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Balanced Mix Design Benchmarking of Field-Produced Asphalt Mixtures in Vermont

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Acronyms

- AASHTO: American Association of State Highway Transportation Officials
- ASTM: American Society for Testing and Materials
- ANOVA: Analysis of Variance
- BMD: Balanced Mixture Design
- CT_{index}: Cracking index
- DP: Dust proportion
- FHWA: Federal Highway Administration
- HWTT: Hamburg Wheel Tracking Test
- IDEAL-CT: Ideal cracking test
- IDEAL-RT: Ideal rutting test
- MaineDOT: Maine Department of Transportation
- MATC: Mobile Asphalt Technology Center
- MSCR: Multiple Stress Creep Recovery
- NMAS: Nominal maximum aggregate size
- NRRI: Normalized rutting resistance index
- P_b: Percent of asphalt binder in mixture
- PG: Performance grade
- RAP: Reclaimed asphalt pavement
- RAS: Reclaimed asphalt shingles
- RSI: stress sweep rutting index
- S_{app}: cyclic fatigue index parameter
- SIP: Stripping inflection point
- SSR: Stress Sweep Rutting Test
- VFA: Voids filled with asphalt
- VTrans: Vermont Agency of Transportation

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Why do you care?

What are you going to get out of this?

- Good example of benchmarking for an agency
- Analysis of mix design properties versus index properties
- Production variability analysis of BMD parameters in statistical acceptance program

Balanced Mixture Design (BMD)

- FHWA collaborates with stakeholders to advance and implement BMD in an impartial and data-informed manner
- Per AASHTO PP 105-20, BMD is defined as:
  - "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."

What are the key points of that definition?

- Use of performance tests
- Appropriately conditioned specimens
- Multiple modes of distress (more than rutting and cracking)
- Taking into account the use of the mixture

Design "philosophy" used to optimize the mix performance against distresses pertinent to the climate & traffic specific to the region where it will be placed.

Study Background

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Motivations

- VT State Law has mandated up to 50% RAP by aggregate weight since 2008
  - 3% RAS by aggregate weight max was added to specifications in 2018
  - State Law was amended in 2022 under Annual Transportation Budget to consider other “sustainable building components” (19 VSA § 10m)
- Observed Distresses in VT Pavements
  - Rutting
  - Raveling
  - All 3 Modes of Cracking (Fatigue, Thermal, Reflective)
- Original Superpave Performance tests too complex for Vermont Agency of Transportation (Vtrans)

VT Rationale for Chosen BMD Tests

- HWTT
  - Raveling distresses were suspected to be moisture susceptibility related
  - Not confident in AASHTO T 283 TSR method in VT's climate conditions
  - Purchased in 2015, began evaluating in 2016
- Illinois Flexibility Index Test (I-FIT)
  - Highlighted as test to look at thermal and fatigue cracking in NCHRP 09-57
  - Increase in Recycled Asphalt Materials (RAM) was anticipated
  - Purchased in 2017, began evaluating in 2018
- IDEAL-CT
  - Initially looked at as "surrogate" test to I-FIT during mix production
  - Purchased in 2019, began evaluating in 2020

Background and Objective

- VTrans conducted several performance tests on their plant-produced asphalt mixtures in order to:
  - Develop baseline performance of common VTrans asphalt mixtures for potential implementation in balanced mix design.
  - Analyze mixture performance test results against typical mixture properties, such as NMAS, binder PG, and other volumetric properties to measure the effects of these properties on mixture performance.
  - Analyze the typical production variability observed with the selected performance tests to aid in specification development for performance testing in Acceptance.
- FHWA Mobile Asphalt Technology Center (MATC) worked with VTrans to help analyze the dataset

Overall BMD Implementation Process

8 Tasks That Can be Undertaken (Schedule Example)

Task		Sub Task	Description	Years -1	1	2	3	4	5	6	7
1	Understanding the why and benefits of Performance Specifications										
2	Overall Planning	2.1	Identification of Champions								
		2.2	Establishing a Stakeholders Partnership								
		2.3	Doing Your Homework								
		2.4	Establishing Goals								
		2.5	Mapping the Tasks								
		2.6	Identifying Available External Technical Information and Support (periodically)								
		2.7	Developing an Implementation Timeline								
3	Selecting Performance Tests	3.1	Identifying Primary Modes of Distress.								
		3.2	Identifying and Assessing Performance Test Appropriateness.								
		3.3	Validating the Performance Tests								
		4.1	Acquiring Equipment								
		5.5	Determining How to Adjust Asphalt Mixtures Containing Local Materials								
6	Specifications and Program Development	6.1	Sampling and Testing Plans								
		6.2	Pay Adjustment Factors (If Part of the Goals)								
		6.3	Developing Pilot Specifications and Policies								
		6.4	Conducting Pilot Projects								
		6.5	Final Analysis and Specification Revisions								
7	Training, Certifications, and Accreditations	7.1	Developing and/or Updating Training and Certification Programs								
		7.2	Establishing or Updating Laboratory Accreditation Program Requirements								
8	Initial Implementation										

Task		Sub Task	Description
5	Establishing Baseline Data	5.1	Reviewing Historical Data & Information Management System
		5.2	Conducting Benchmarking studies
		5.3	Conducting Shadow Projects
		5.4	Analyzing Production Data
		5.5	Determining How to Adjust Asphalt Mixtures Containing Local Materials

Inter-related tasks or subtasks activities.

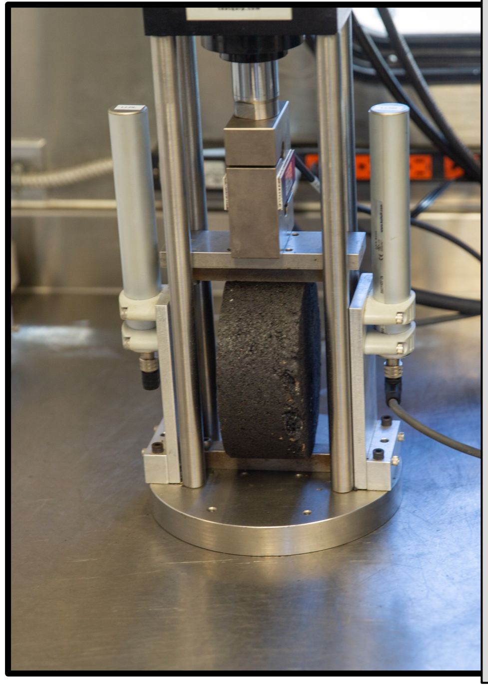
Study Details

- Splits from plant-produced acceptance samples taken at plant
- Reheated to fabricate specimens for volumetric and BMD testing without additional laboratory aging
- Data collected over last 4 years
- HWTT & I-FIT since 2018
- Added IDEAL-CT in 2020

Year	Mix Type	Binder Grade	Design Gyration	No. of Sublots
2018	IIS	58-28	65	3
	IIS	70-28	65	4
	IIS	70-28	80	21
	IIIS	70-28	65	3
	IVS	58-28	65	9
	IVS	70-28	50	12
	IVS	70-28	65	10
	IVS	70-28	80	5
2019	IIS	58-28	65	1
	IIS	70-28	65	24
	IIIS	70-28	65	12
	IVS	58-28	65	1
	IVS	70-28	50	11
	IVS	70-28	65	54
	IVS	70-28	80	11
2020	IIS	70-28	65	7
	IIS	70-28	80	7
	IVS	70-28	50	2
	IVS	70-28	65	32
	IVS	70-28	80	3
2021	IIS	70-28	65	2
	IVS	70-28	50	7
	IVS	70-28	65	53
	IVS	70-28	80	12
Number of Sublots Tested in 4 Years				306

Study Details (continued)

- Rutting & Moisture Damage Resistance
  - HWTT per AASHTO T324 at 45°C
    - Passes to 12.5 mm deformation, Stripping Inflection Point, Normalized Rutting Resistance Index (NRRI)
- Cracking Resistance
  - I-FIT per AASHTO T393 at 25°C
    - FI
  - IDEAL-CT per ASTM D8225 at 25°C
    - CT_{index}



Source: FHWA

Criteria For Analysis

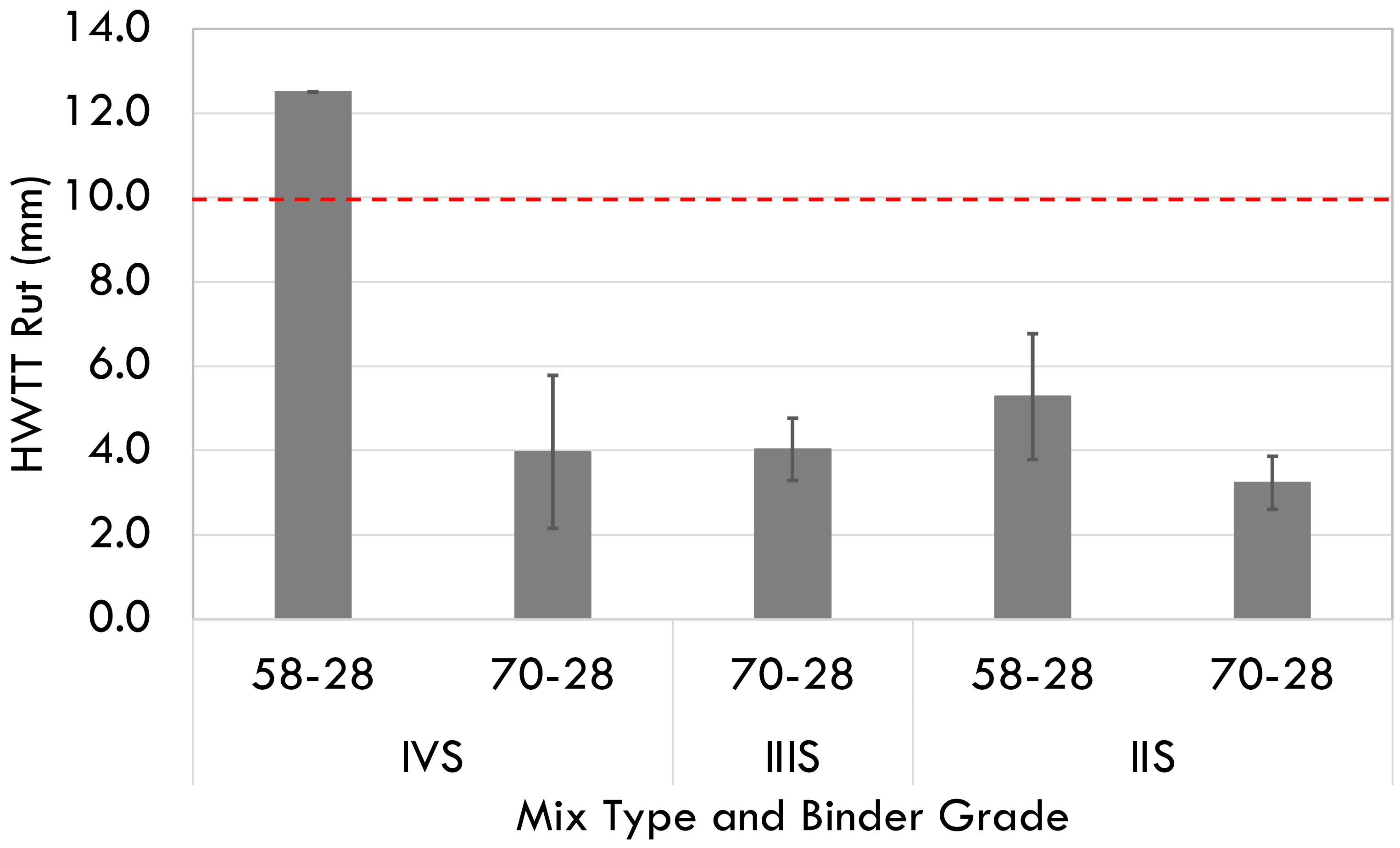
- HWTT
  - Maximum 10.0 mm deformation after 20,000 passes
  - 45°C
- I-FIT
  - Minimum FI of 10
- IDEAL-CT
  - Recent NETC study by Mogawer & Bennert recommended a minimum CT_{index} of 150

All AASHTO & ASTM standards mentioned in this presentation content are private, voluntary standards and are not required under Federal law.

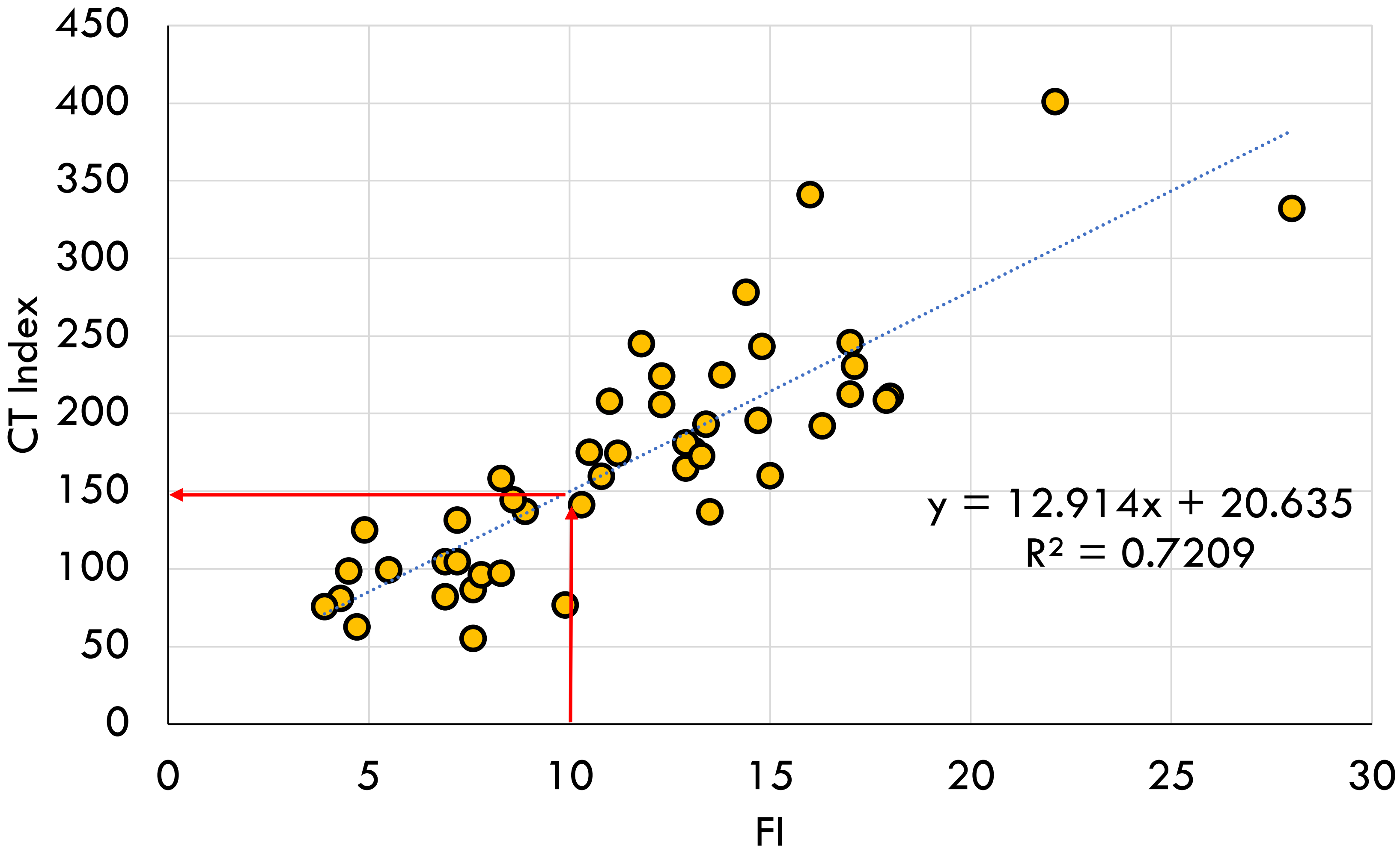
Results

HWTT Results – Rut Depth at 20,000 Passes

- ANOVA: P_b, Binder PG, Mix Type (NMAS), Air Voids significant
- Significant portion of mixes failing to meet current VTrans criteria
- Effect of binder grade / modification
  - PG58-28 struggle to meet
  - PG70-28 routinely have less than 4 mm rutting



Comparison of I-FIT and IDEAL-CT



- Good correlation as noted by other researchers
- Proposed criteria of FI = 10 corresponds to proposed criteria of CT_{index} = 150

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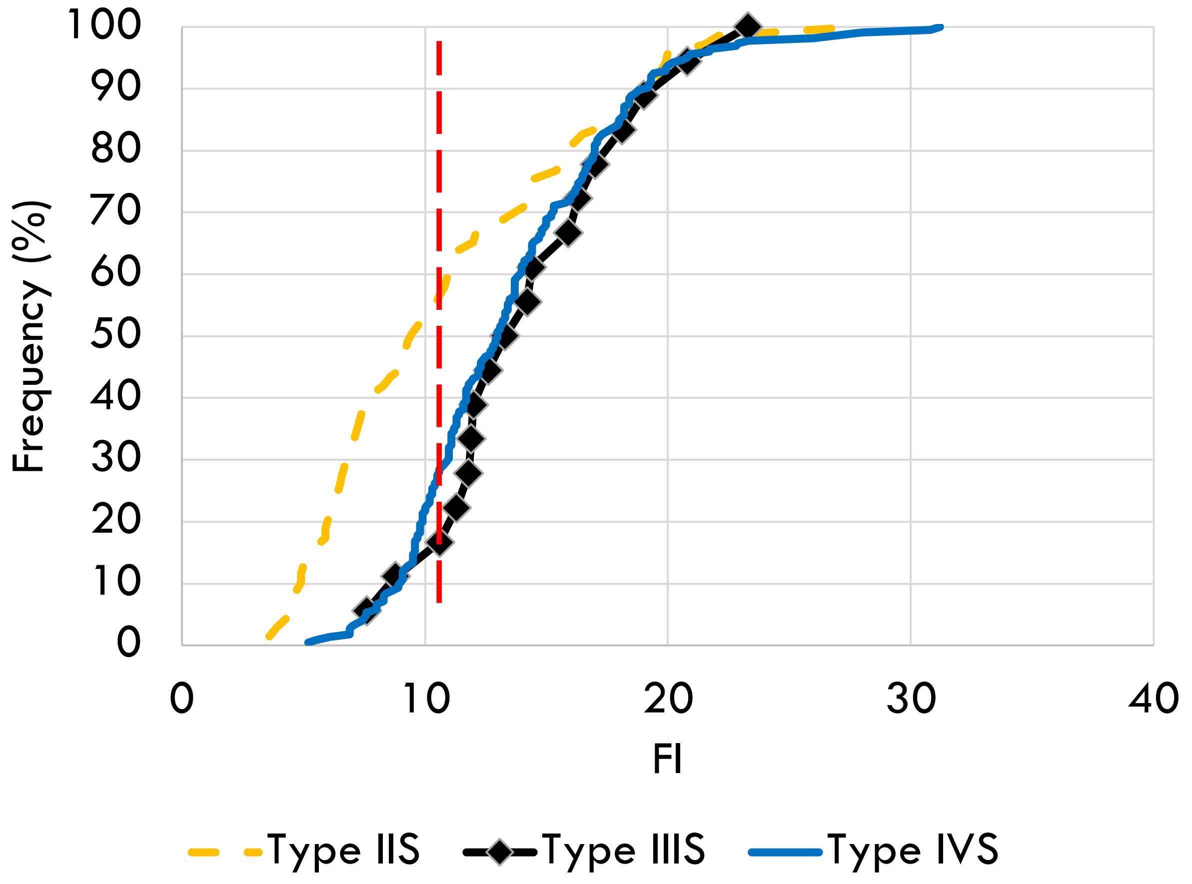
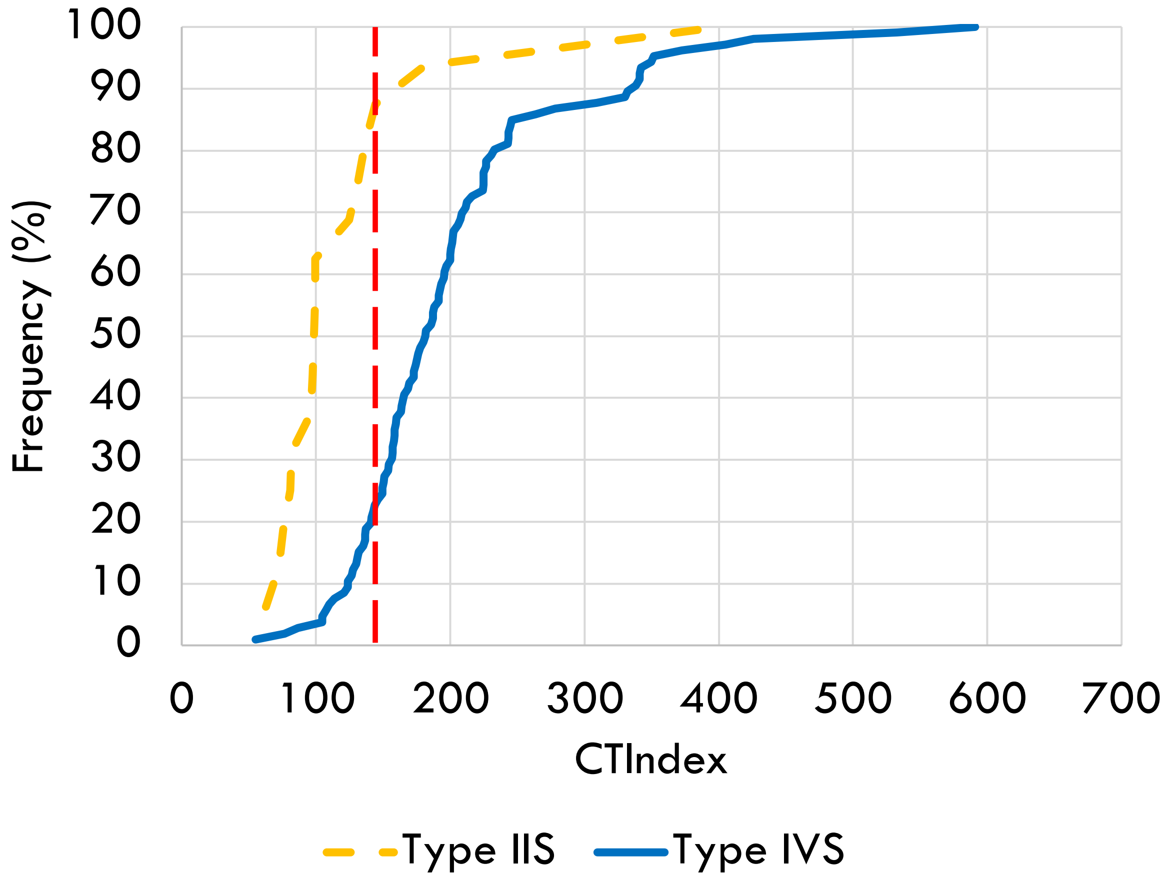
Cracking Test Results





- ANOVA: RAP%, Mix Type

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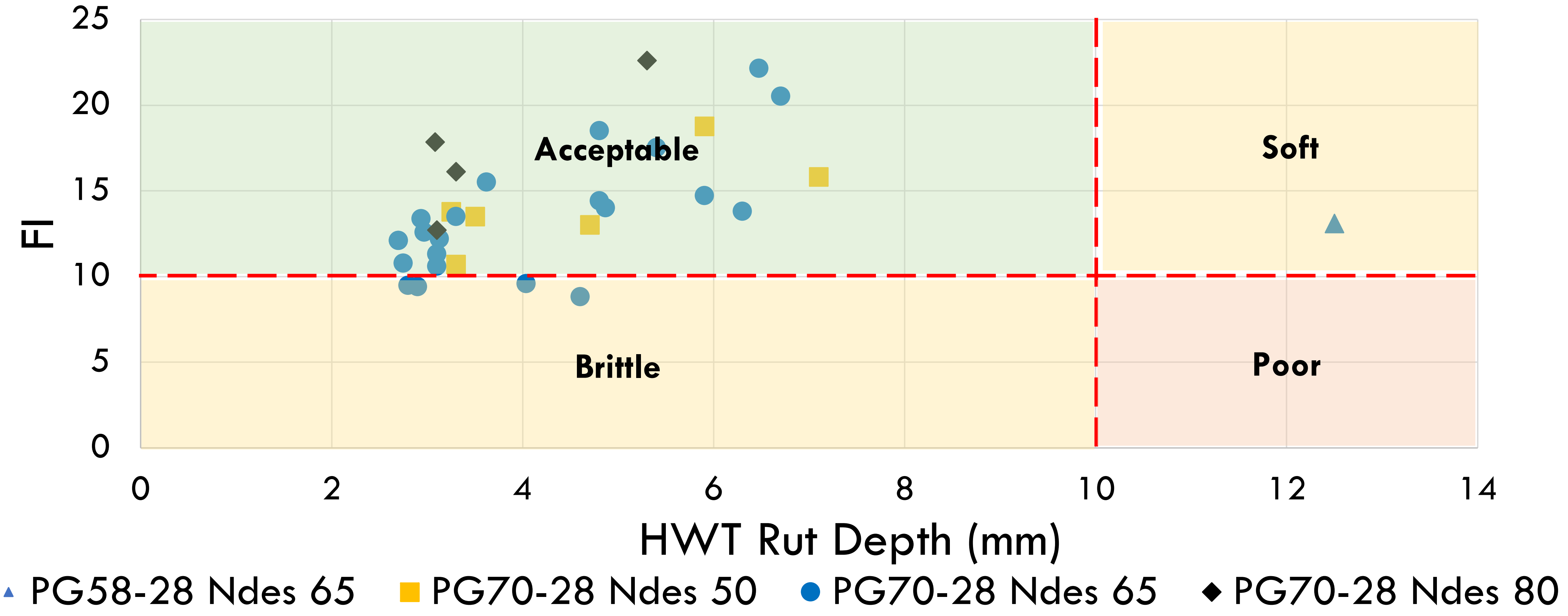
I-FIT (25°C) versus HWT (45°C)



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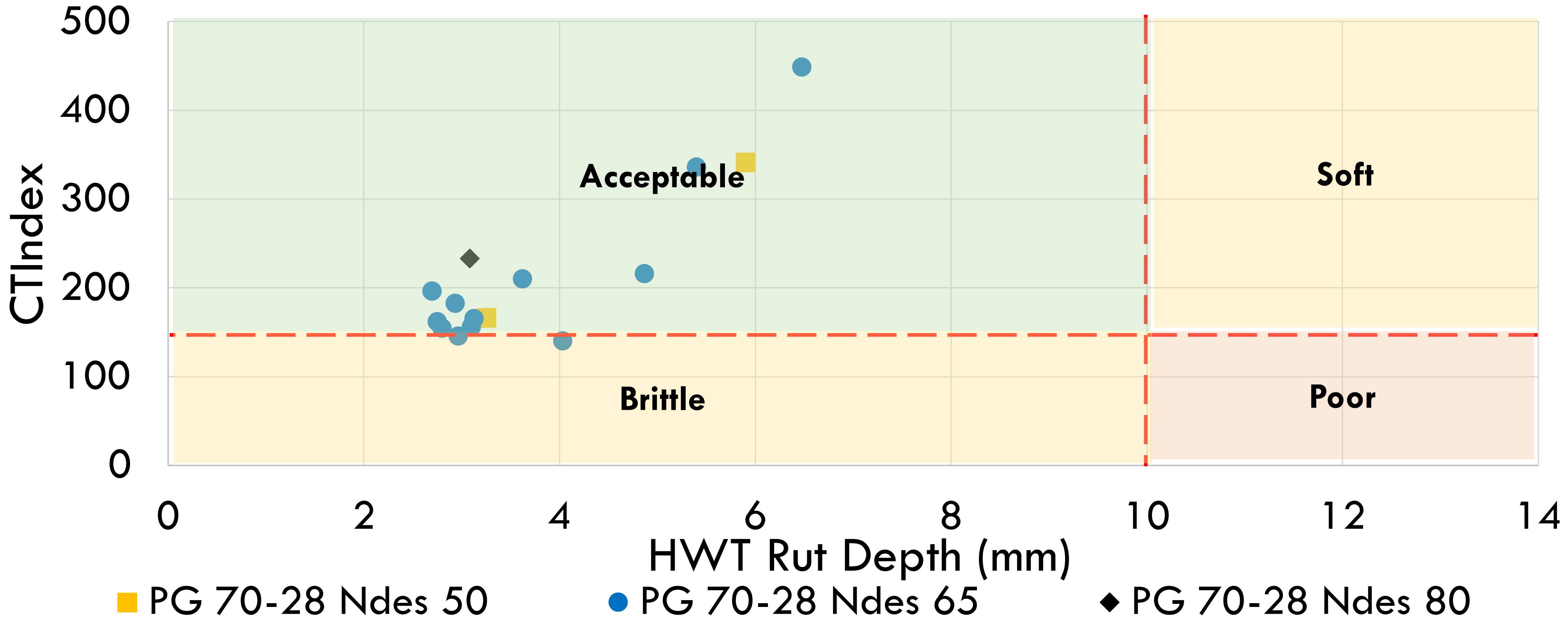
IDEAL-CT (25°C) versus HWT (45°C)



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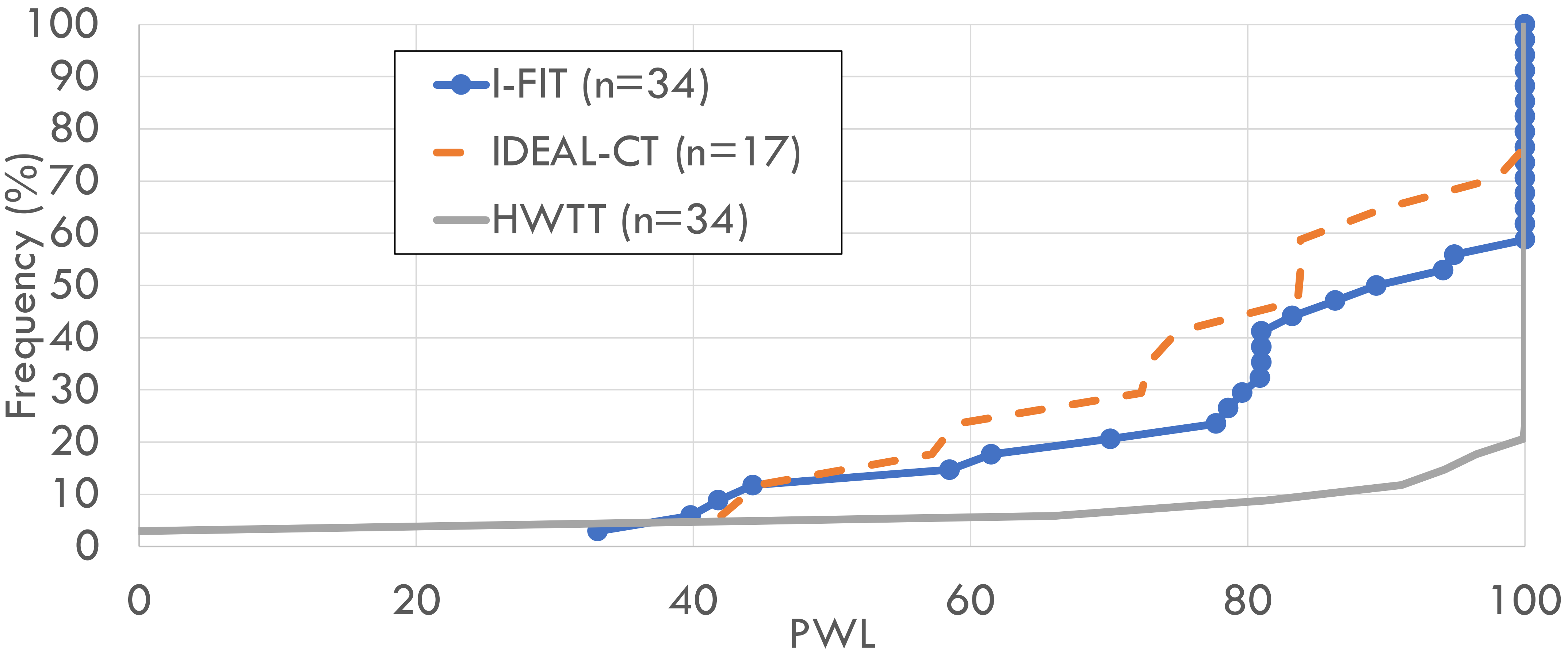
Lot ID	HWTT – *Rut Depth (mm)*				I-FIT – *FI*				IDEAL-CT - CT_{index}			
	Lot Avg	Lot Std Dev	No. of Sublots	PWL	Lot Avg	Lot Std Dev	No. of Sublots	PWL	Lot Avg	Lot Std Dev	No. of Sublots	PWL
A	12.5	0.0	8	0	13.1	3.5	8	81				
B	3.3	0.7	3	100	10.7	2.2	3	59				
C	7.1	2.0	3	100	15.8	5.6	3	86				
D	4.7	3.2	8	97	13.0	2.0	8	94				
E	3.5	0.5	4	100	13.5	1.8	4	100				
F	3.3	0.4	4	100	13.8	4.4	4	79	166	24	4	72
G	5.9	0.5	3	100	18.8	1.9	3	100	341	32	3	100
H	4.6	3.3	4	100	8.8	2.4	4	33				
I	2.9	0.3	5	100	9.4	2.5	5	42				
J	6.3	3.1	3	100	13.8	5.6	3	70				
K	3.1	0.5	7	100	11.3	1.3	8	83				
L	4.8	2.2	10	100	14.4	3.6	10	89				
M	6.7	2.7	4	91	20.5	4.4	4	100				
N	4.8	0.8	4	100	18.5	2.9	4	100				
O	3.3	0.3	3	100	13.5	2.6	3	100				
P	5.9	1.0	3	100	14.7	2.9	3	100				
Q	4.9	0.7	6	100	14.0	2.7	6	95	216	39	6	98
R	3.6	0.7	9	100	15.5	2.2	9	100	210	17	7	100
S	2.8	0.2	6	100	9.5	1.8	6	40	154	17	6	59
T	2.9	0.2	3	100	13.4	1.5	6	100	182	32	6	84
U	5.4	1.0	3	100	17.5	3.9	3	100	336	71	3	100
V	6.5	3.8	4	81	22.1	6.1	4	100	448	153	4	100

PWL Analysis



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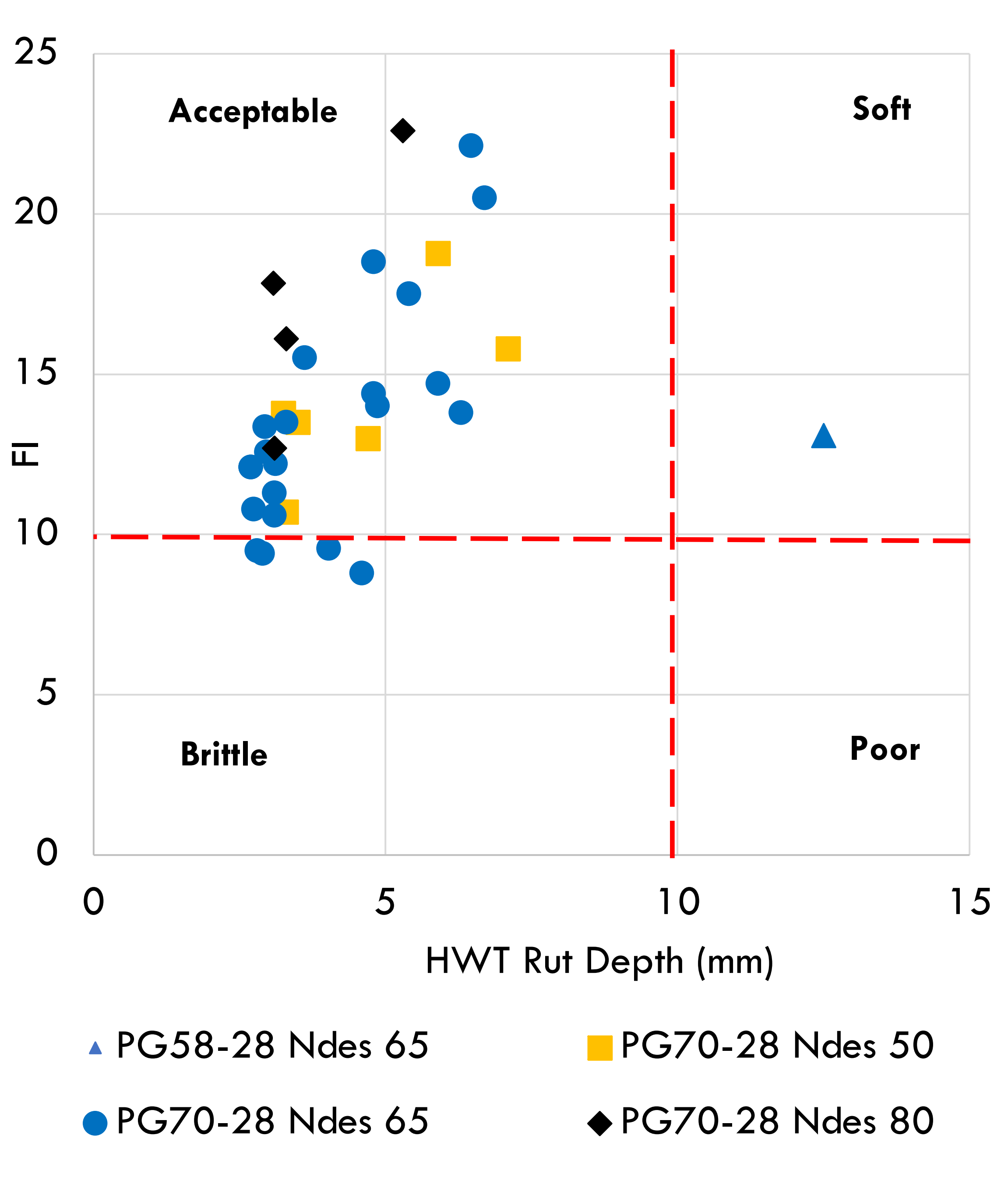
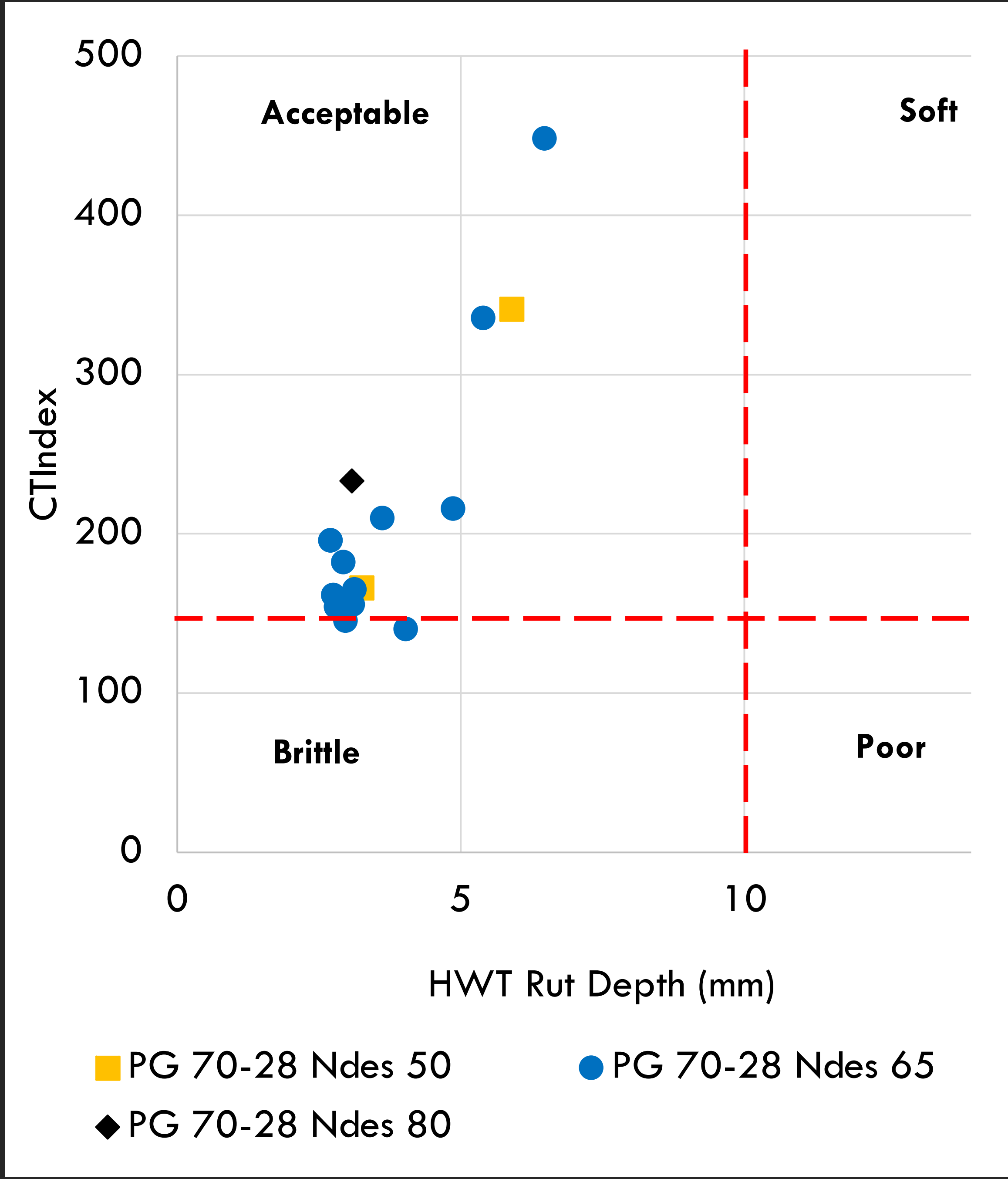
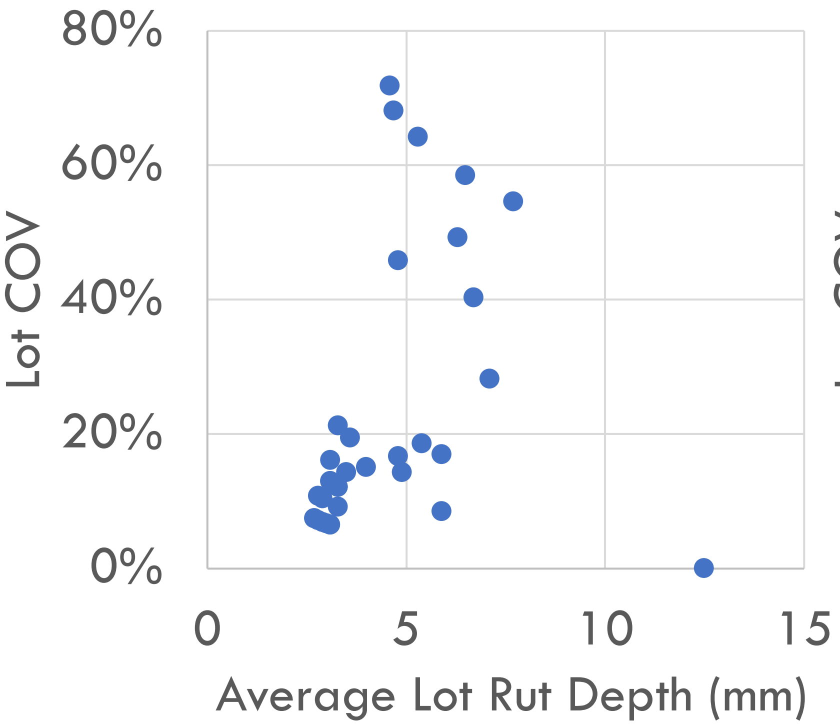


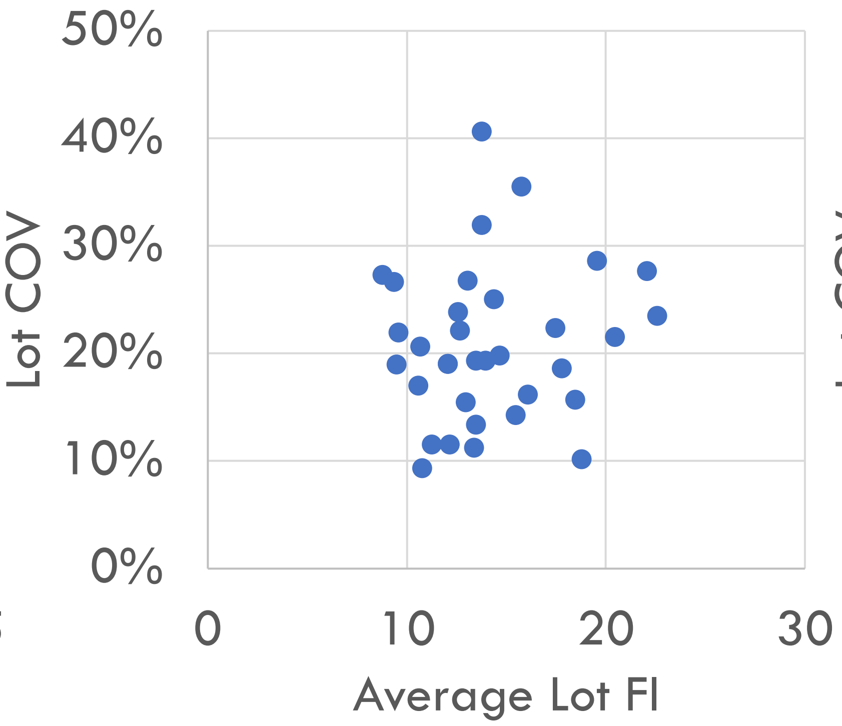
25
20
15
10
5
0
FI
Acceptable
Soft
Brittle
Poor
0
5
10
15
HWT Rut Depth (mm)
PG58-28 Ndes 65
PG70-28 Ndes 50
PG70-28 Ndes 65
PG70-28 Ndes 80

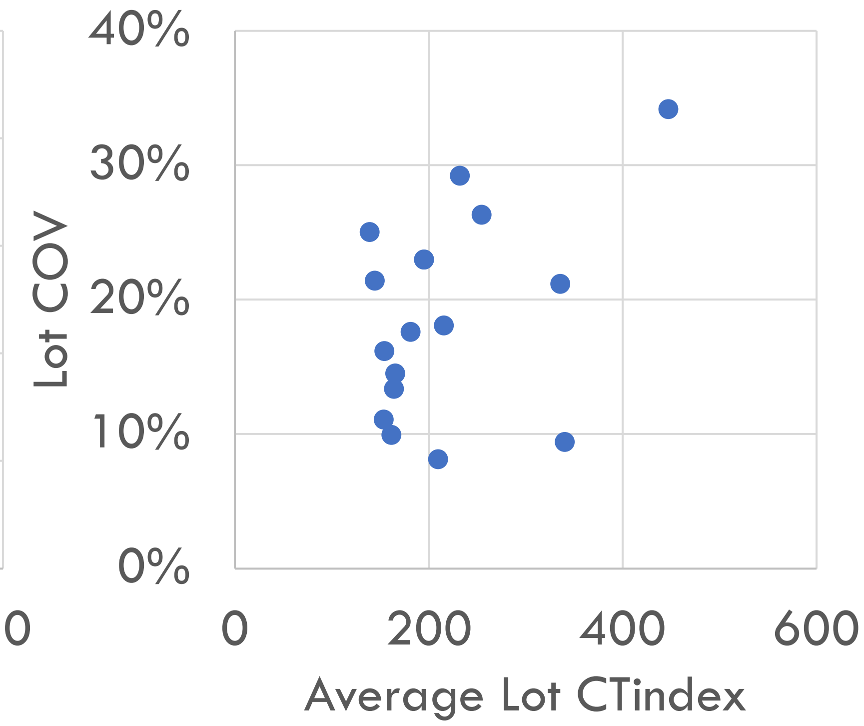


500
400
300
200
100
0
CTIndex
Acceptable
Soft
Brittle
Poor
0
5
10
HWT Rut Depth (mm)
PG 70-28 Ndes 50
PG 70-28 Ndes 65
PG 70-28 Ndes 80

Lot Variability by BMD Test







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Typical Lot Variability

Test	No. of Lots	Total No. of Sublots	Pooled Estimate of within-Lot Variance	Typical Lot Standard Dev
HWTT – Rut Depth (mm)	34	161	2.7	1.6
I-FIT – FI	34	166	9.4	3.1
IDEAL-CT - CT_{index}	17	77	2526.5	50.3

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Findings and Future Work

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Findings

- Mix type (i.e., IIS, IIIS and IVS) statistically significant to BMD test results.
- The benchmarking results indicated that the test results appear to reflect the beneficial effects of polymers (i.e., PG70-28) on rutting resistance and finer mixtures (i.e., smaller NMAS) on crack resistance. Most of the mixtures tested in 2018 and 2019 and all those mixtures tested in 2020 and 2021 are modified, so there is not enough data to evaluate the effect of polymers on cracking resistance.
- Direct correlation between FI and CT_{index} observed for VTrans mixtures.
- Variability for BMD tests presents challenges for field production applications, especially statistical acceptance frameworks.
- The typical within-lot standard deviation values for HWTT, I-FIT, and IDEAL-CT were generated based on VTrans projects with more than three sublots. The standard deviation values were relatively high as compared to the criteria and average values, especially for the cracking tests. More work is needed to identify and reduce variability in each of the three major categories (sampling, testing, and materials variability).

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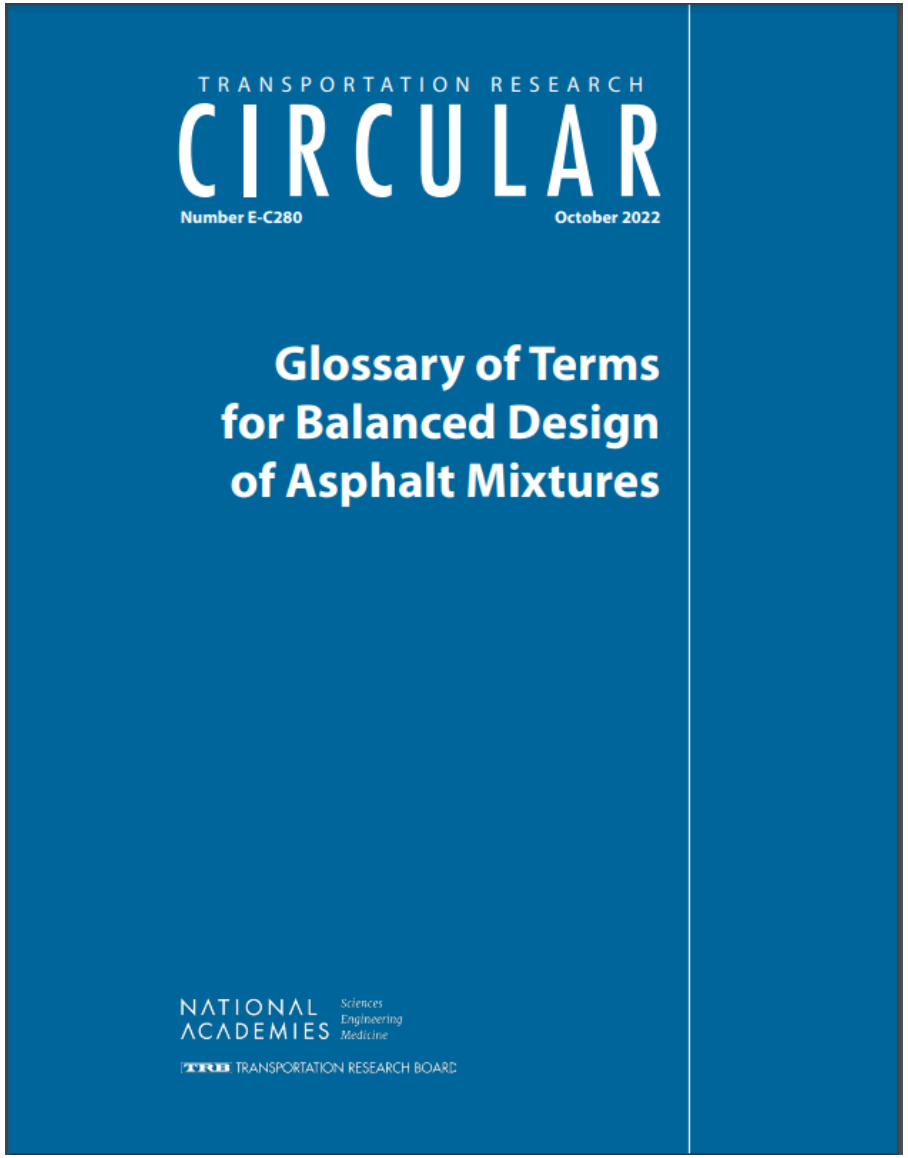
Future Research

- VTrans may investigate the differences between three gyrations levels to determine whether any further consolidation of gyration levels would be worthwhile.
- IDEAL-RT: Long-term goal is to begin assessing the IDEAL-RT as a "surrogate" test to the HWTT and also test roadway cores in the various performance tests.
- Long-term oven aging (LTOA): Still TBD
- Tracking of in-place field performance: Intend to on certain projects
- Next VT specifications book…
  - HWTT Criteria
    - 12.5 mm maximum rut depth, minimum SIP of 15,000 passes
  - Discontinue specifying I-FIT results for informational purposes only in lieu of IDEAL-CT
  - Multiple Stress Creep Recovery PG binder grading – the "benchmarking" continues

Hot off the presses!

- Glossary for BMD Terms developed and championed by TRB Committee AKM10
- TRB E-Circular E-C280

https://onlinepubs.trb.org/onlinepubs/circulars/ec280.pdf


TRANSPORTATION RESEARCH
CIRCULAR
Number E-C280
October 2022

Glossary of Terms for Balanced Design of Asphalt Mixtures

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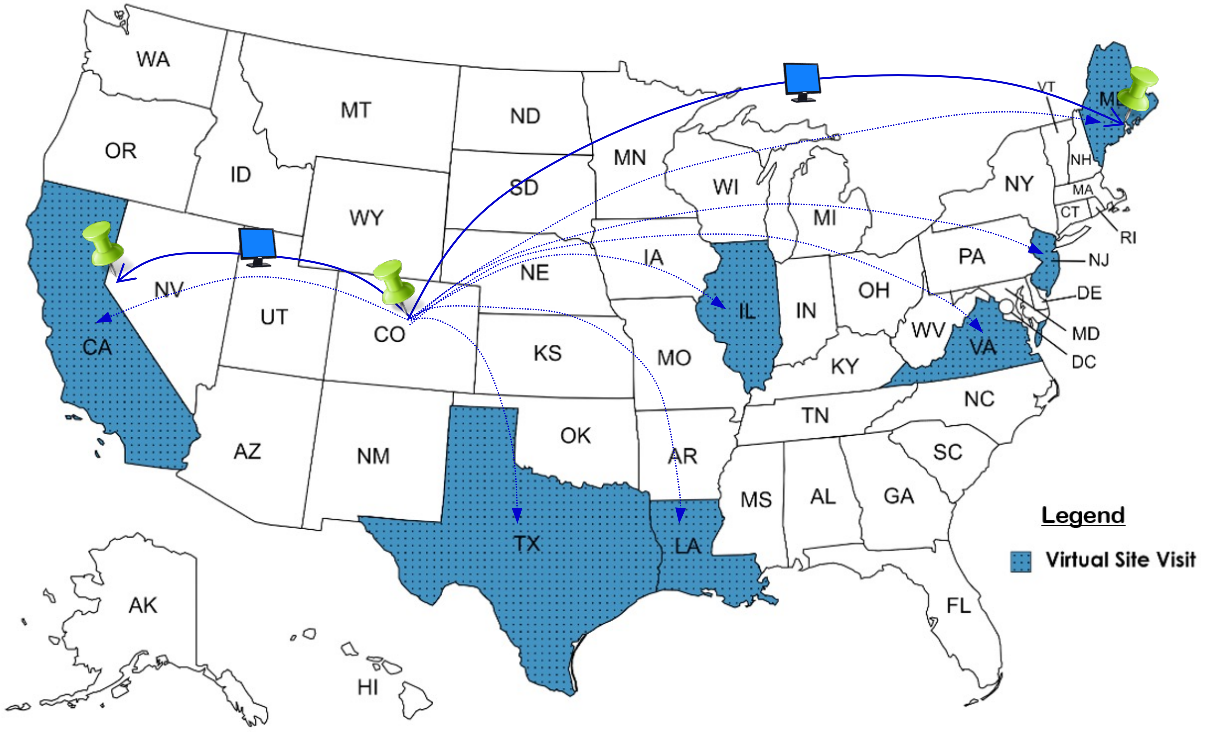
FHWA BMD Case Studies Virtual Workshop



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Balanced Mix Design (BMD) Case Studies Virtual Workshop: Moving Forward with Implementation

Description

This free Federal Highway Administration (FHWA) workshop will provide State DOTs with knowledge on how to get started and/or move forward with the implementation of BMD as learned from in-depth case studies of key State DOTs. It is **customized** to a State DOTs current situation with its BMD implementation program.

This unique workshop includes providing managers and practitioners with knowledge on:

a. the overall BMD process and its benefits;
b. the planning and activities needed for the selection, evaluation, and implementation of performance tests for routine uses in a BMD process; and
c. positive practices and lessons learned by key State DOTs.

The workshop will focus on a BMD implementation process that was developed and conducted from in-depth case studies of key State DOTs.

Location

The **free virtual workshop** will be delivered using Microsoft Teams or any other virtual meeting platform accepted by a State Department of Transportation (DOT).

Length

The workshop is a total of six hours and will include multiple segments with a maximum of three hours per segment. The workshop can be delivered over the course of several days.

Target Audience

The successful implementation of BMD will need to be a team effort. Thus, the target audiences for the workshop are managers and practitioners interested in the implementation of BMD from State DOTs, industry, academia, and consultants. This involves participants from various offices of a State DOT, such as materials, pavement design, construction, and pavement management.

Outcomes

Upon completion of the workshop, participants will be able to:

- Understand the overall benefits of BMD.
- Recognize the planning and coordination effort associate with the implementation process of BMD.
- Identify the tasks that need to be completed for the development and implementation of BMD.
- Recognize successful key State DOTs practices and experiences related to BMD.
- Recognize available external technical information and support.

Register Today

Contact **Derek-Nener-Plante** at derek.nenerplante@dot.gov for more information.

https://www.fhwa.dot.gov/pavement/asphalt/


Thank you!
Questions?

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SPREADING ASPHALT PAVEMENT TECHNOLOGY INNOVATION

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