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

Ram Kumar Veeraragavan
Project Engineer
Highway Technology Partners, LLC

Aaron Schwartz, P.E.
Bituminous Concrete Engineer
Vermont Agency of Transportation

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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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Co-Authors

- **Derek Nener-Plante, M.S., P.E.**

  Pavement and Materials Engineer

  Federal Highway Administration

- **Aaron Schwartz, P.E.**

  Bituminous Concrete Engineer

  Vermont Agency of Transportation

- **Leslie Myers, Ph.D., P.E.**

  Senior Asphalt Pavement Engineer

  Federal Highway Administration

- **Nam H. Tran, Ph.D., P.E.**

  National Center for Asphalt Technology

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

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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.

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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)

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Issues and Concerns

- Original Superpave system consists of three elements: asphalt binder specification, volumetric mix design, and mix performance analysis.
- Volumetric mix design procedure helps to address rutting; however, mix performance analysis procedure, including performance tests and prediction models not been adopted due to its complexity.
- Superpave volumetric mix design procedure - stiffer mixes for better resistance to rutting; stiffer mixtures become less flexible; more prone to cracking and other durability issues.
- With increasing use of recycled materials make the Superpave volumetric design mixtures stiffer and potentially more susceptible to cracking and raveling
- Warm Mix additives. recycling agents enhance compactability, but no tools to evaluate their effectiveness
- Need to develop asphalt mix design procedure considering performance testing to address multiple modes of distress

Summary of BMD Implementation progress

State	Mix Type	Cracking Test	Rutting Test	Implementation Status
California	Long-life pavement mixtures	Bending Beam Fatigue	Flow Number	Implemented
	Superpave mixtures	IDEAL-CT	HWTT	Under evaluation
Illinois	All mixtures	I-FIT	HWTT	Implemented
Louisiana	WC and Base course mixtures	SCB	HWTT	Implemented
Maine	Specialty mixtures		HWTT	Implemented
	Superpave mixtures	IDEAL-CT	IDEAL-RT	Under evaluation
Texas	Specialty mixtures	Overlay Test	HWTT	Implemented
	Dense graded		HWTT	Implemented
	Dense graded	Overlay Test, IDEAL-CT	IDEAL-RT	Under evaluation
Virginia	Superpave mixtures	IDEAL-CT	APA and Cantabro	Under evaluation

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.
  - Compare the performance test results with the proposed specification criteria for evaluating the rutting and cracking resistance of asphalt mixtures in Vermont in the future.
- 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	-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			●	—	—	●		
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.

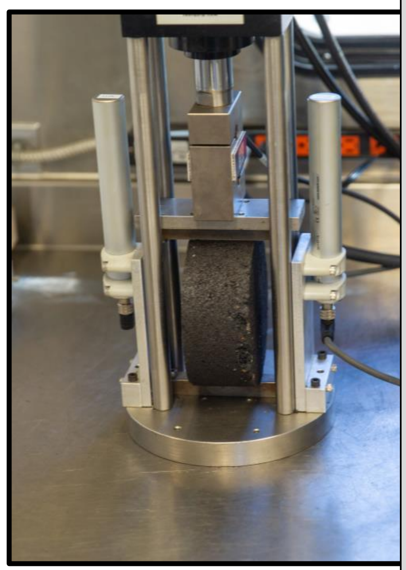
Study Details

- 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

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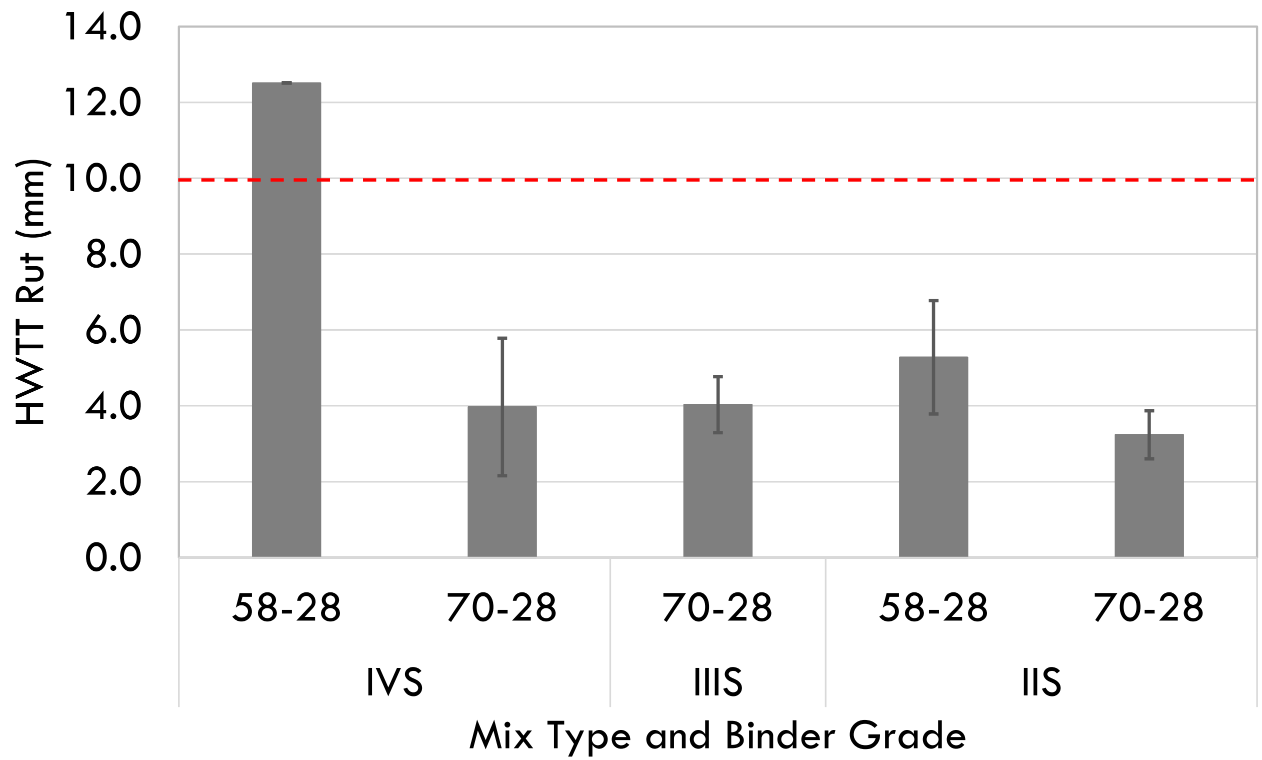
HWTT Results – Rut Depth at 20,000 Passes

- 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



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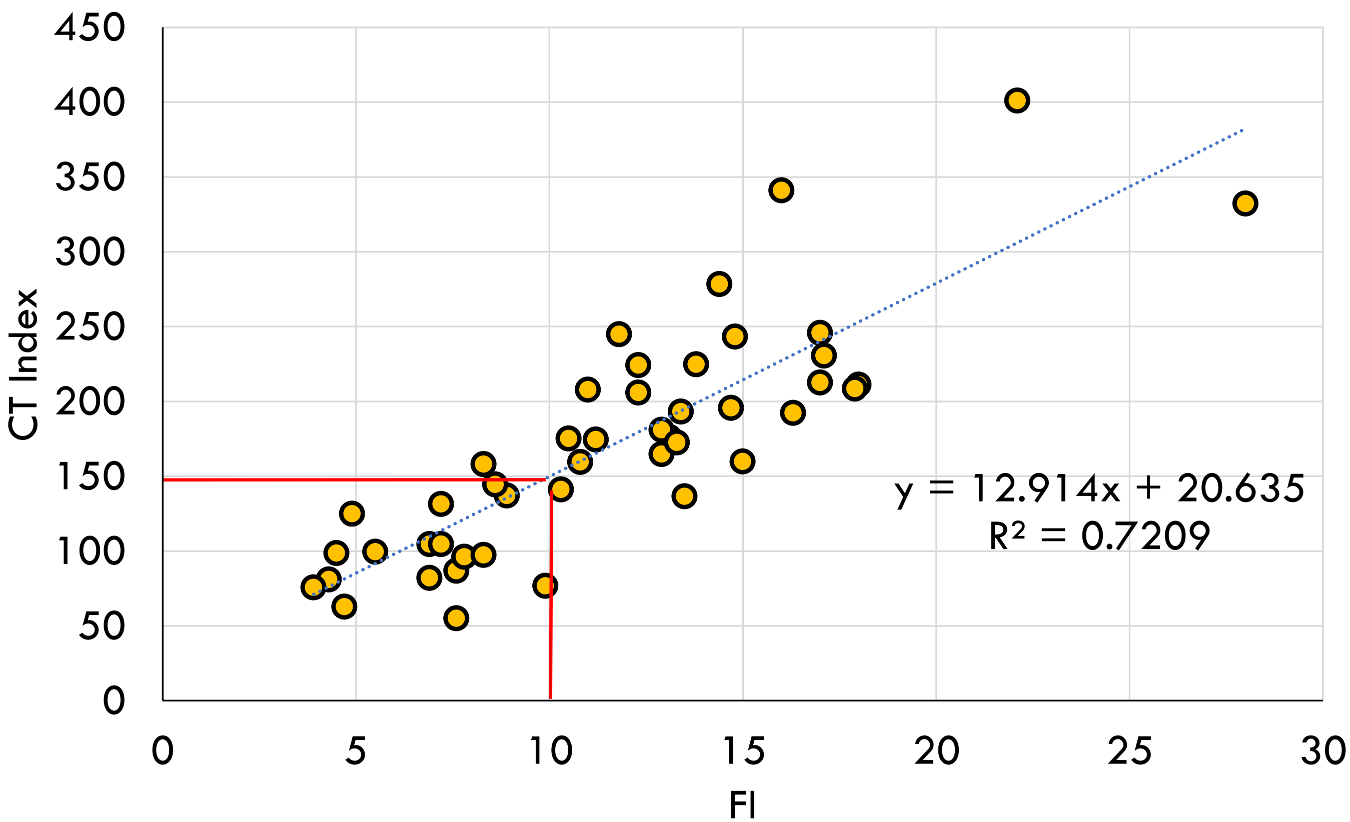
Comparison of I-FIT and IDEAL-CT



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

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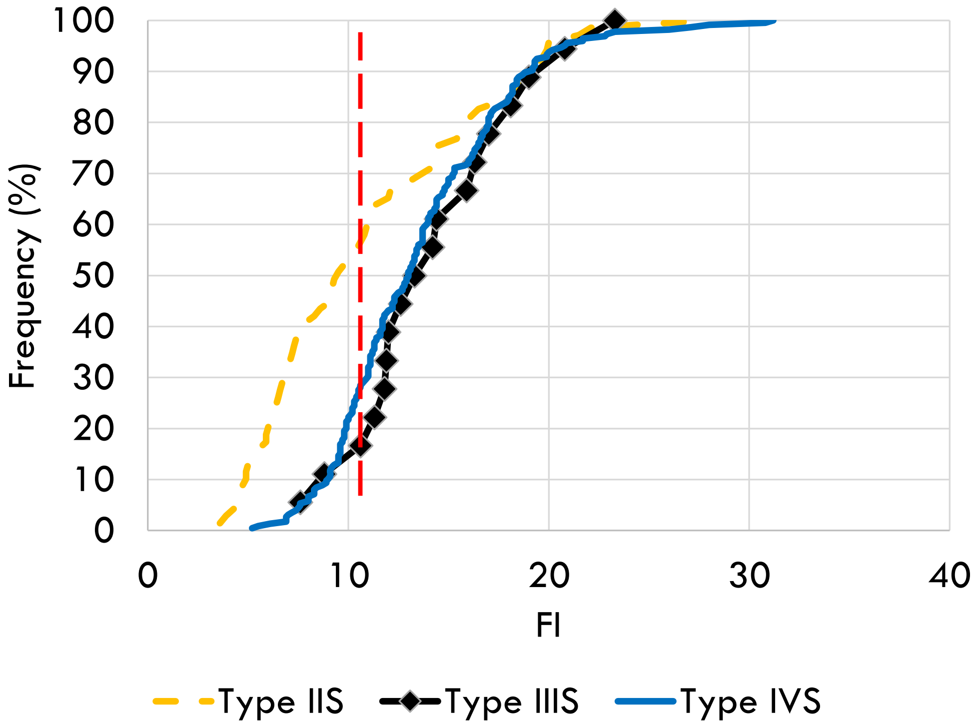
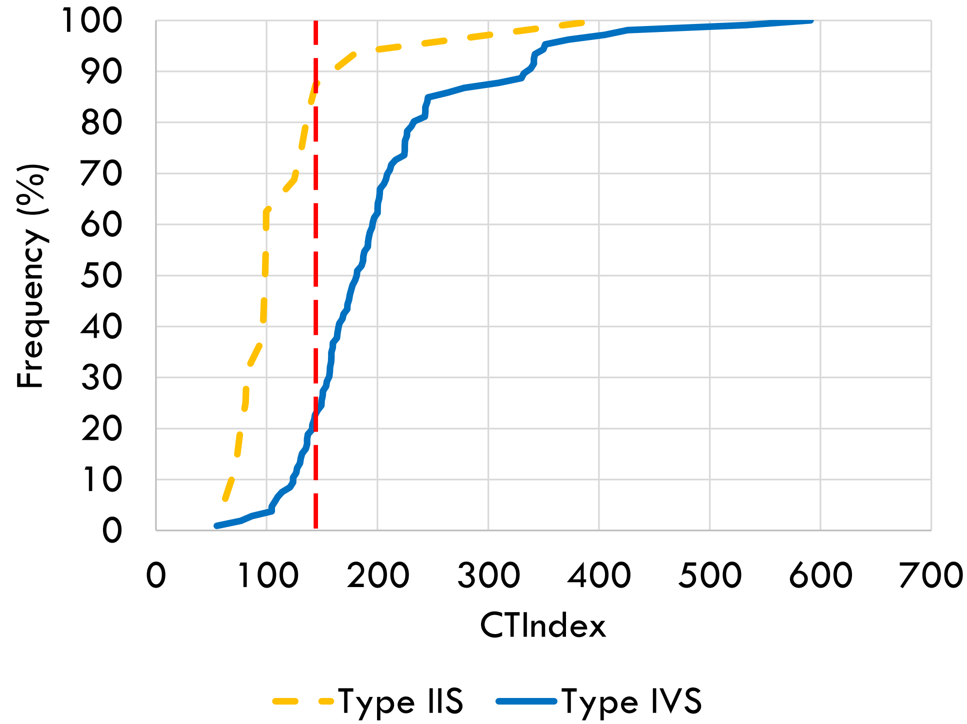
Cracking Test Results





- ANOVA: RAP%, Mix Type

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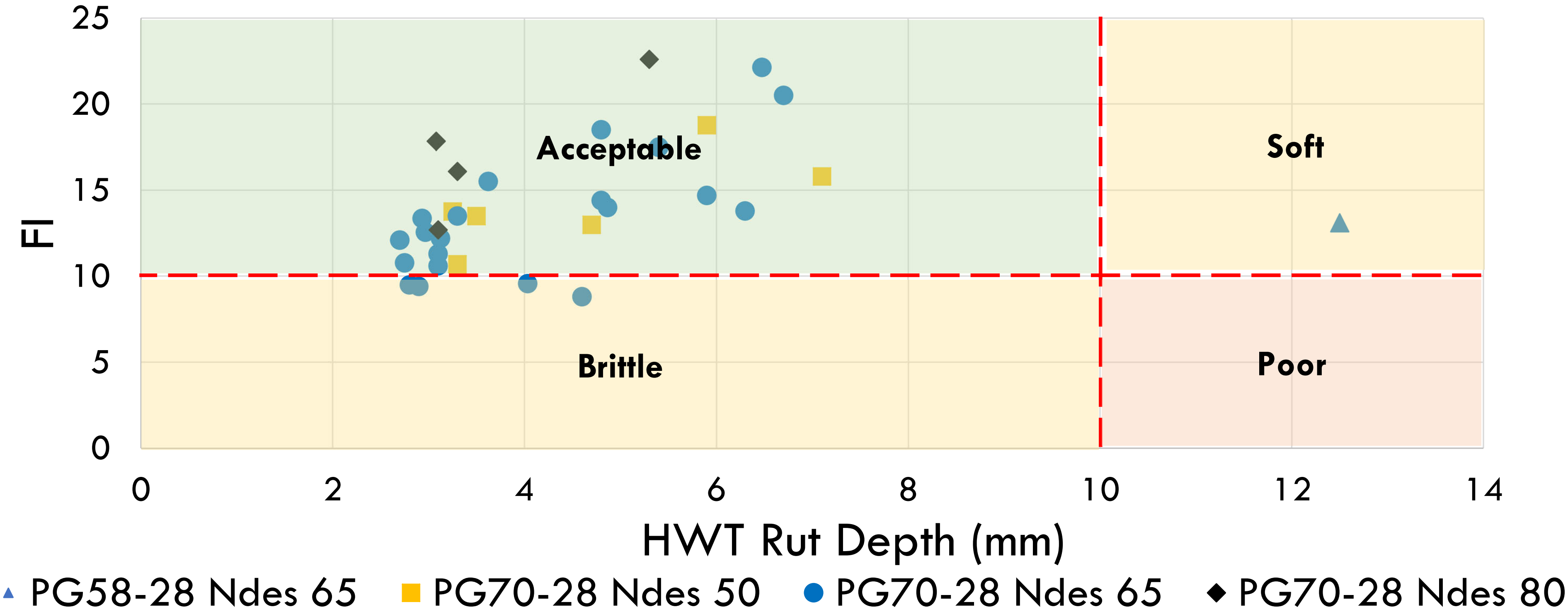
I-FIT (25°C) versus HWT (45°C)



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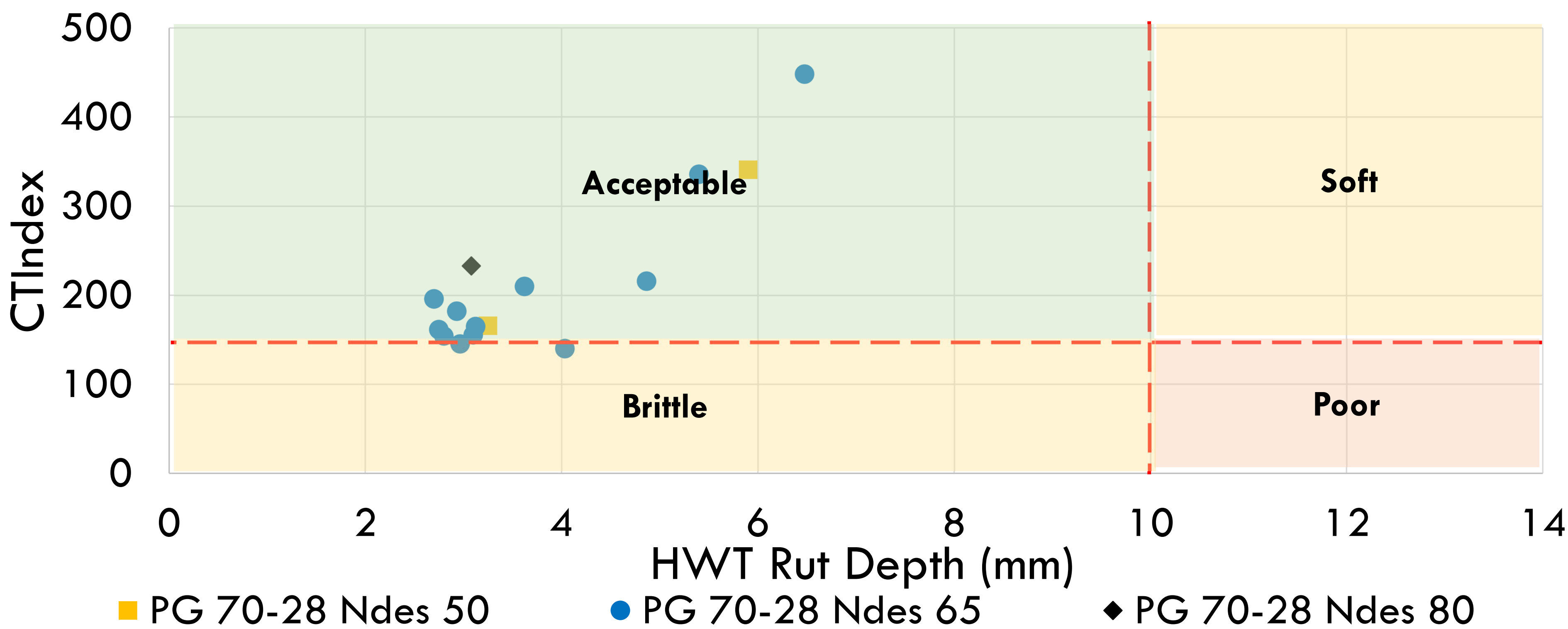
IDEAL-CT (25°C) versus HWT (45°C)



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Findings and Future Work

Findings

- Effect of mix type on rutting and cracking resistance can be confirmed using the HWTT, I-FIT and IDEAL-CT on typical Vermont mixtures.
- Effect of design gyration was found to be statistically insignificant from the HWTT results of all the mixtures tested. VTrans may further investigate to determine whether any further consolidation of gyration levels would be worthwhile ?
- Benchmarking results indicate 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.

Findings

- There is a good direct correlation ($R^2 = 0.72$, $n = 46$) between FI and CT_{index}.
- Based on this correlation, a preliminary minimum CT_{index} threshold of 150 is comparable to the minimum FI threshold of 10.0 proposed in the VTrans draft performance-engineered method for mix design and acceptance.
- Results support future specification changes reflect both rutting and cracking resistance, which may require minor adjustments to improve the cracking resistance of a few mix designs.

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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.
- 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

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Thank you!
Questions?