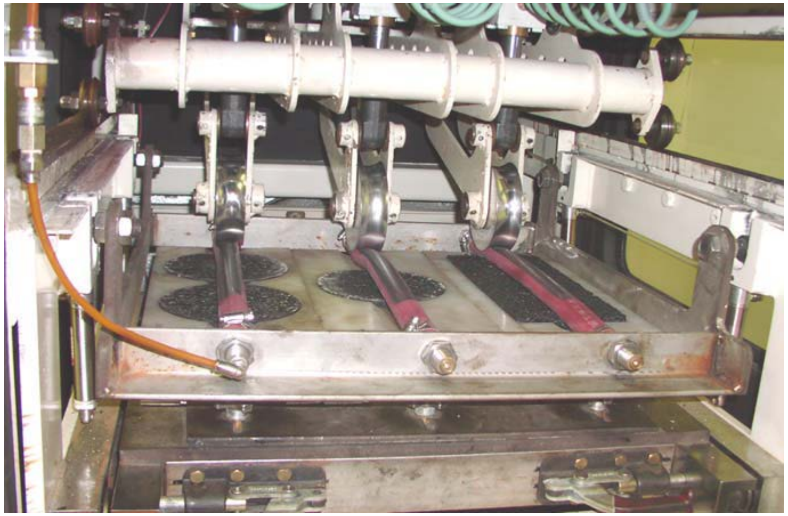
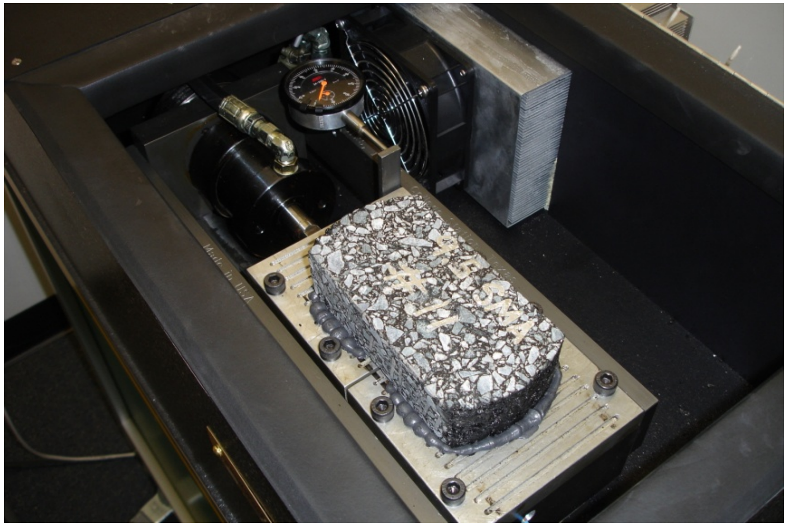
Use of IDT Testing for Asphalt Mixture Performance – Design and QC/QA

Thomas Bennert, Ph.D.
Rutgers University
Center for Advanced Infrastructure and Transportation (CAIT)

NJDOT Performance Related Specifications (PRS)

- NJDOT developed PRS using the Asphalt Pavement Analyzer (AASHTO T340) and Overlay Tester (NJDOT B-10)
- Criteria established for different mixes based on research and field performance history





New Jersey's Experience

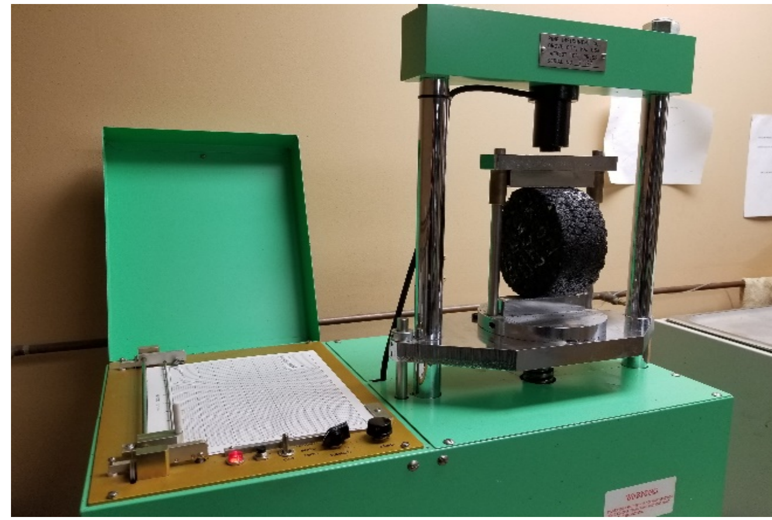
- Implementing Performance Related Specifications (PRS) and Balanced Mixture Design (BMD)
  - Mixture Design/Test Strip
    - Easy to implement – production held until completed and passed criteria
  - Production (?)
- Asphalt suppliers' comments regarding PRS testing;
  - "Too expensive to purchase equipment"
  - "Takes too long to get back test results"
  - "Test methods not suited for Quality Control work"

Performance Test Method Requirements for QC

- Simplicity: no instrumentation, cutting, gluing, drilling and/or notching
- Equipment Cost: as inexpensive as possible
- Practicality: minimum training necessary
- Efficiency: test completed within 1 minute
- Repeatability: Coefficient of Variation (COV) less than 25%
- Sensitivity: sensitive to asphalt content, volumetrics, binder type, aging
- Correlation to Field: a must!

Who Remembers This?

- Most plants still have Marshall equipment
  - TSR's
  - FAA work
- Proposing the use of Marshall equipment as the loading frame for "new" tests in NJ during production
- Rutting and cracking performance can be assessed with minor investments using IDT set-up



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Indirect Tensile Test (IDT) to Determine Asphalt Mixture Performance Indicators during Quality Control Testing in New Jersey

Thomas Bennert[1], Edwin Haas[1], and Edward Wass[1]

Abstract

In recent years, there has been a growing interest in incorporating performance testing during the mixture design and quality control testing of asphalt mixtures. The move toward utilizing performance related specifications (PRS) and balanced mixture design concepts have pushed the need for asphalt mixture performance testing to the forefront. Numerous researchers have proposed a variety of laboratory tests that have showed promise at predicting asphalt mixture performance, yet most of these test methods are never adopted due to a number of issues often cited by the asphalt industry: (1) equipment cost; (2) equipment/test method complexity; and (3) time/labor effort required. The research presented here summarizes the effort to evaluate the indirect tensile test (IDT) as a potential performance indicator for hot-mix asphalt that can be easily utilized during quality control testing at an asphalt plant. Utilizing the same test equipment and basic procedure, both high-temperature rutting and intermediate-temperature fatigue cracking can be evaluated in a timely manner. Comparison testing to more standardized and accepted rutting and fatigue cracking test methods have shown excellent agreement, indicating that the suite of IDT tests have potential for adoption within a quality control testing program. Examples of criteria are given utilizing the New Jersey Department of Transportation's (NJDOT) PRS.

Quick History of IDT

- Developed in Brazil (Carneiro, 1943) and Japan (Akazawa, 1943) at same time to determine tensile strength of concrete
- Livneh and Shklarsky (1962) first to use it for HMA (cohesive properties)
- Kennedy and associates at U. of Texas looked at both static and dynamic properties in IDT in 70's & 80's (resilient modulus)
- SHRP program (80's and 90's) – eventually recommended for low temperature cracking
- Penn State (2001, 2004) and AAT (2004, 2007) recommended for rutting properties (NCHRP 9-33)
- TTI (2016) and NCAT (2017) developed similar procedures for fatigue cracking

Surrogate Testing

- For NJ's condition, performance testing in place for mix design – lack of speed for QC plant work
  - Surrogate testing needed for QC
- To implement Surrogate Testing in NJ, need to develop relationship between existing test methods and IDT
  - For state agencies without testing, IDT methods could be implemented directly
- Rutting
  - IDT compared to Asphalt Pavement Analyzer
- Fatigue Cracking
  - IDT compared to the Overlay Tester (additional comparison to SCB Flexibility Index)

NJDOT Performance Criteria

Mixture Type			Minimum OT Cycles to Failure	Maximum APA Rutting (mm)
HRAP	Surface	76-22	275	4.0
		64-22	200	7.0
	Intermediate/ Base	76-22	150	4.0
		64-22	100	7.0
BRIC	Mixture Design		700	6.0
	Production		650	6.0
HPTO	Mixture Design		600	4.0
	Production			5.0

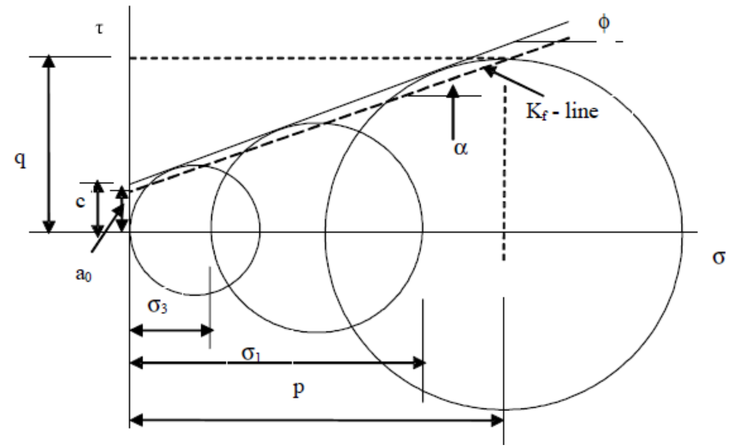
NJDOT – QC Performance

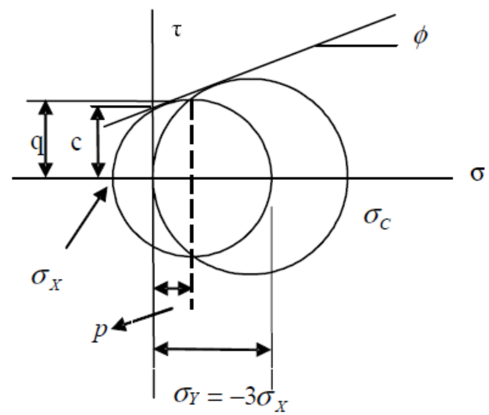
- Although APA and Overlay Tester are great tools for mix design and assurance, not suited for QC testing during plant production
  - APA
    - 4 to 6 gyratories
    - 4 to 6 hours conditioning; 2 hours testing
    - Larger sized equipment and moderately expensive
  - Overlay Tester
    - 5 gyratories
    - Cutting, trimming, gluing and testing > 2 days
    - Larger sized equipment and moderately expensive

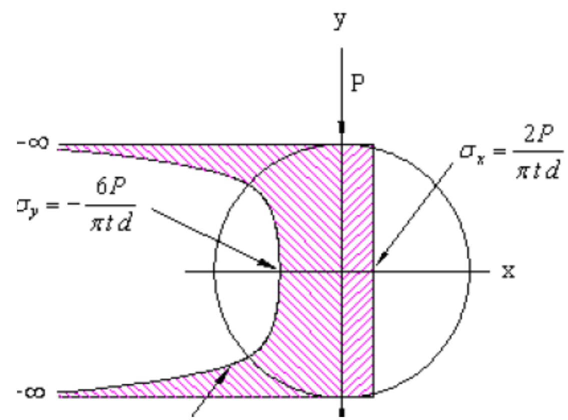
NJDOT Rutting Surrogate Testing for Performance Related Specifications

IDT Related to Permanent Deformation

- Indirect tensile strength (IDT) is related to the shear strength of materials
  - Mohr-Coulomb
- Rutting a function of the shear strength
  - Cohesion (C) ≈ binder properties
  - Friction (ϕ) ≈ aggregate properties



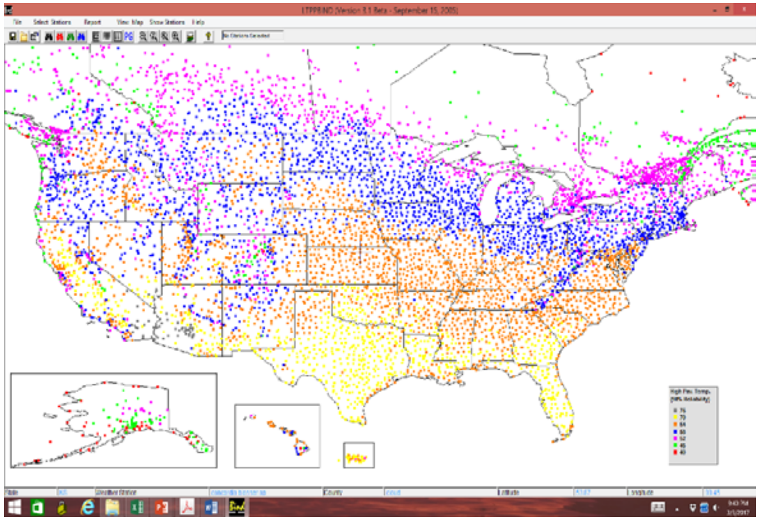


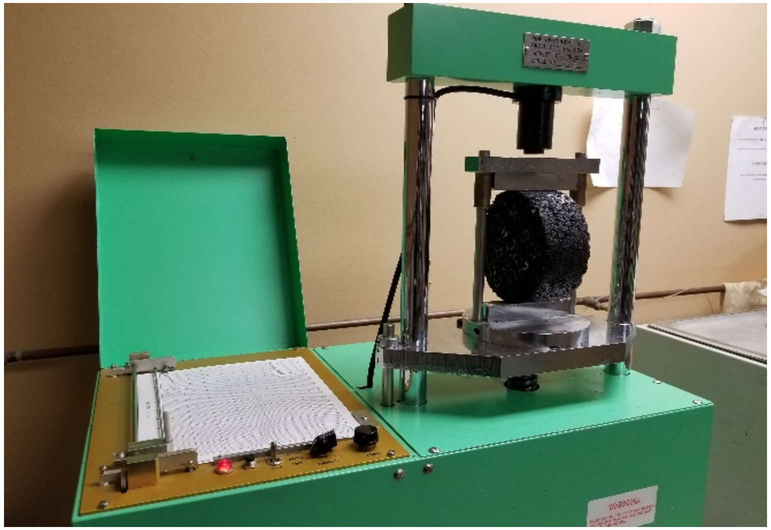


Christensen et al. (E-Circular, 2004)
Pellinen and Xiao (AAPT, 2005)

Rutting – High Temperature IDT (HT-IDT)

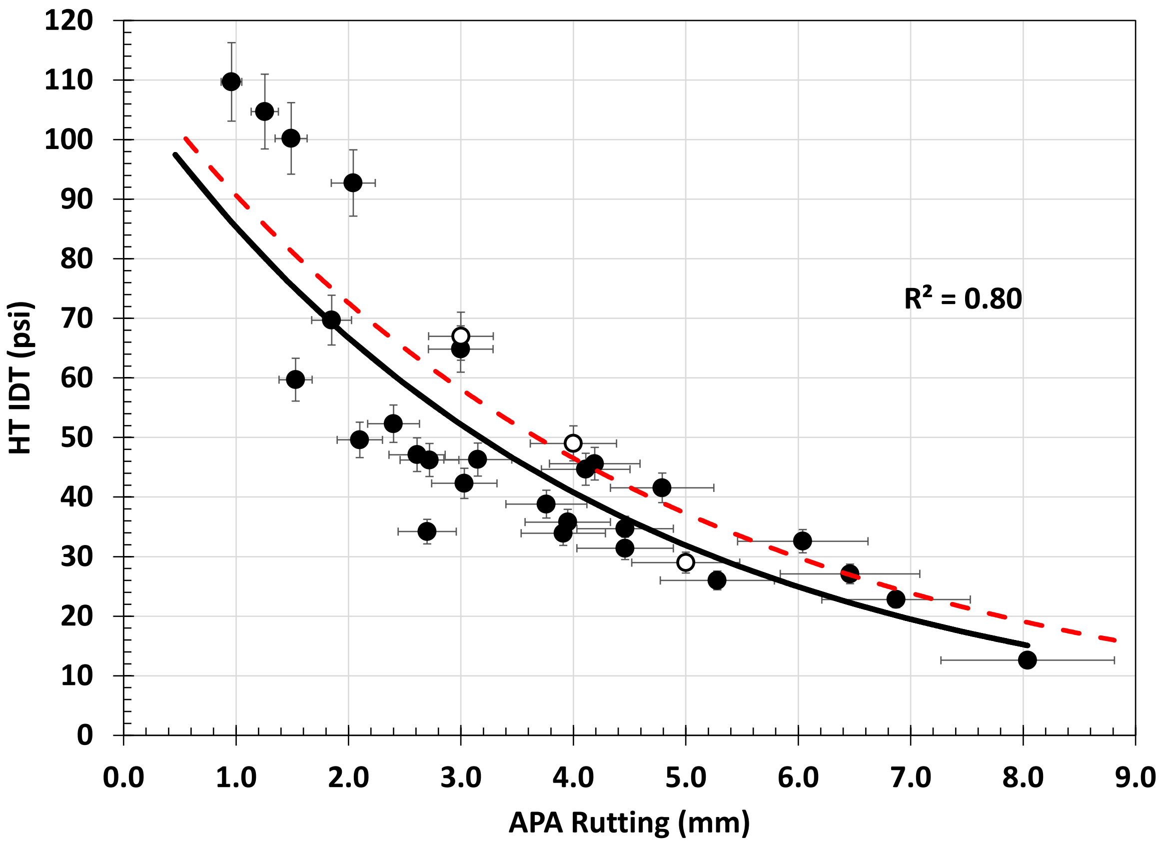
- High temperature IDT (NCHRP 9-33 Recommendations)
  - Uses TSR IDT frame with Lottman head (used for TSR; AASHTO T283)
  - Gyratory compacted samples (set air void level to specified)
  - 50 mm/min (2 inch/min) deformation rate
  - Test temperature is 10°C lower than local climate (LTPPBind 3.1, 98% Reliability, 20 mm below surface, not corrected for traffic or vehicle speed)
    - For NJ = 44°C





HT-IDT vs APA Rutting – Preliminary Guidance Values

- Error bars represents average COV
  - APA = 9.6%; HT-IDT = 6.0%



- Open Symbols from NCHRP 9-33
- Filled Symbols Rutgers data
- Black line correlation
- Red dotted line is proposed Pass/Fail criteria that includes HT-IDT COV%

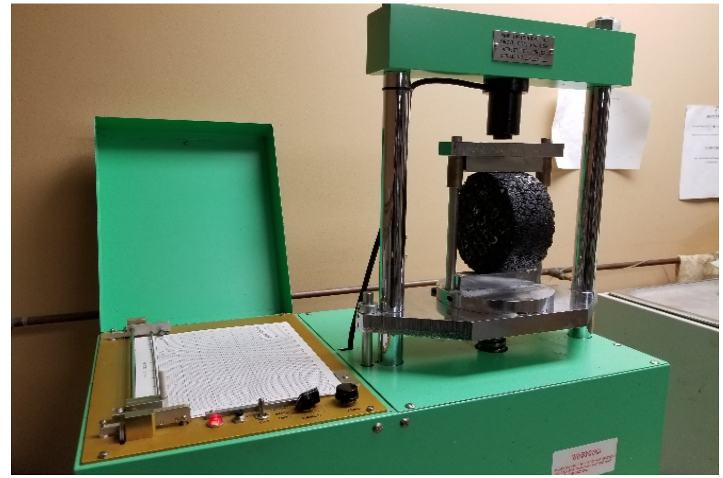
HT-IDT vs APA Rutting – Preliminary Guidance Values

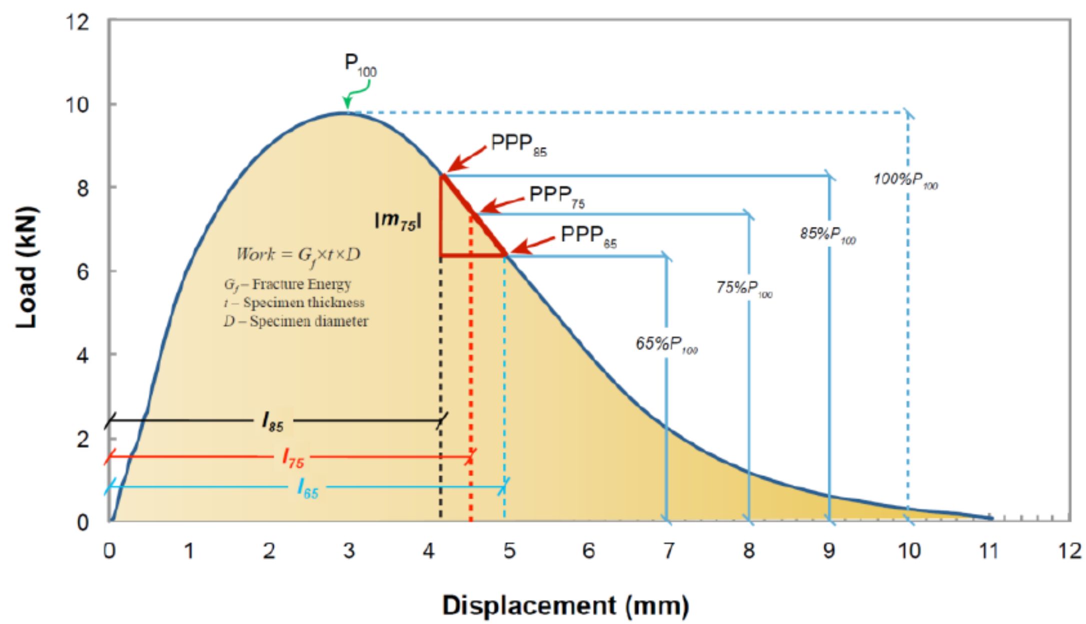
NJDOT PRS Asphalt Mixture	Asphalt Pavement Analyzer Rutting Requirement	HT-IDT Strength Requirement
High Performance Thin Overlay (HPTO)	< 4 mm	> 47 psi
Bituminous Rich Intermediate Course (BRIC)	< 6 mm	> 30 psi
High RAP - Surface Course	< 4 mm	> 47 psi
High RAP - Inter/Base Course	< 7 mm	> 25 psi

NJDOT Fatigue Cracking Surrogate Testing for Performance Related Specifications

Fatigue Cracking – IDEAL-CT (Zhou et al., AAPT 2017)

- Fatigue Cracking (IDEAL-CT Recommendations)
  - Uses TSR IDT frame with Lottman head (used for TSR; AASHTO T283)
  - Gyratory compacted samples (set air void level to specified)
  - 50 mm/min (2 inch/min) deformation rate
  - Test temperature is 25°C





IDEAL-CT

- Advantages of IDEAL-CT over Overlay Tester for Quality Control testing
  - Quicker testing time
  - Inexpensive equipment
  - Quicker specimen prep time (no gluing)
  - Less specimens (OT needs 5 gyratories; IDEAL-CT needs 3 gyratories)
- Advantages of IDEAL-CT over SCB-FI for Quality Control testing
  - No sawing or notching required

Resultant Fatigue Cracking Criteria

Mixture Type			Min. Cycles in Overlay Tester	Min. SCB Flexibility Index	Min. IDEAL-CT (Rounded)
HRAP	Surface	76-22	275	9.0	125
		64-22	200	8.0	110
	Intermediate/ Base	76-22	150	7.0	100
		64-22	100	6.0	80
BRIC	Mixture Design		700	14.0	200
	Production		650	14.0	200
HPTO	Mixture Design		600	13.0	175
	Production				

IDEAL-CT Criteria for Other States

- TxDOT
  - Crack Arresting Mix (CAM) > 320
  - Thin Overlay Mix (TOM) > 185
  - SMA > 145
  - Surface Course > 105
  - Minimum Accepted > 65
- VDOT
  - Minimum Accepted > 70

Mixture Type			Min. IDEAL-CT
HRAP	Surface	76-22	125
		64-22	110
	Intermediate/Base	76-22	100
		64-22	80
BRIC	Mixture Design		200
	Production		200
HPTO	Mixture Design		180
	Production		

Proposed "Balanced" IDT Performance

Mixture Type			Min. HT-IDT Strength	Min. IDEAL-CT
HRAP	Surface	76-22	47	125
		64-22	25	110
	Intermediate/Base	76-22	47	100
		64-22	25	80
BRIC	Mixture Design		30	200
	Production			200
HPTO	Mixture Design		47	180
	Production			

Proposed Testing Methodology

General Test Procedures

HIGH TEMPERATURE IDT (RUTTING)

- Compact specimens to 95mm tall and to appropriate air voids
- Place specimen in plastic bag and submerge in water bath at 44C for >2 hours
- Place conditioned specimen in IDT fixture and load at 2 inches/min
- Record peak load and determine indirect tensile strength

IDEAL-CT (FATIGUE CRACKING)

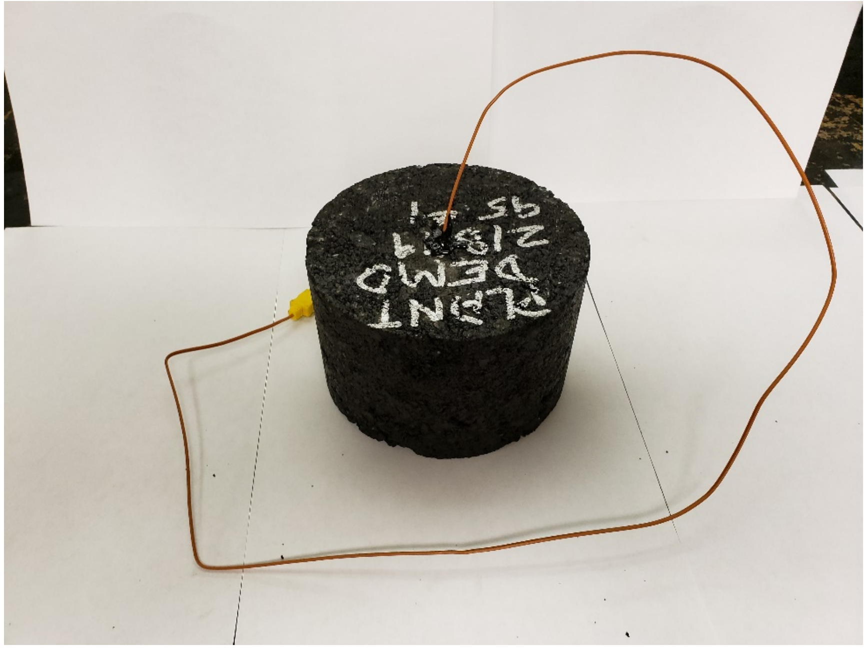
- Compact specimens to 62mm tall and to appropriate air voids
- Place specimen in plastic bag and submerge in water bath at 25C for > hours
- Place conditioned specimen in IDT fixture and load at 2 inches/min
- Determine area under curve and post-peak slope of curve
- Calculate "Cracking Index"

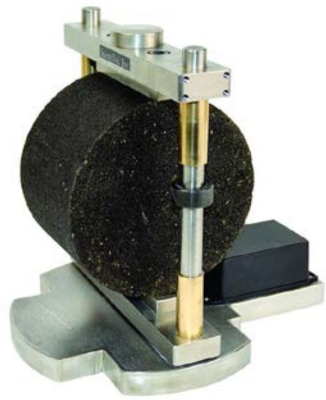
Required IDT Test Procedure Equipment

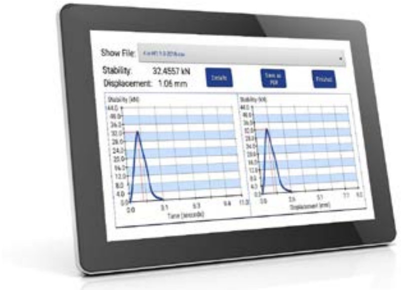
- 2 Water baths (or environmental or combination of both)
- Loading frame with capacity of 10,000 lbs and loading rate of 2 inches/min

Recommended IDT Test Procedure Equipment

- Dummy sample with embedded thermistor
- IDT Smart Jig – can be easily run without it – just makes things much simpler



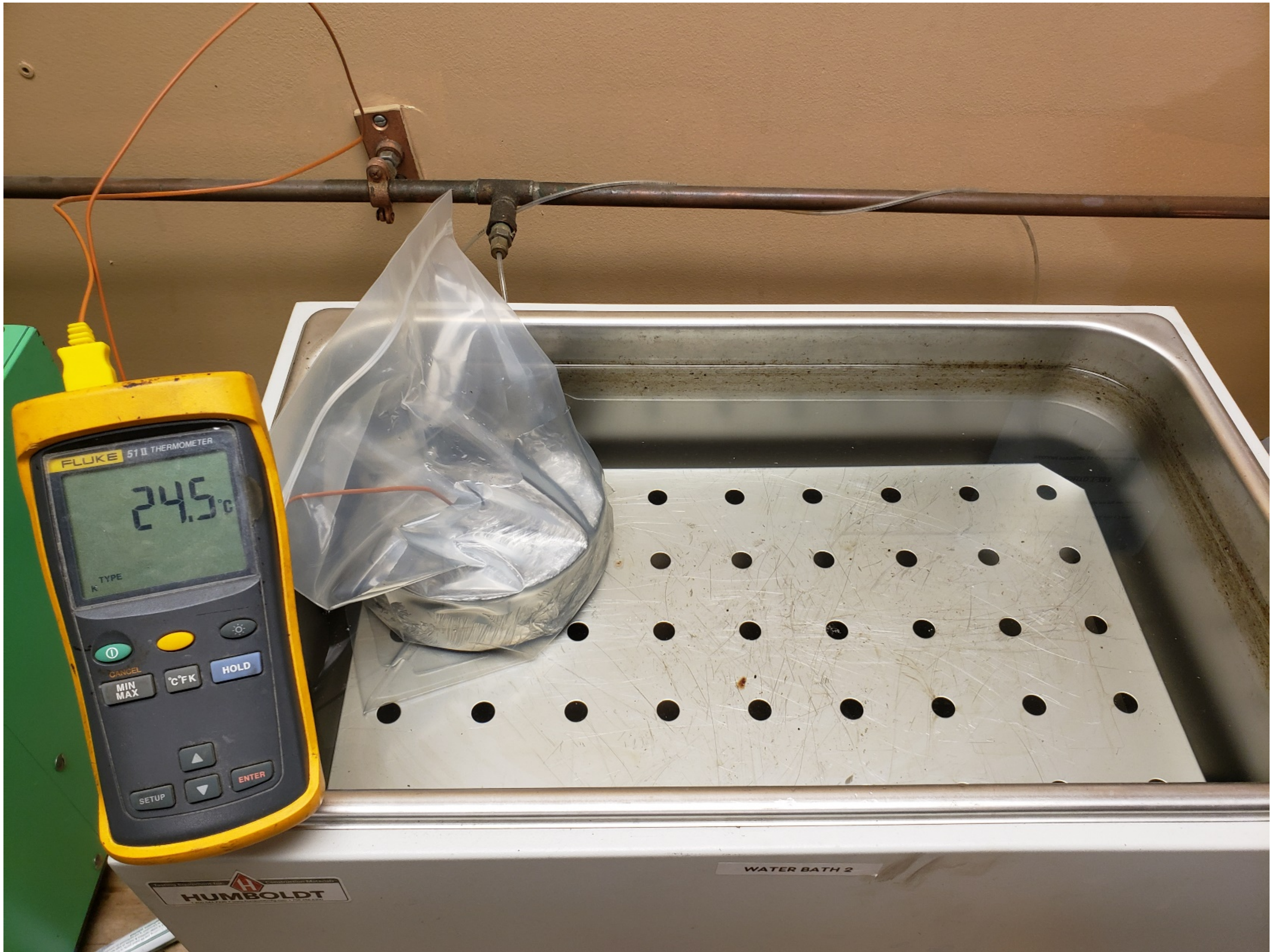




Conditioning Specimens

- Water is a better medium to condition than air
  - Minimum 2 hours conditioning in water
  - Minimum 4 hours conditioning in air
- Include means of verifying temperature
- If using water, samples should be wrapped to remain dry during conditioning and testing

"Dummy" Sample

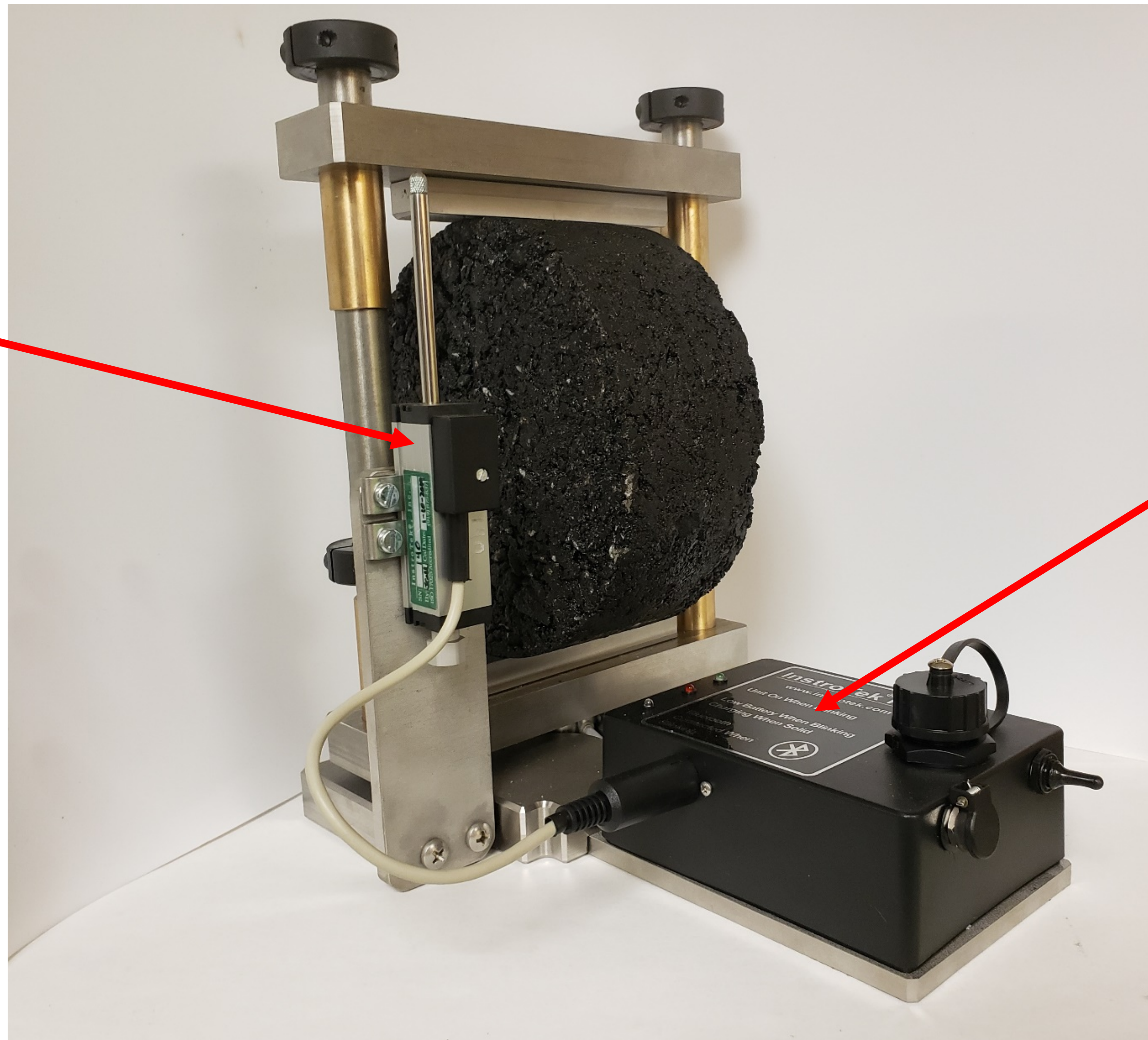


Conducting Tests

- After conditioned, mount specimen in IDT fixture
- Ensure proper seating on loading strips
  - Clean off strips before each test
- Ensure guide rods are “frictionless”

InstroTek's SMART IDT Jig

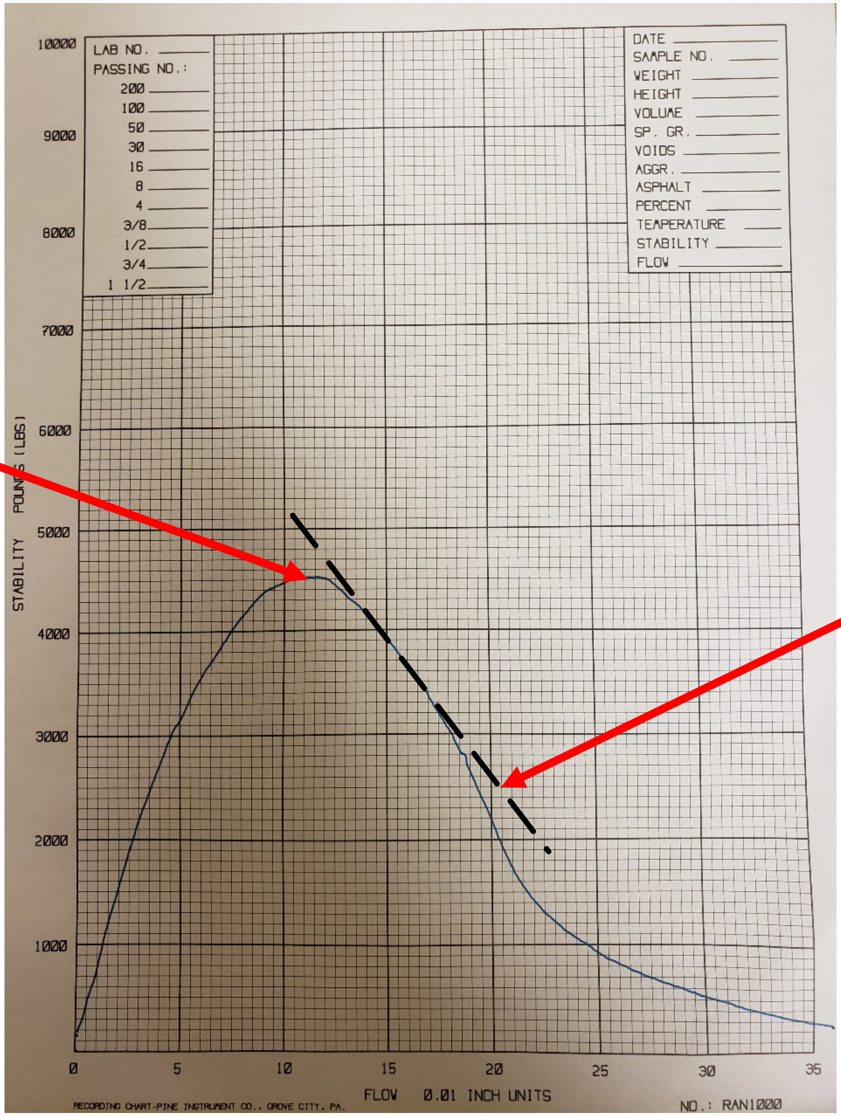
Spring loaded LVDT



Load Cell

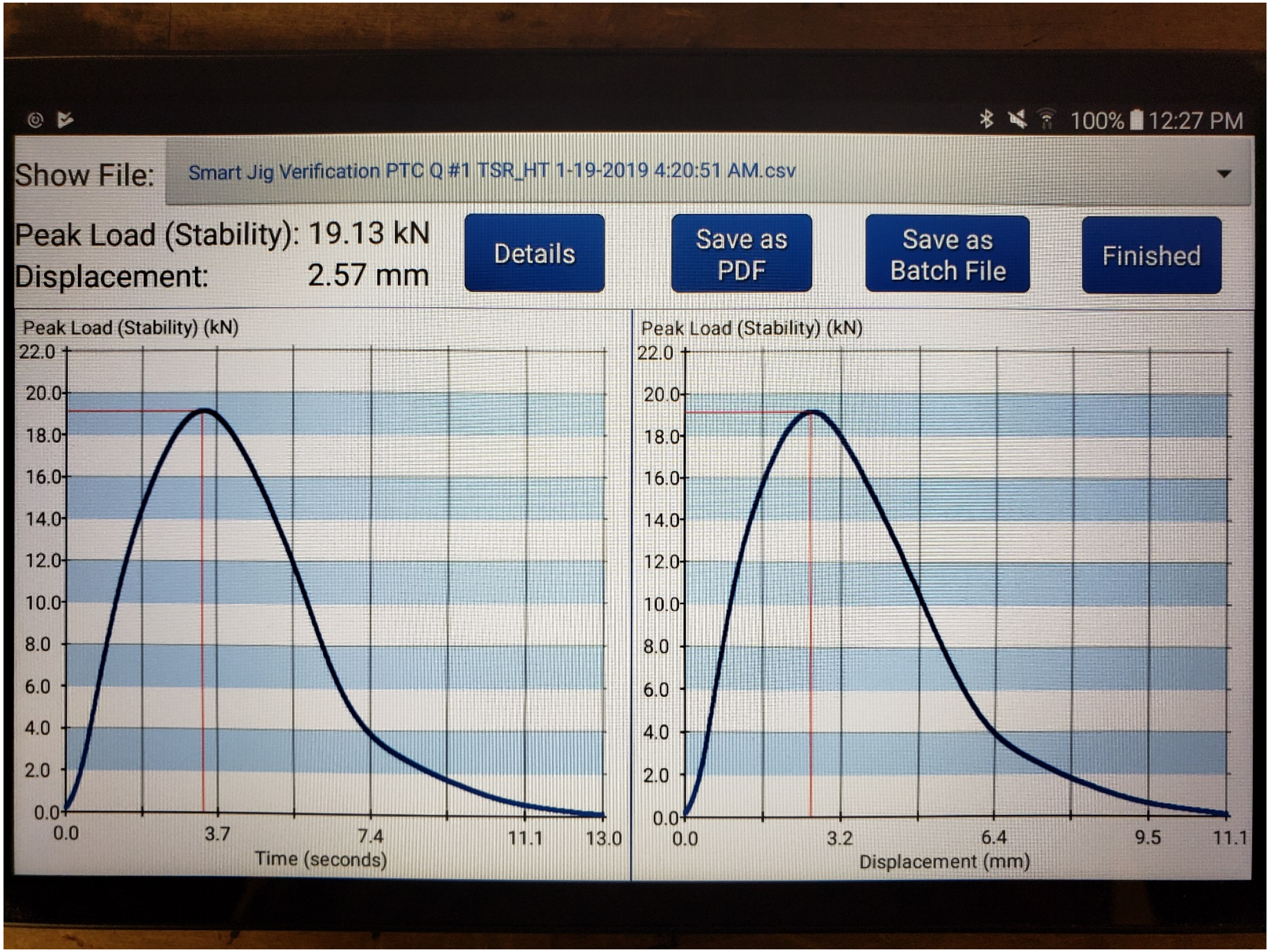
Test Data Output – Pen & Paper

Peak Load

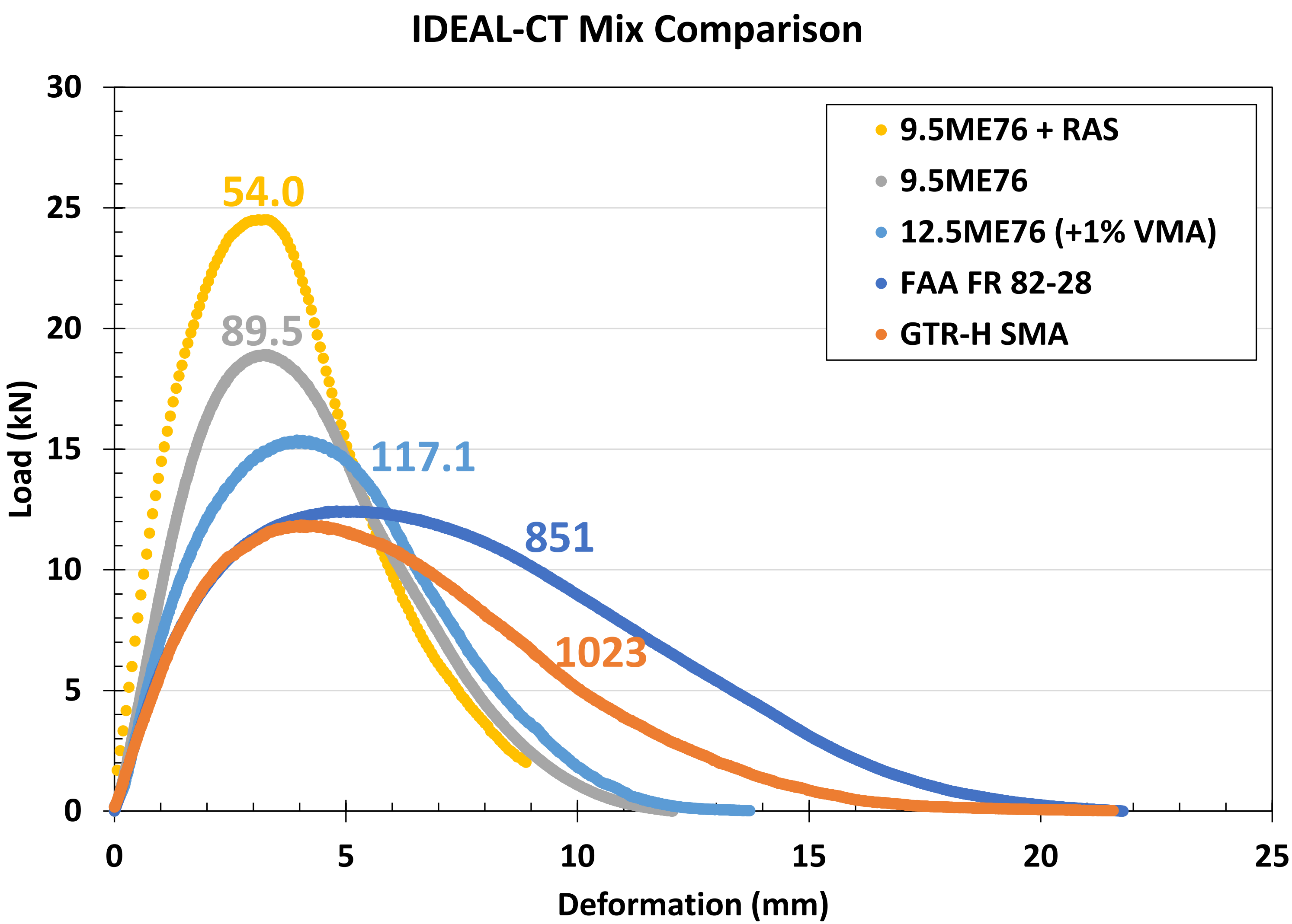


Post Peak Slope

Test Data Output – SMART Jig



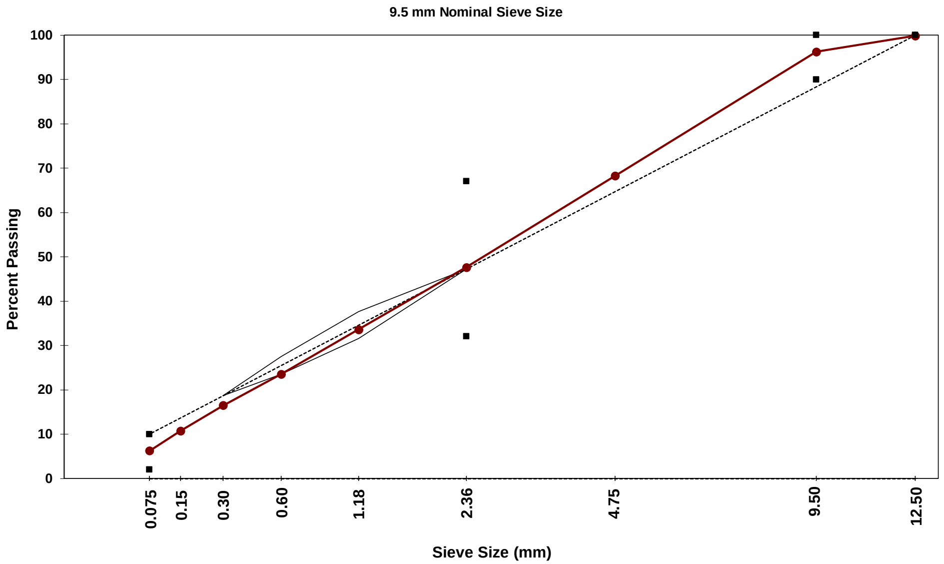
Test Data Output – Different Curves



Designing for Performance with IDT Tests – Balanced Mixture Design

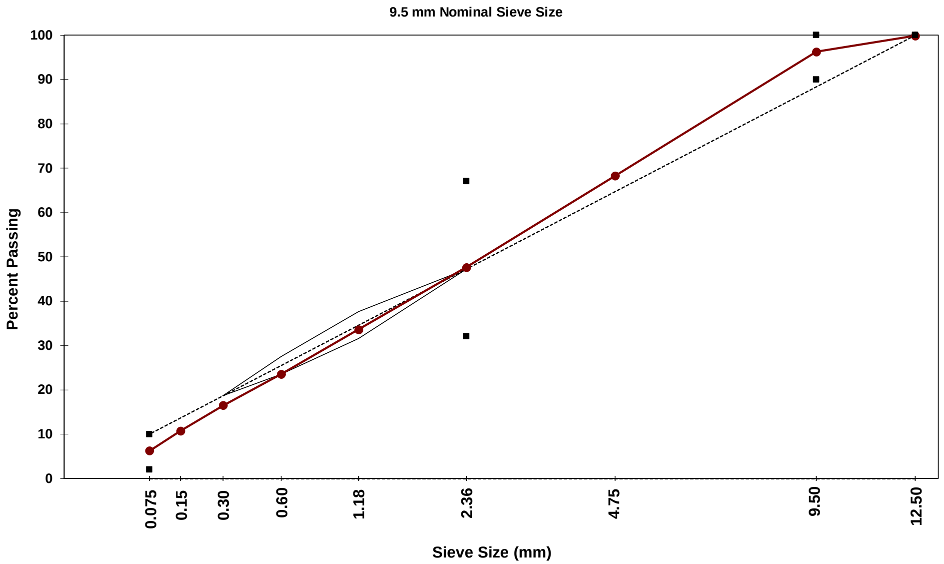
Balanced Mixture Design Example

- 9.5 mm NMAS Superpave mix
  - Ndesign = 75 gyrations
  - Designed for surface course
  - Optimum asphalt content = 5.4%
  - Design VMA = 15.8% (15% minimum)
- Evaluated for performance using the IDT test methods



Balanced Mixture Design Example

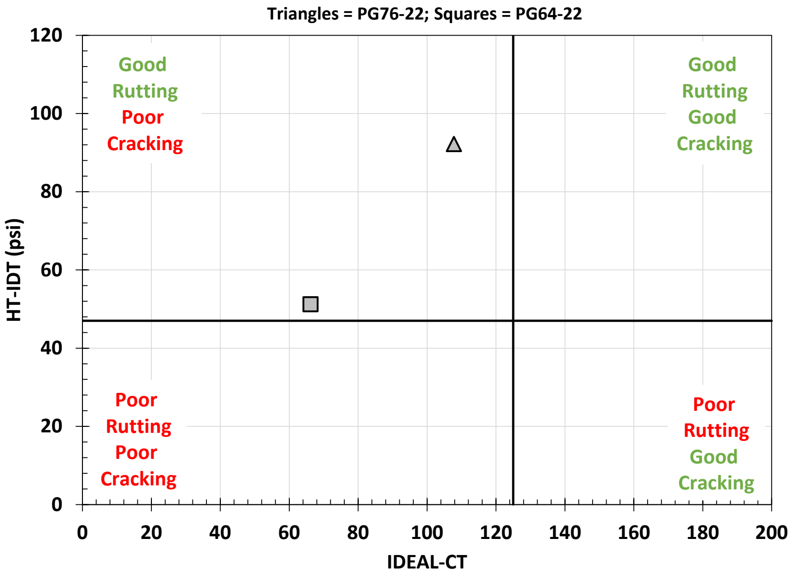
- Design for HRAP, Surface, High Traffic
- Approach 1 **(PRS)**
  - Evaluate optimum asphalt content for performance
- Approach 2 **(BMD)**
  - Evaluate at optimum and asphalt content above and below



Approach 1 – HRAP Surface

Approach 1 – HRAP Surface

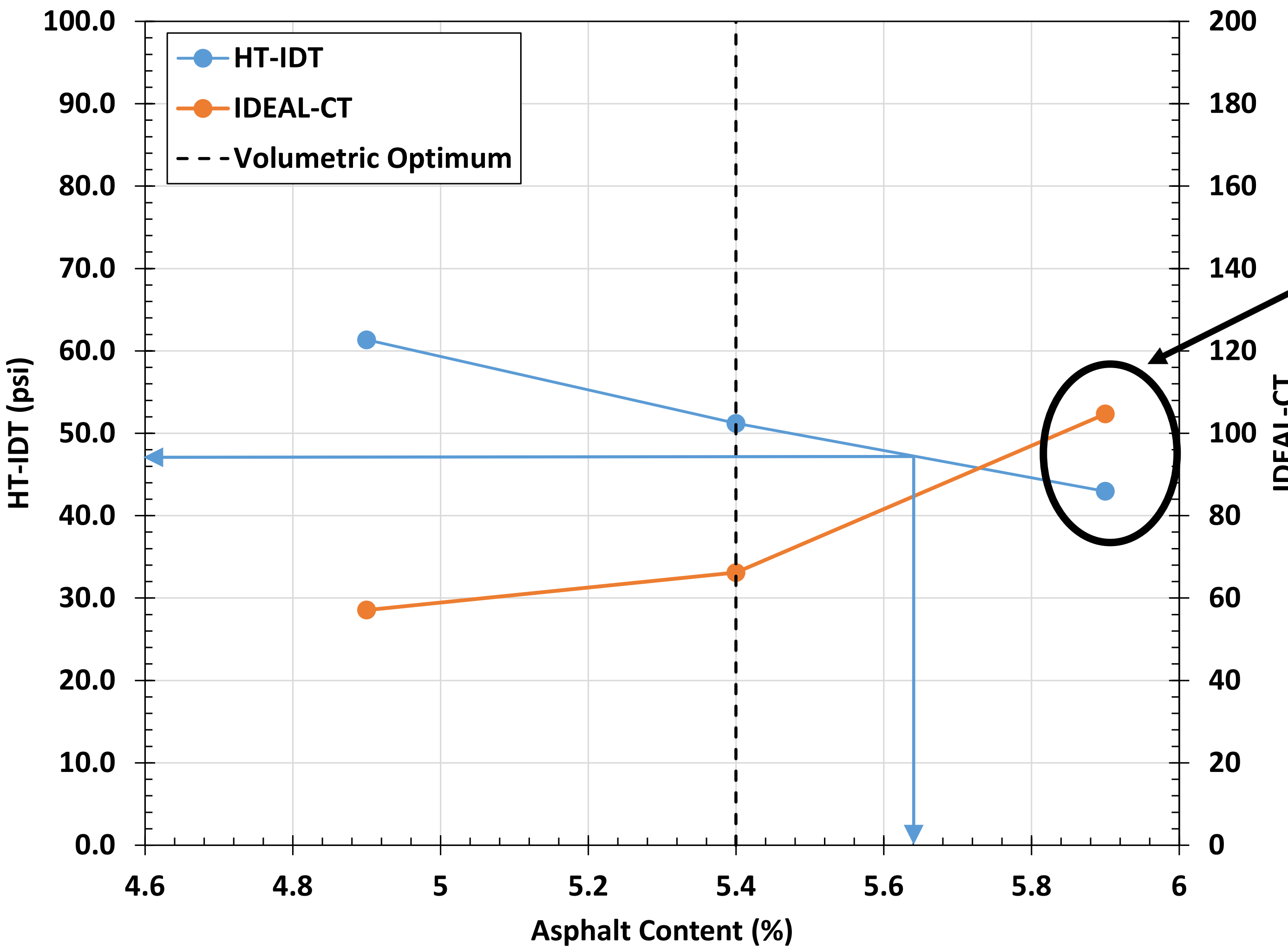
- At "volumetric optimum", Good Rutting/Poor Cracking observed
- Performance Space can help designers/plant operators make adjustments
- Factors Affecting Cracking
  - Low effective AC%, dust content, high recycled content



BMD Approach 2

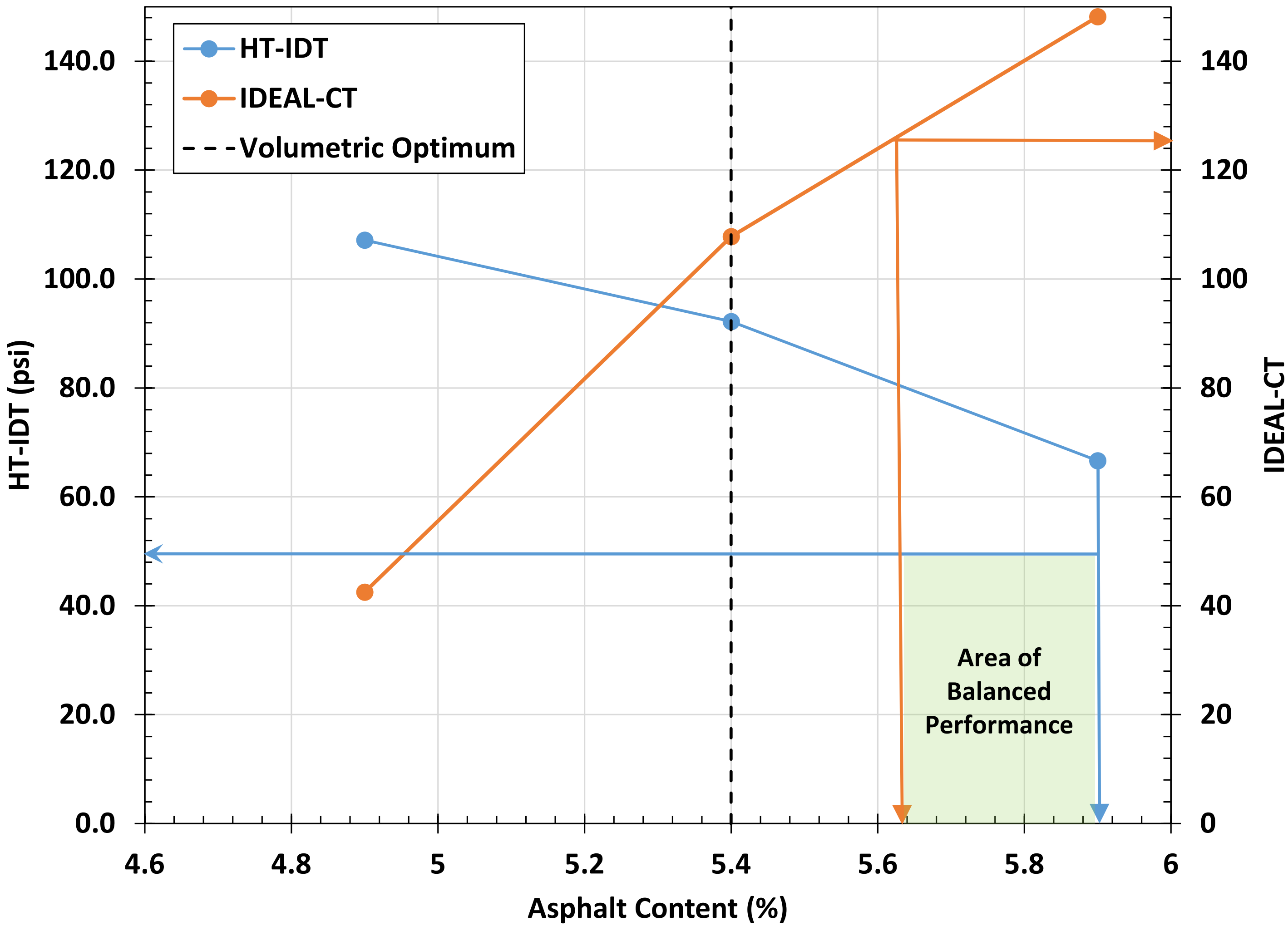
- For BMD Approach 2, used volumetric optimum asphalt content as a starting point
  - Evaluated -0.5% optimum, optimum, +0.5% optimum
  - All test specimens were compacted to 5.5 to 6.5% air voids to simulate anticipated field densities
- Conducted IDT tests to determine performance and potential “balanced” mix

Approach 2 – PG64-22 Binder

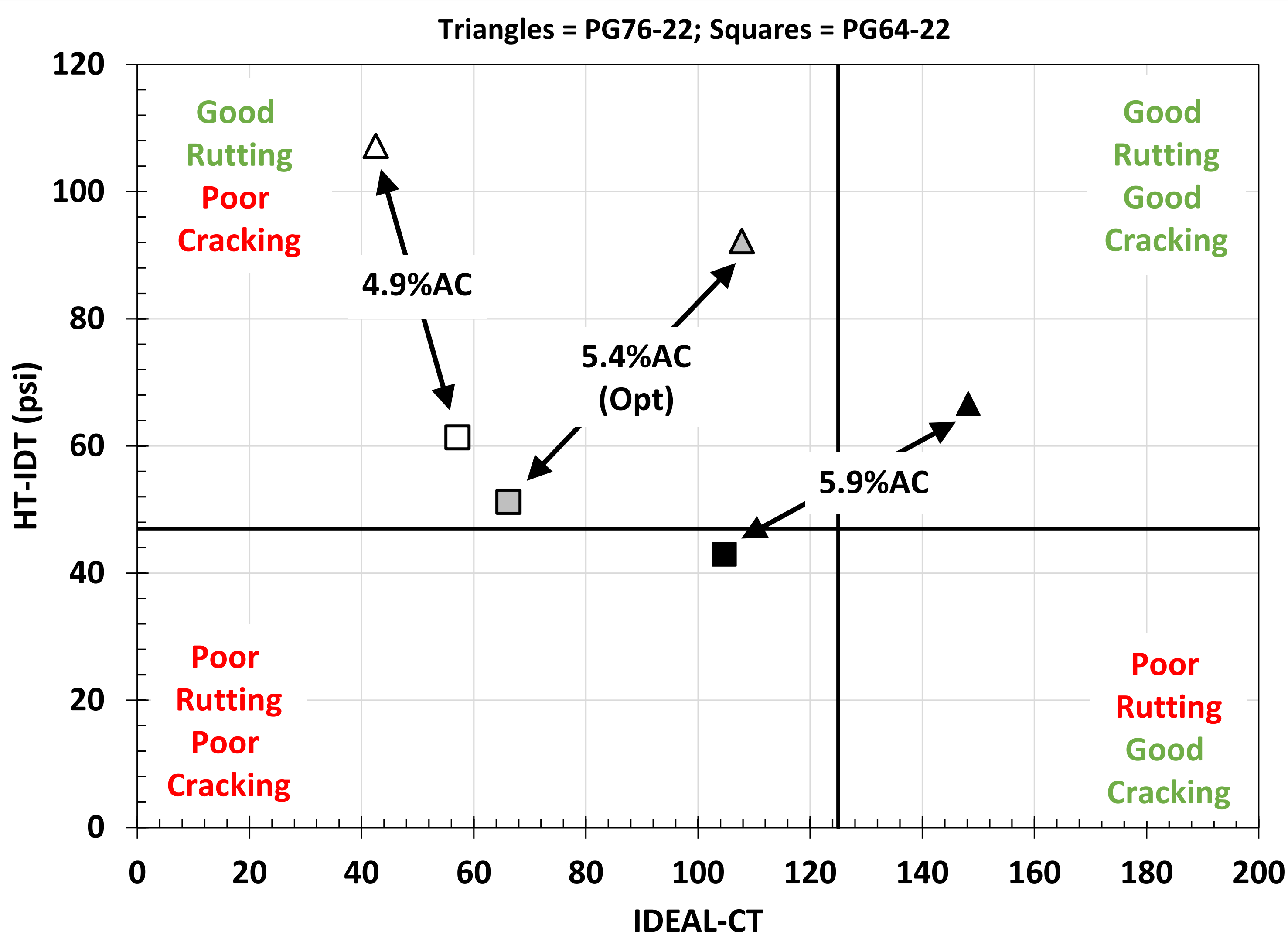


Rutting Failed Before Cracking Could Pass

Approach 2 – PG76-22 Binder



Approach 2 – High Traffic Surface



Balanced Mixture Design Example

- Using Approach 1, it was determined that the asphalt mixture evaluated at optimum asphalt content did not meet fatigue cracking
  - Dust?, Low effective AC?, Too High Recycled?
- Using Approach 2, it was determined that a PG64-22 could not achieve a "balanced" condition
- Using Approach 2, it was determined that a PG76-22 could achieve a "balanced" design when asphalt content > 5.6%
  - Volumetric optimum was 5.4%

Round Robin Study

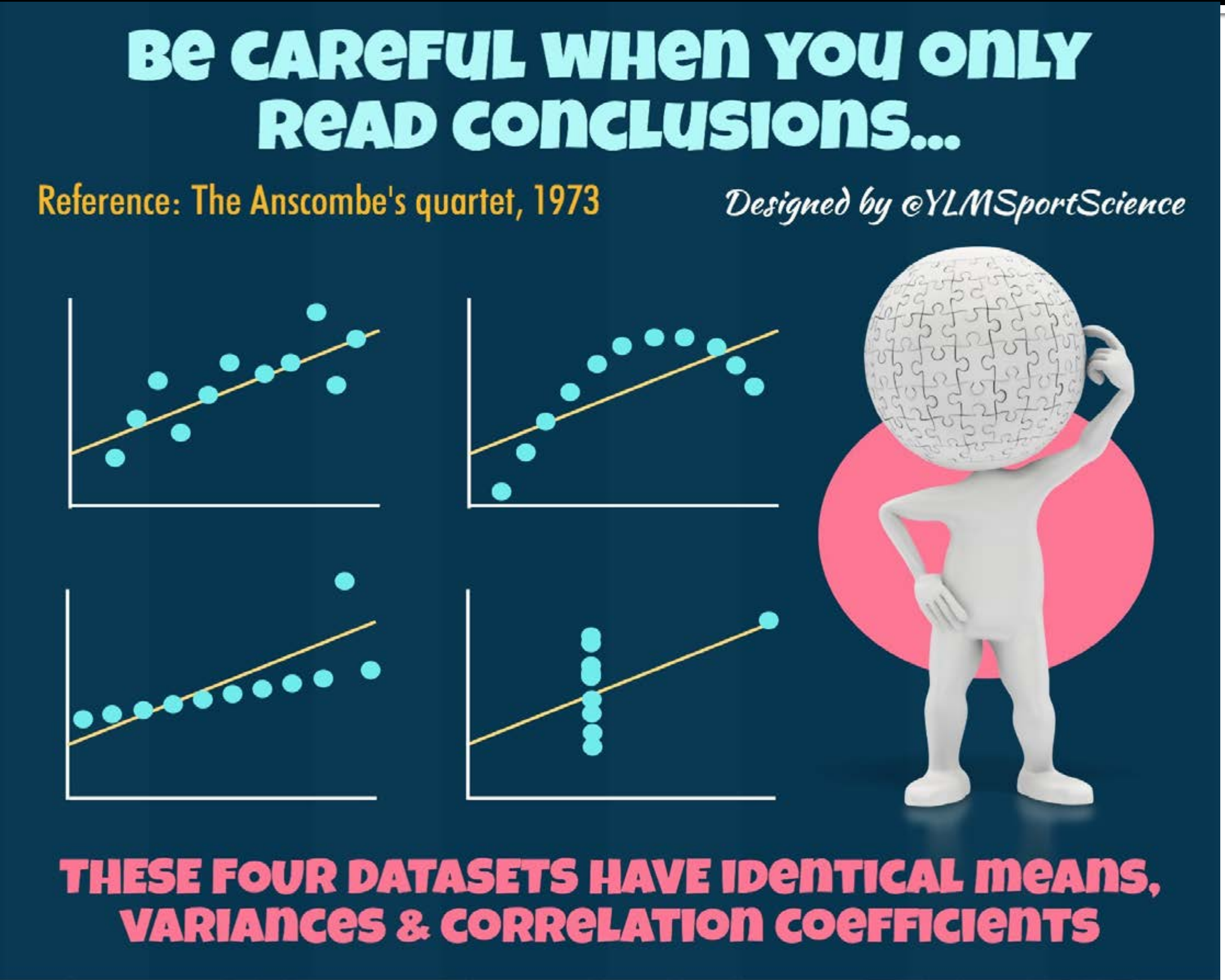
IDT Round Robin Study

- Developed Round Robin study for IDT tests
  - Determine variability of test methods
  - Provide feedback regarding procedures
- Each lab will receive 5 different asphalt mixtures
  - 3 specimens each for High Temperature IDT
  - 3 specimens each for Fatigue Cracking (IDEAL-CT)
- Test specimens according to procedures provided and determine values
  - Datasheets will be provided
  - Software can be provided if needed (RAAT)

Final Comments

- Current asphalt mixture design procedures are moving towards Performance Testing
  - A lot to choose from for design – limited for plant production QC
- IDT procedures provide a quick alternative during QC at the plant
  - Strong relationship to APA (rutting) and Overlay Tester (cracking)
- Criteria being established (initial values proposed here) – future piloting and Round Robin will help to finalize criteria

Thank you for your time! Questions?



Thomas Bennert, Ph.D.
Rutgers University
609-213-3312
bennert@soe.rutgers.edu