test Strips

Combined Bid

jul

2016

jul

2017

jul

2018

jul

2019

jul

2020

jul

2021

Regressed Air Voids

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Department Verified Asphalt Contents

# Core Only Projects

- Use SPV's on QMP website
- Mixture use table needs to show Core Only for acceptance
- Projects can use both gauges and core only if desired
  - Must clearly show in mixture use table
  - Both STSP and SPV must be in special provisions
  - Example would be where it doesn't make sense to do a density correlation such as small segments



# Core Only Projects – Cont'd

- Roundabout projects
- Designer may need to calculate the area for incentive
- Need a minimum of 3 cores for PWL calculation



# PWL for roundabouts

- Mixture testing: normal PWL
- Density with cores
- Designer will calculate the area for incentive for legs and circle
- Need a minimum of 3 cores for PWL calculation



# Comparison Issues: Gmm

- Splitting/segregation
- Equipment
  - Vacuum setup
  - Pot calibration
- Operator error
- Absorptive mix



# Comparison Issues: Gmb

- Splitting/segregation
- Equipment
  - Gyrotor out of calibration
  - Worn out molds
- Operator error
  - Incorrect temperature/oven issues/preheat molds
- Absorptive mix



# Comparison Issues: AC content

- Splitting/segregation
- Equipment
  - Asphalt analyzer out of calibration
  - Incorrect ignition oven calibration
- Operator error
  - Incorrect wash/dry cycles
  - Overloading basket
- Absorptive mix



# Comparison Issues: Density Gauge

- Regular Footprint testing is required
- Follow recommendation in the appendix spec. document
- Run a new standard
- Check that the correct offset is being used
- Bring all 4 gauges and 10 locations
- Consider another correlation if issue is not resolved



# Comparison Issues: General

- Splitting/segregation
- QC can test split of the mix in another lab
- QV gradation to determine splitting issues
- Contact department IA staff or BTS staff for solutions



# Reasons to contact BTS

- Comparison issues mix or density
- Any disincentives
- Underlying material questions
- Unable to achieve density due to existing conditions
- Others????



# Do Not Ignore Comparison Issues

- Pay factor comparison greater than 102%

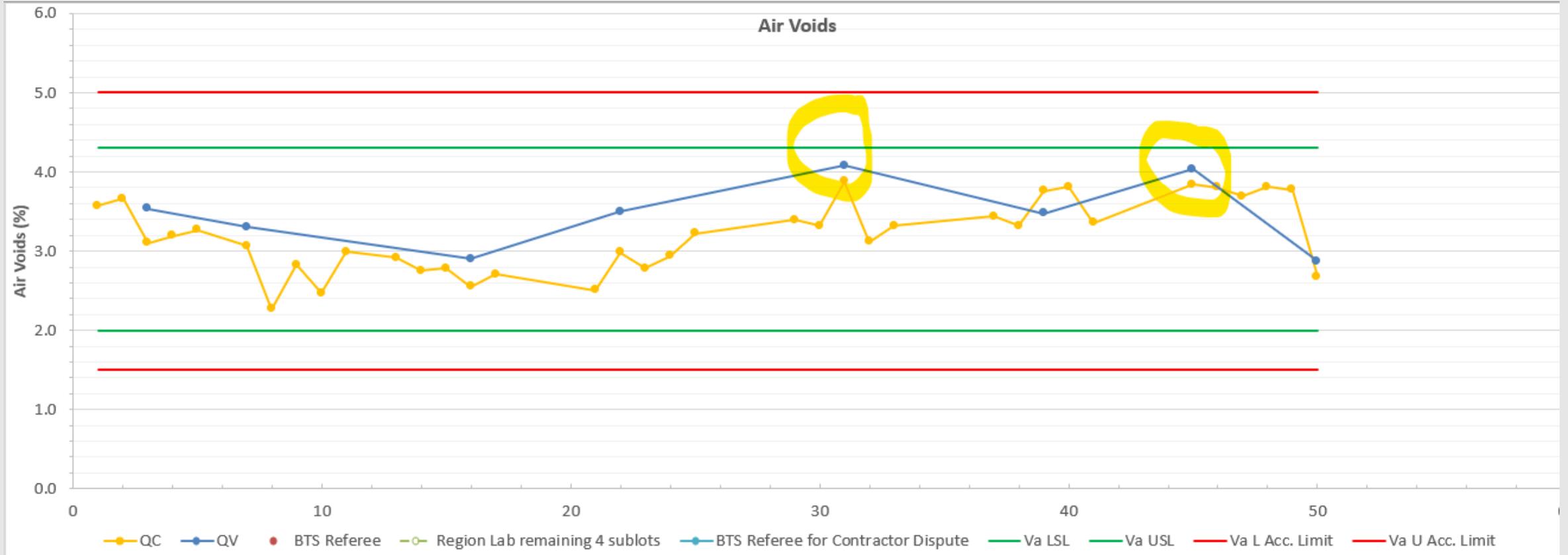
2												
3	4A	3750.00	750.00	8/27/2024	2.478							
4	4B		750.00	8/27/2024	2.482	2.490						
5	4C		750.00	8/27/2024	2.479							
6	4D		750.00	8/28/2024	2.482							
7	4E		750.00	8/28/2024	2.482							
0	Means do not compare, but the Pay Factor is greater than 102%. No dispute resolution testing required.						0.00003	2.478	0.00003	2.487	Yes	No
1	5A		750.00	8/28/2024	2.477							

1	4.4721	0.0902	100.00	2.6766	4.4721	0.1850	99.85	99.85	103.94		Yes	

[actors](#) | 
 [Total Pay Adjustment Summary](#) | 
 [Volumetrics Charts](#) | 
 [Va Pay Factor\\_Comparison](#)



# Pay factor comparison greater than 102%





# Two consecutive tests out

- Reminder to update Gsb

Replace standard spec 460.2.8.2.1.7 Corrective Action with the following:

## 460.2.8.2.1.7 Corrective Action

- (1) Material must conform to the following action and acceptance limits based on individual QC and QV test results (tolerances relative to the JMF used on the PWL Test Strip):

ITEM	ACTION LIMITS	ACCEPTANCE LIMITS
Percent passing given sieve:		
37.5-mm	+/- 8.0	
25.0-mm	+/- 8.0	
19.0-mm	+/- 7.5	
12.5-mm	+/- 7.5	
9.5-mm	+/- 7.5	
2.36-mm	+/- 7.0	
75- $\mu$ m	+/- 3.0	
AC in percent	-0.3	-0.5
Va		- 1.5 & +2.0
VMA in percent <sup>[1]</sup>	- 0.5	-1.0

<sup>[1]</sup> VMA limits based on minimum requirement for mix design nominal maximum aggregate size in table 460-1.

- (2) QV samples will be tested for Gmm, Gmb, and AC. Air voids and VMA will then be calculated using these test results.
- (3) Notify the engineer if any individual test result falls outside the action limits, investigate the cause and take corrective action to return to within action limits. If two consecutive test results fall outside the action limits, stop production. Production may not resume until approved by the engineer. Additional QV samples may be collected upon resuming production, at the discretion of the engineer.
- (4) For any additional non-random tests outside the random number testing conducted for volumetrics, the data collected will not be entered into PWL calculations. Additional QV tests must meet acceptance



# Two consecutive tests out

Sublot	Sublot Size (tons)	Lot Size (tons)	Sampled Date	Gsb (Reported)	Target AC%	QC Asphalt Content (Avg: 5.6%)	QV Asphalt Content (Avg: 5.3%)	BTS Asphalt Content (%)
1A	750.00	3750.00	6/17/2024	2.672	5.5	5.9		
1B	750.00		6/17/2024	2.672	5.5	5.6		
1C	750.00		6/18/2024	2.672	5.5	5.7		
1D	750.00		6/18/2024	2.672	5.5	5.7		
1E	750.00		6/18/2024	2.672	5.5	5.6	5.3	
2A	750.00	3750.00	6/24/2024	2.672	5.5	5.8		
2B	750.00		6/24/2024	2.672	5.5	5.7		
2C	750.00		6/25/2024	2.672	5.5	5.6	5.3	
2D	750.00		6/25/2024	2.672	5.5	5.9		
2E	750.00		6/25/2024	2.672	5.5	5.6		
3A	750.00	3280.14	6/25/2024	2.672	5.5	5.7		
3B	750.00		6/26/2024	2.672	5.5	5.1	5.2	
3C	750.00		6/26/2024	2.672	5.5	5.0		
3D	750.00		6/27/2024	2.672	5.5	5.8		
3E	280.14		6/27/2024	2.672	5.5	5.6		

**Notify Engineer: QC Non-Conforming, take a non-random QV sample and follow STSP 460-050 460.2.8.2.1.7(4). STOP PRODUCTION: 460.2.8.2.1.7(3). Two consecutive %AC test results outside of action limits.**





# Where are we headed?

- AASHTOWare - PWL Lite for lower tonnages
- PWL for SMA
- PWL for Asphalt Content



# AASHTOWare:

## An Update on WisDOT's Current Practice and Future Plans

**Daniel Kopacz, PE**



# New HMA QAP Programs

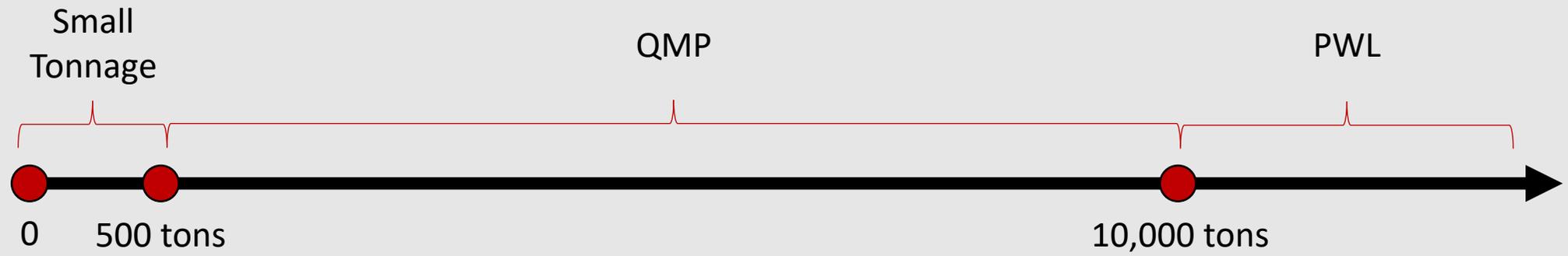
(Replacement for QMP program)



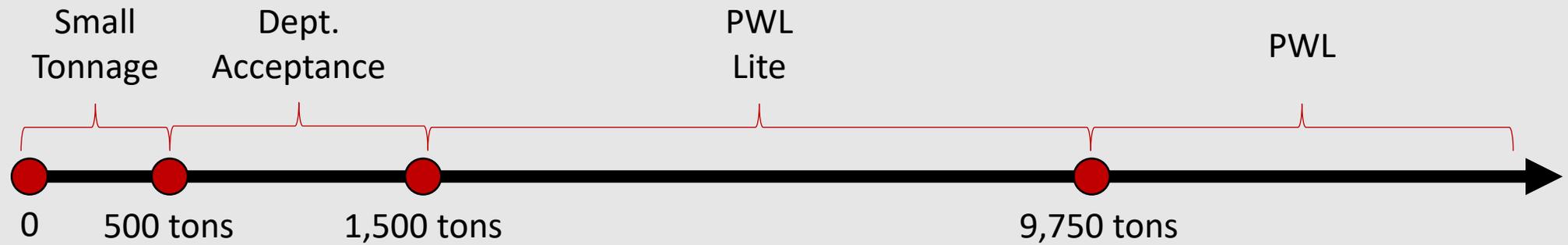
# Mixture / Volumetric Testing



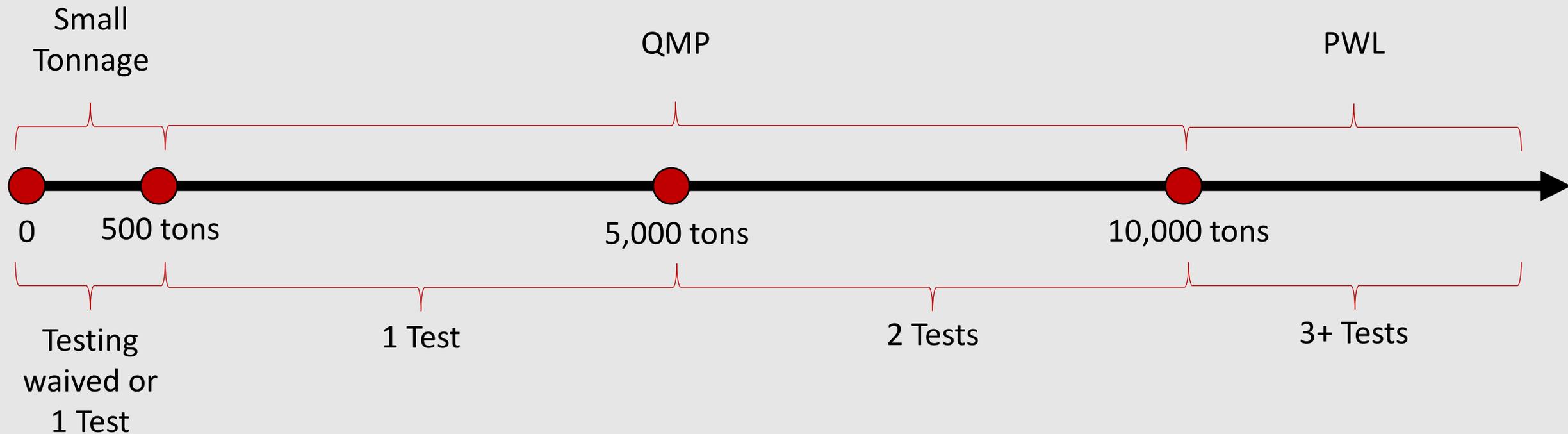
# Existing QMP



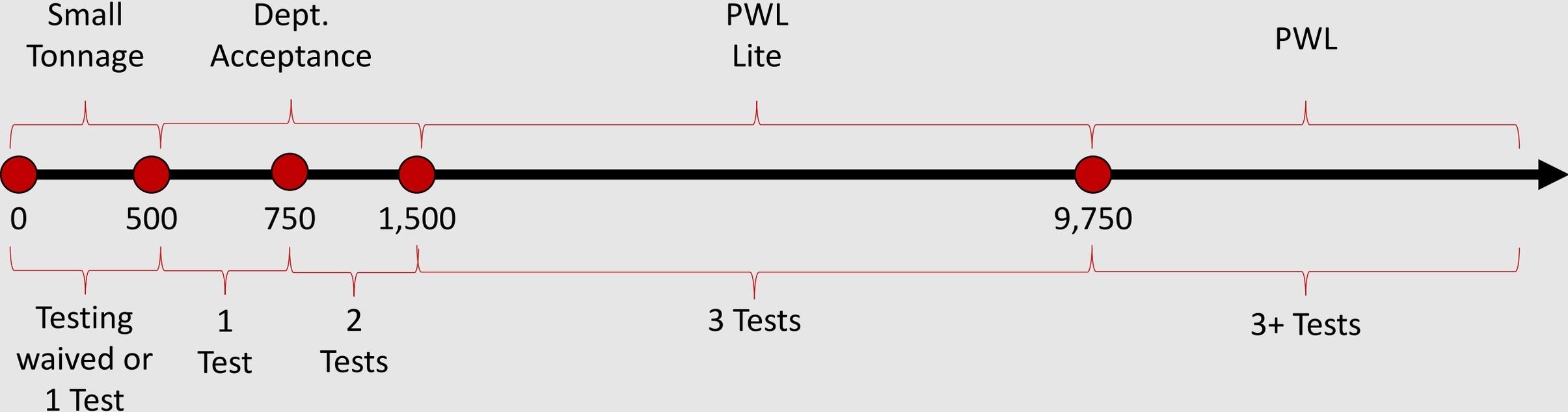
# New QAPs



# Existing QMP QV Testing Breakdown



# New QAP QV Testing Breakdown



# Density Testing

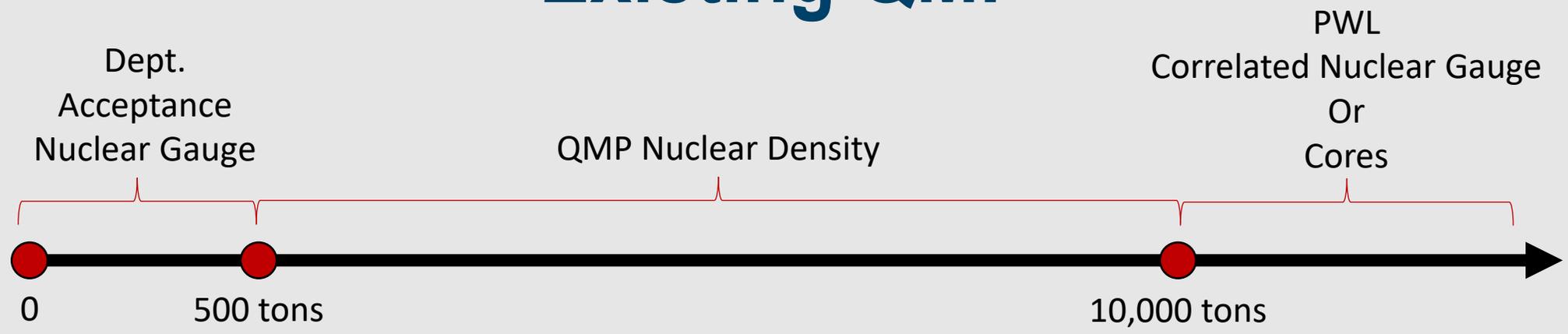


# Density / Correlation Test Strips

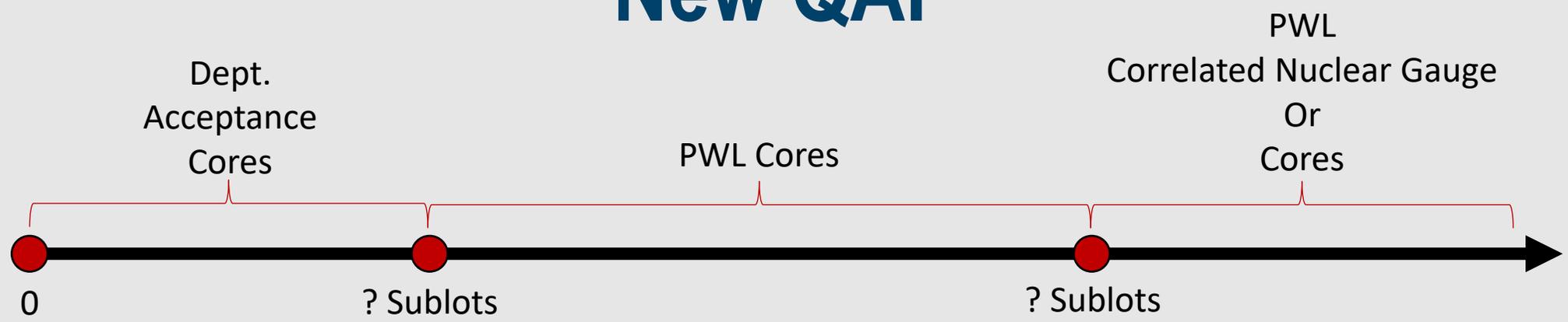
- **ONLY** required for correlation purposes **when** using a nuclear gauge.
  - Density Correlation/Test Strips to be either 2 density sublots (3,000 LF) or 750 tons.
    - Use 750 tons when performing combined volumetric/density test strip.
    - Use 2 sublots otherwise.



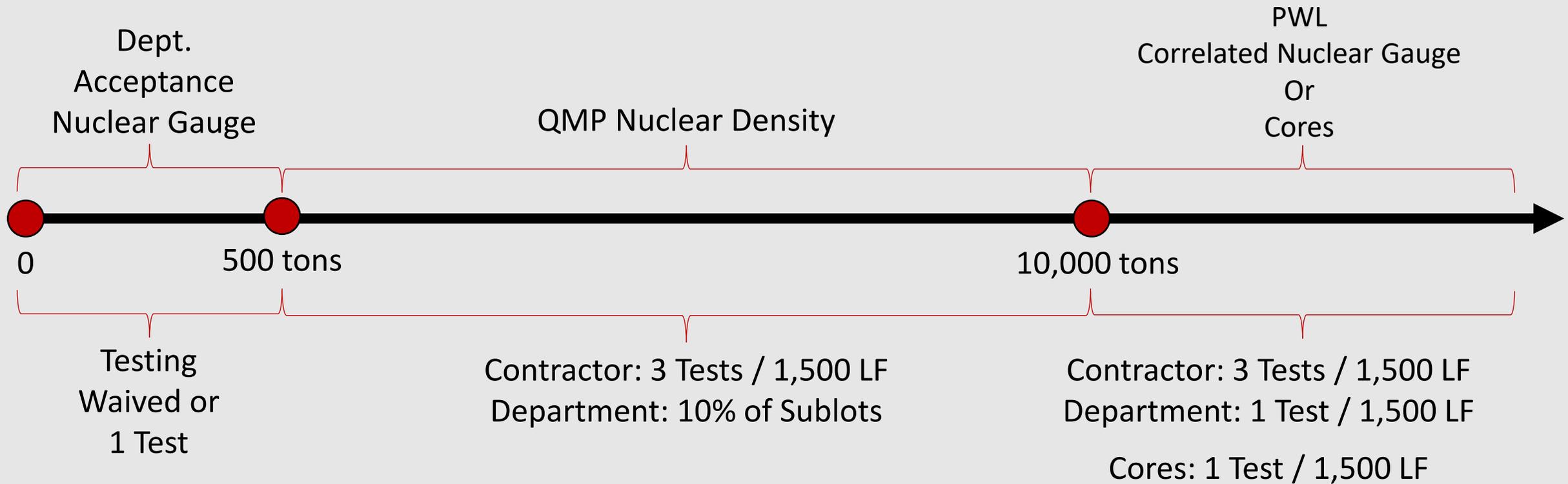
# Existing QMP



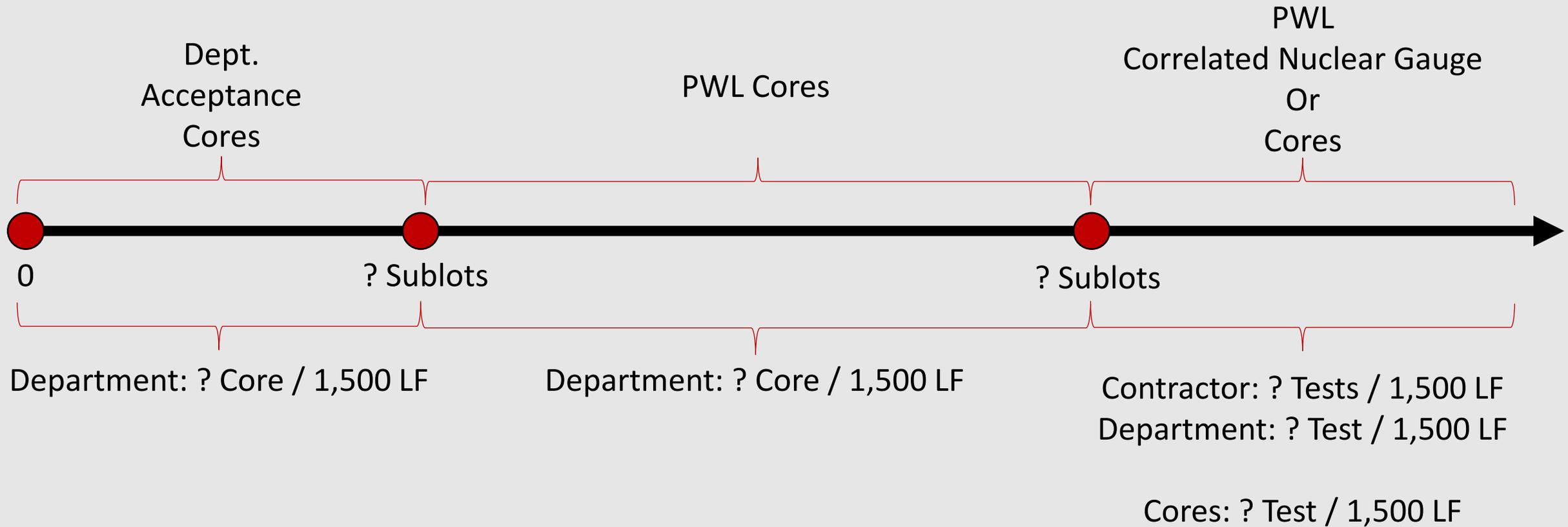
# New QAP



# QMP Density Testing Breakdown



# New Density Testing Breakdown



# AASHTOWare:

- We need to find pilots this Winter once BPD is complete with their review.
- Pilots in 2025 -2026
- Full Implementation 2027



# PWL for SMA

- PWL for SMA
- Review F&t analysis
  - Review potential for additional dispute resolution
- Review air void targets
  - +/-1.3 from 4.5% target? (3.2 – 5.7%)



# PWL for Asphalt Content

- PWL for Asphalt Content
  - % Binder or VMA
- Review F&t analysis
  - Review potential for additional dispute resolution
- Review targets
  - -0.3% below JMF



# BMD:

## An Update on WisDOT's Current Practice and Future Plans

Casey Wierzchowski, PE



# BMD: a method for increasing the durability of asphalt mixtures in WI

- Balanced Mix Design (BMD)

- What is BMD?

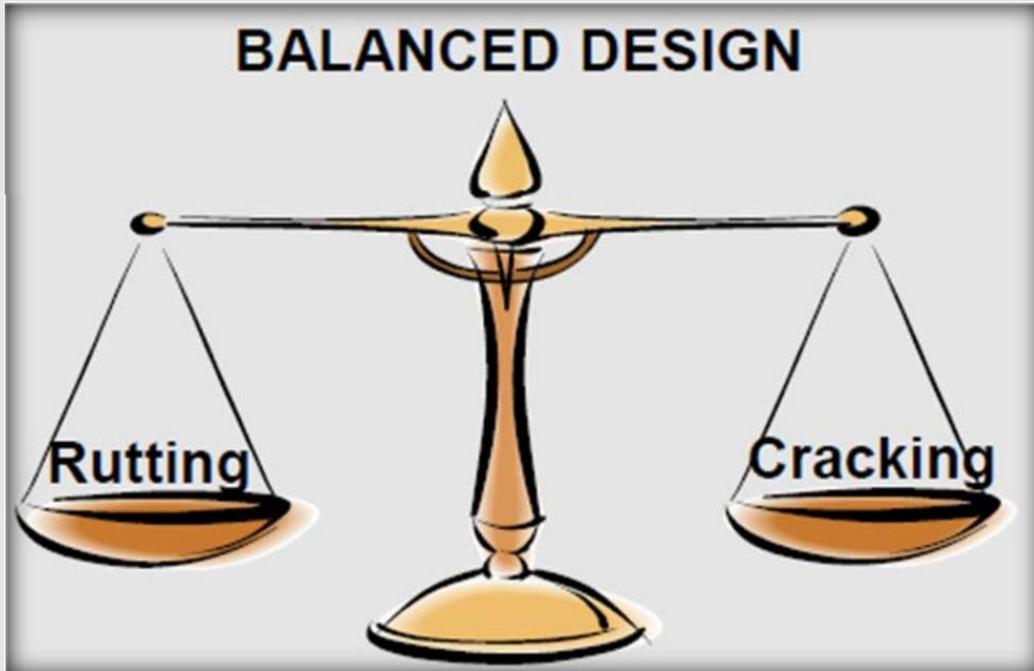
- According to Federal Highway Administration (FHWA) Expert Task Group (ETG) BMD Task Force, BMD is “*asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate and location within the pavement structure.*”

- Why do we need BMD?

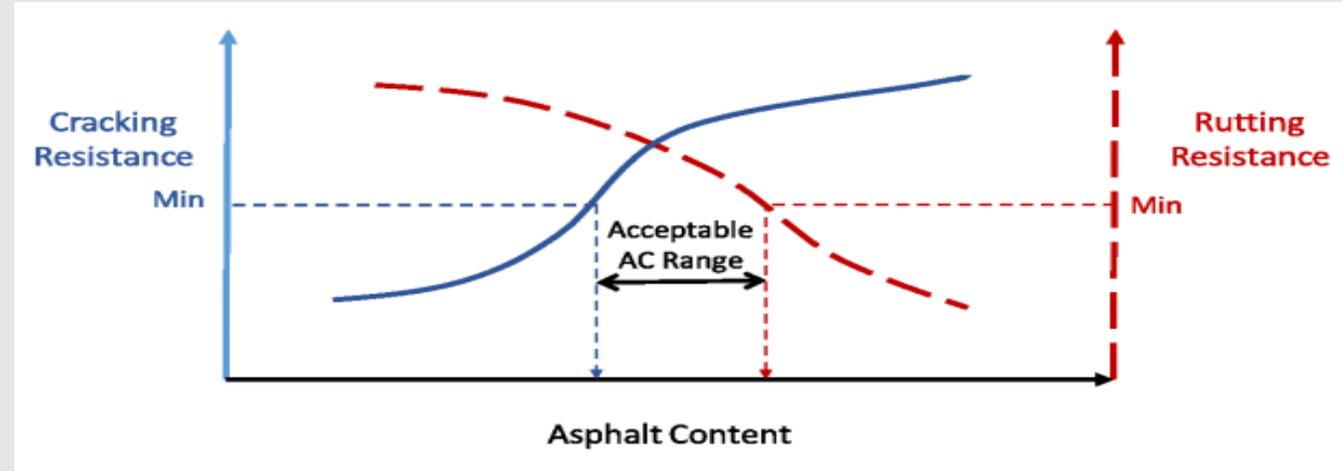
- Ensure performance
    - Enable innovation
    - Enable economic optimization

# BMD: a method for increasing the durability of asphalt mixtures in WI

- BMD concept
  - A balance between cracking and rutting resistance



Buchanan, 2017



Newcomb et al., 2018



Buchanan, 2017

# BMD: a method for increasing the durability of asphalt mixtures in WI

- BMD approaches (currently investigating the appropriateness of Approach A)
  - **Approach A: Volumetric Design with Performance Verification**
    - Starts with an agency approved mix design
    - The mix design is tested with selected mixture rutting and cracking tests
    - If the mix design is failed, the entire mix design is repeated until all the volumetric and performance test criteria are satisfied
  - **Approach B: Volumetric Design with Performance Optimization**
    - Similar to approach A, except for
    - Testing the performance at OBC and two or more additional binder contents of  $\pm 0.3$  to  $0.5\%$
    - Selecting a binder content that satisfies the performance criteria

# BMD: a method for increasing the durability of asphalt mixtures in WI

- BMD approaches (currently investigating the appropriateness of Approach A)
  - **Approach C: Performance-Modified Volumetric Design**
    - Similar to approach A, except for
    - Adjusting the binder content or other mix component properties such as aggregates, binders, recycled materials, and additives.
    - Making sure that certain volumetric properties are in compliance with agency's relaxed requirements
  - **Approach D: Performance Design**
    - An existing agency-approved mix design is used
    - The mix design is tested with selected mixture rutting and cracking tests at three or more binder contents at intervals of 0.3 to 0.5 %
    - A binder content that satisfies both the rutting and cracking criteria is selected as the OBC

# BMD Performance Tests Used in WI

- There are many different types of performance tests
- WisDOT uses:
  - Hamburg Wheel Tracking Test (HWTT)
  - Indirect Tensile Asphalt Cracking Test (IDEAL-CT)
  - Rapid Shear Rutting Test (IDEAL-RT)

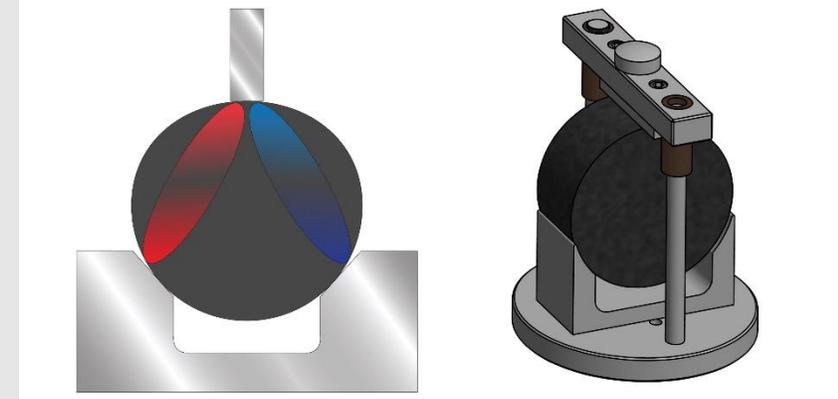


Image Source: FHWA  
Load Frame performing Ideal-RT

# BMD Implementation Train is Unstoppable ...

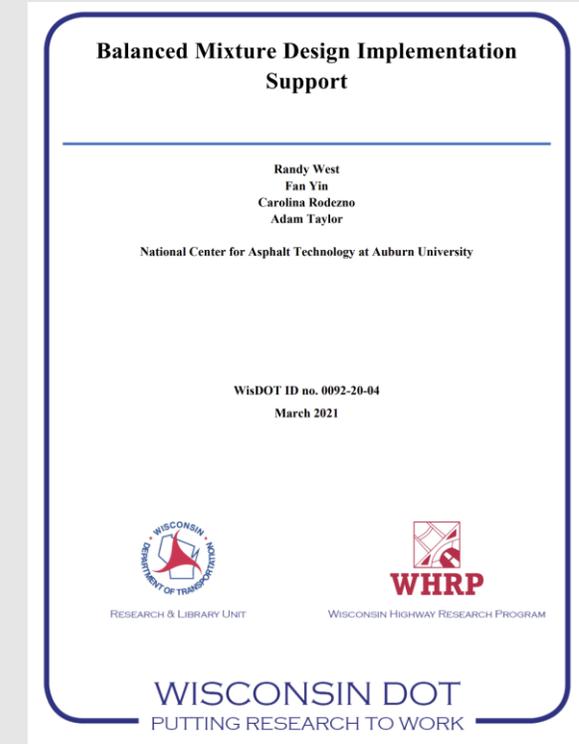
- We have invested substantially and will continue to do so
  - External research
    1. Balanced Mix Design Implementation Support
    2. HWTT and IDEAL-RT for Rutting Evaluation of Asphalt Mixtures in Wisconsin
    3. Evaluation of Hamburg Wheel Track Test for Rutting Resistance
  - In-house research
    - BMD Aging Procedures
- In the future, it can be a tool for justifying the sustainability of unsustainable materials used at the plant
- There will be challenges ...
  - We are committed to collaborate with the regions and industry to make the transition as **smooth** as possible

\*Note: WHRP and TOC are the abbreviations of Wisconsin Highway Research Program and Technical Oversight Committee.



# External Research Project No.1

- *Balanced Mixture Design Implementation Support* (status: completed in May 2021)
  - A benchmarking experiment was conducted by NCAT\* researchers to establish preliminary performance criteria
  - 18 Total mix designs were tested.
    - Thirteen 12.5-mm mixes
      - Three HT Mixes (PG 58-28S)
      - Five MT Mixes (PG 58-28S)
      - Four LT Mixes (PG 58-28S)
      - One SMA (PG 58-28V)
    - Five 9.5-mm mixes
      - Four MT Mixes (3 - PG 58-28S and 1 - PG 52-34S)
      - One LT Mix (PG 58-28S)



<https://wisconsindot.gov/documents2/research/0092-20-04-final-report.pdf>

\*Note: NCAT is the abbreviation for National Center for Asphalt Technology.



# External Research No. 1

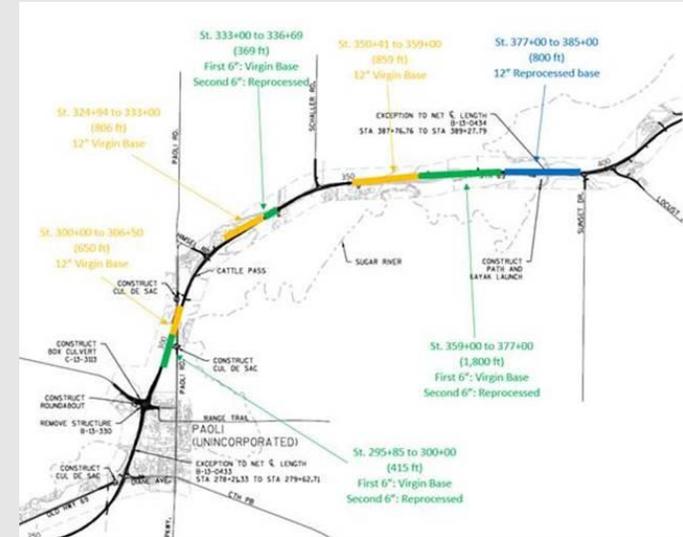
- For part one of the research, the NCAT researchers suggested the construction of 6 test sections:
  - To establish correlation between BMD test results and field performance
    - Test sections had a range of expected field performance

Experimental Matrix

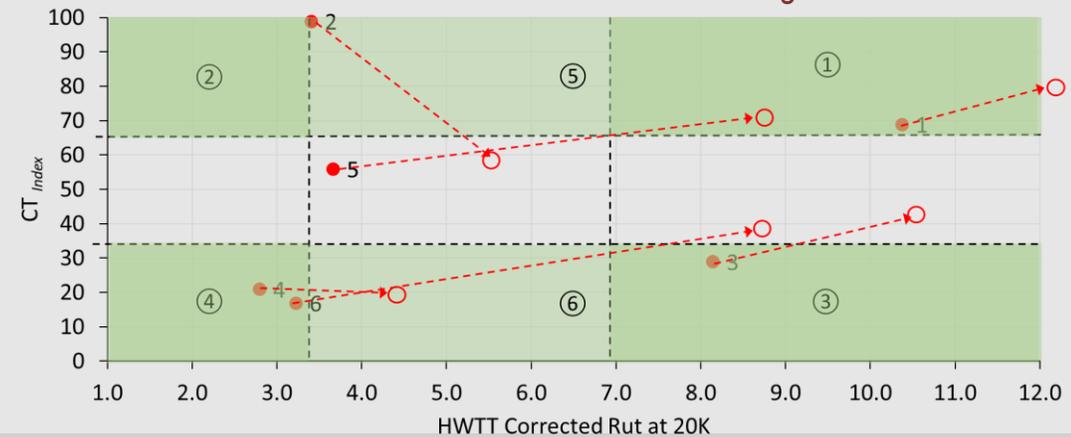
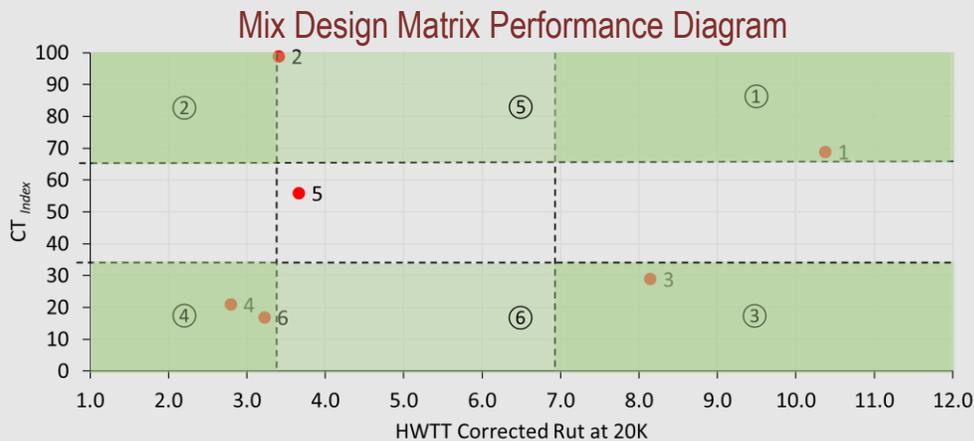
HWTT Corrected Rut Depth	IDEAL $CT_{Index}$ (after 6-hours @ 135°C aging)	
	> 65	< 35
> 7.0 mm	①	③
< 3.5 mm	②	④
V-grade binder	⑤	⑥

<sup>1</sup> Section identical to mixture design 1 with "V" binder replacing "S" binder

<sup>2</sup> Section identical to mixture design 3 with "V" binder replacing "S" binder



Produced Matrix Performance Diagram



# External Research No. 2

- WisDOT Directed Research through CAPRI TPF-5(465) Using HWTT CRD and IDEAL-RT for Rutting Evaluation of Asphalt Mixtures in Wisconsin
  - The evaluation of Wisconsin asphalt mixtures for rutting resistance using the CRD parameter.
  - The validation of CRD parameter by running the HWTT in both wet and dry conditions.
  - The assessment of correlation between CRD and IDEAL-RT test results.
  - If necessary, proposing new thresholds for the CRD for the dense graded and stone mastic asphalt (SMA) mixes.
  - Propose threshold for IDEAL-RT for the acceptance of asphalt mixtures during the production stage.



# External Research No. 3

- WisDOT Directed Research through WHRP
- Evaluation of Hamburg Wheel Tracking Test (HWTT) for Rutting Resistance Assessment FFY2026

The research will:

- Determine if the HWT test accurately represents rutting and stripping behaviors of fine-graded asphaltic pavement design mixtures.
- Propose and develop a representative rutting test that allows WisDOT to retain the benefits of fine-graded mixes while supporting the state's goal of fully implementing balanced mix design concepts.



# Internal Research

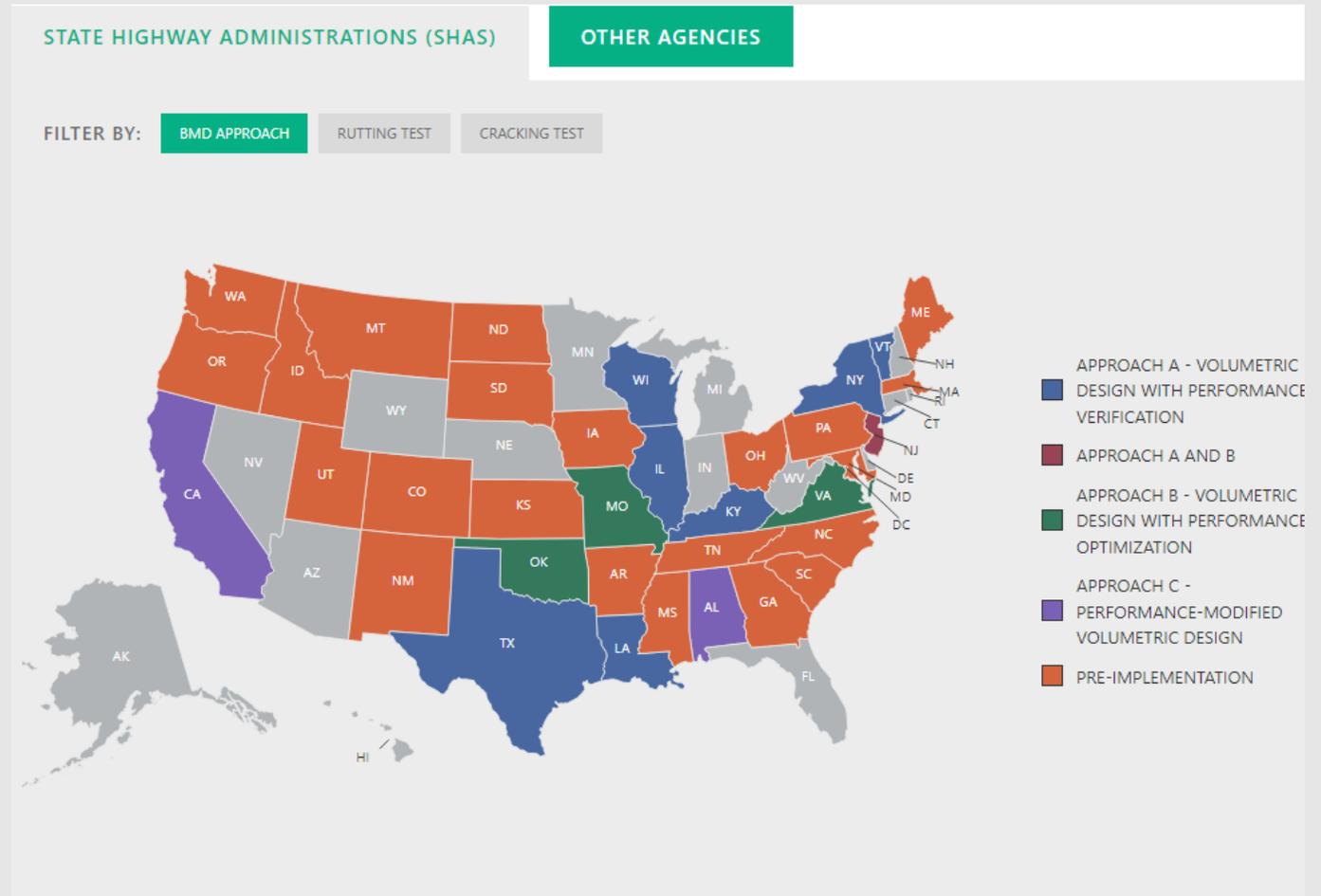
## WisDOT Directed Research through BTS Round Robin Testing

- Continued evaluation of an aging / conditioning and handling procedure developed by the WisDOT to minimize the variability caused by aging and conditioning differences on the balanced mix design test results.
- Addition of performing IDEAL-RT along with HWTT and IDEAL-CT, in plant-aged and long-term aged conditions.



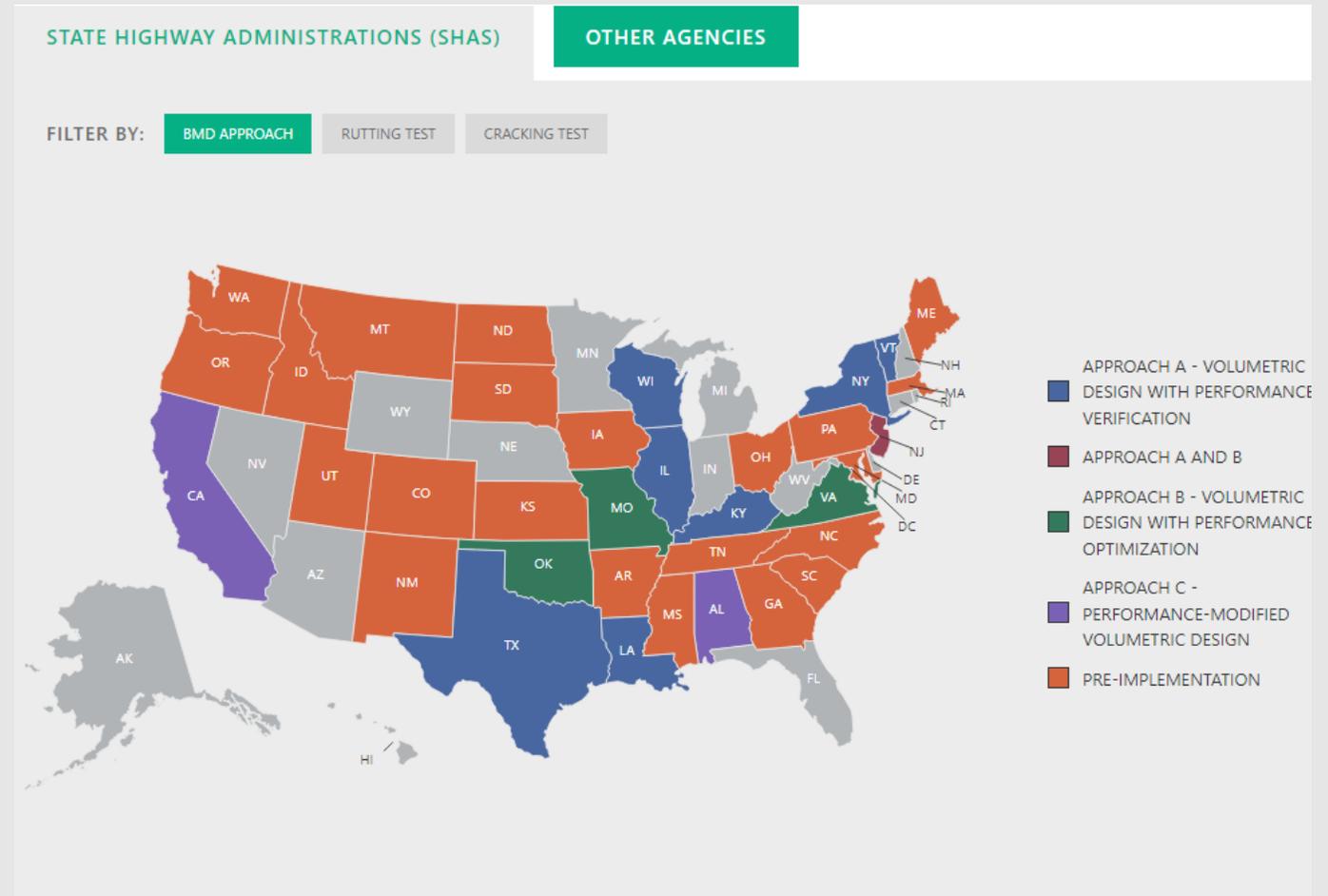
# BMD Pilot Projects in WI

- How do we compare with others?
  - In 2020, WisDOT developed an SPV for BMD pilot projects selected from percent within limits (PWL) projects
    - One pilot project per region
    - Mix design stage, not production
    - HWTT and IDEAL-CT



# BMD Pilot Projects in WI

- How do we compare with others?
  - WisDOT developed an SPV for BMD pilot projects selected from PWL projects
    - From 2021-2023: the criteria set for HWT test were based on **No. of passes to failure** and **SIP**
    - From 2023-present: the criteria set for HWT have been based on **CRD** and **SN**



<https://www.asphaltpavement.org/expertise/engineering/resources/bmd-resource-guide/implementation-efforts>

\*Note: SIP is the abbreviation of stripping inflection point.



# BMD Pilot Projects in WI

- SPV used for pilot BMD projects since 2020
  - Mix design testing criteria from 2021 to 2023

Binder Designation Level <sup>[1]</sup>	S	H	V	E
Hamburg Wheel Tracking (AASHTO T 324 as modified in CMM 836.6.10.1) Passes to 12.5mm rut depth Stripping Inflection Point	10,000 8,000	15,000 8,000	20,000 8,000	20,000 8,000
IDEAL-CT <sup>[2]</sup> (ASTM D8225 as modified in CMM 836.6.10.2) CT-Index	30	30	30	30

→ To ensure rutting and moisture damage resistance

→ To ensure cracking resistance

- Mix design testing criteria from 2023 to present

Mixture Type	LT	MT	HT	SMA
Hamburg Wheel Tracking (WTM T324) Corrected Rut Depth @ 20,000 Passes (mm) Stripping Number (LC <sub>SN</sub> )	≤ 12.0 ≥ 3,000	≤ 7.5 ≥ 3,000	≤ 5.0 ≥ 3,000	≤ 4.0 ≥ 3,000
IDEAL-CT (ASTM D8225 as modified in CMM 836.6.10.2) CT-Index	≥ 30	≥ 30	≥ 30	≥ 80

→ To ensure rutting and moisture damage resistance

→ To ensure cracking resistance

- Testing during the production was for information purpose only



# Days of Future Past

- SPV used for pilot BMD project since 2020
  - BMD is incorporated at the mix design stage for certain PWL projects
  - Applies to upper layer mixtures
  - Mix designs are tested using HWTT and IDEAL-CT methods
- SPV considerations for future pilot BMD projects
  - BMD is incorporated at the mix design stage for certain PWL projects
  - Applies to upper layer mixtures
  - Mix designs are tested using HWTT, IDEAL-RT and IDEAL-CT methods
  - Production Testing using HWTT, IDEAL-RT and IDEAL-CT methods



# Next Steps

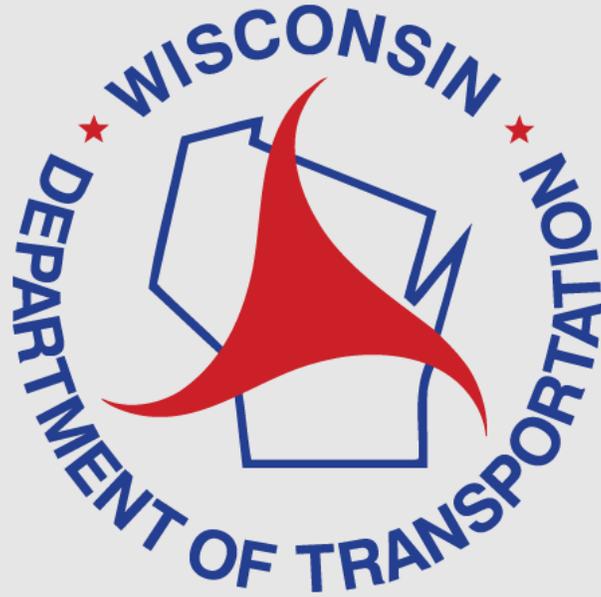
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- If necessary, proposing new thresholds for the CRD for the dense graded and stone mastic asphalt (SMA) mixes.
- Propose threshold for IDEAL-RT for the acceptance of asphalt mixtures during the production stage.



# Next Steps

- Implementing long term rutting and cracking evaluations of BMD test sections on select projects.
  - BMD test sections constructed in 2022 are not showing signs of distress. There are six test sections – one in each BMD quadrant and two of the designs with polymer added.
  - 100% of state highways are currently being scanned each year.
  - Hoping to develop appropriate protocols to eventually incorporate previous and future test sections.





Any questions or comments?

**Thank You!**