Indirect Tensile Testing to Determine Asphalt Mixture Performance

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Acknowledgements

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  - Staff: Edwin Haas, Edward Wass Jr., Christopher Ericson
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  - Susan Gresavage
  - Robert Blight
  - Paul Hanczaryk
  - Stevenson Gauthier

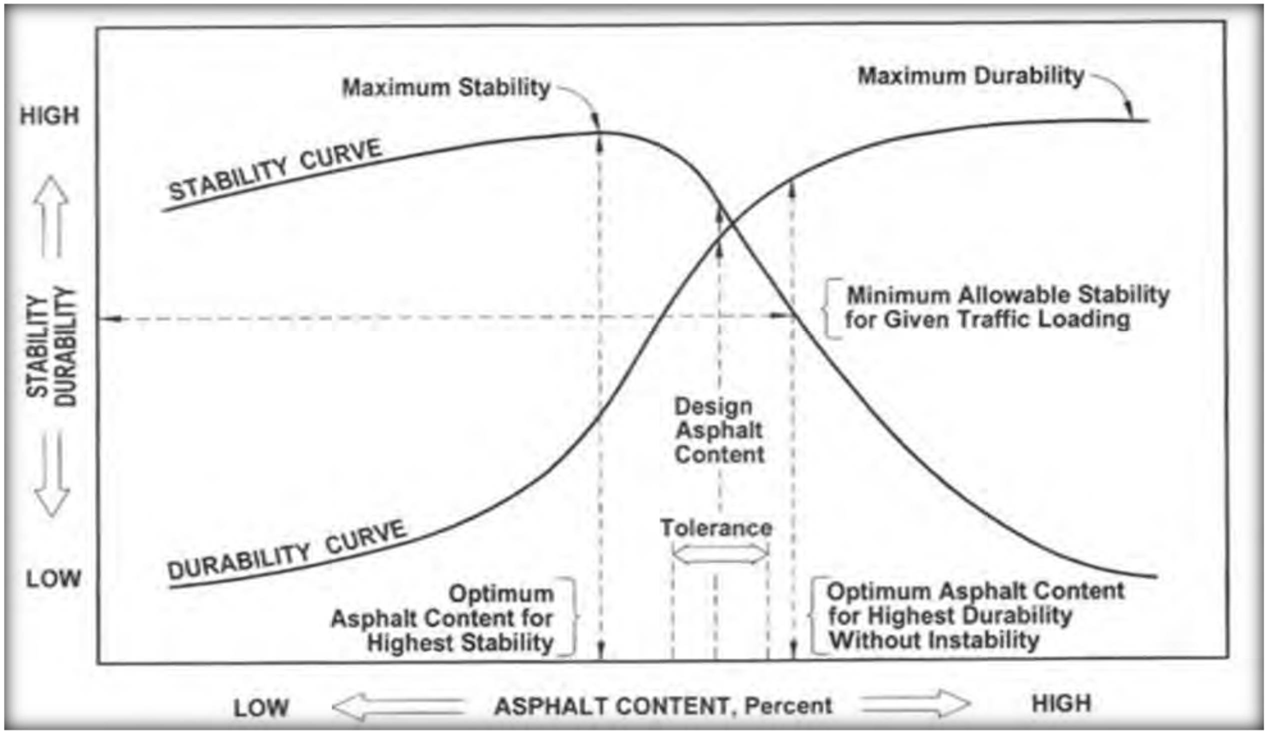
Why the Need for Performance Testing During Mixture Design and Production?

- **Problems:** .
  - Volumetrics alone **can not** adequately evaluate mix variables, such as recycle, warm-mix additives, polymers, rejuvenators, and fibers.
- **Solutions Performance Testing Allows Us to:**
  - **Recognize performance issues** related to dry mixes in some areas.
  - **Increase understanding** of the factors which drive mix performance
  - **Design for performance**
  - **Evaluate changes** in asphalt mixture performance due to production factors
  - **Innovate! Asphalt is an engineered material!**

Buchanan, 2017 (NESMEA)

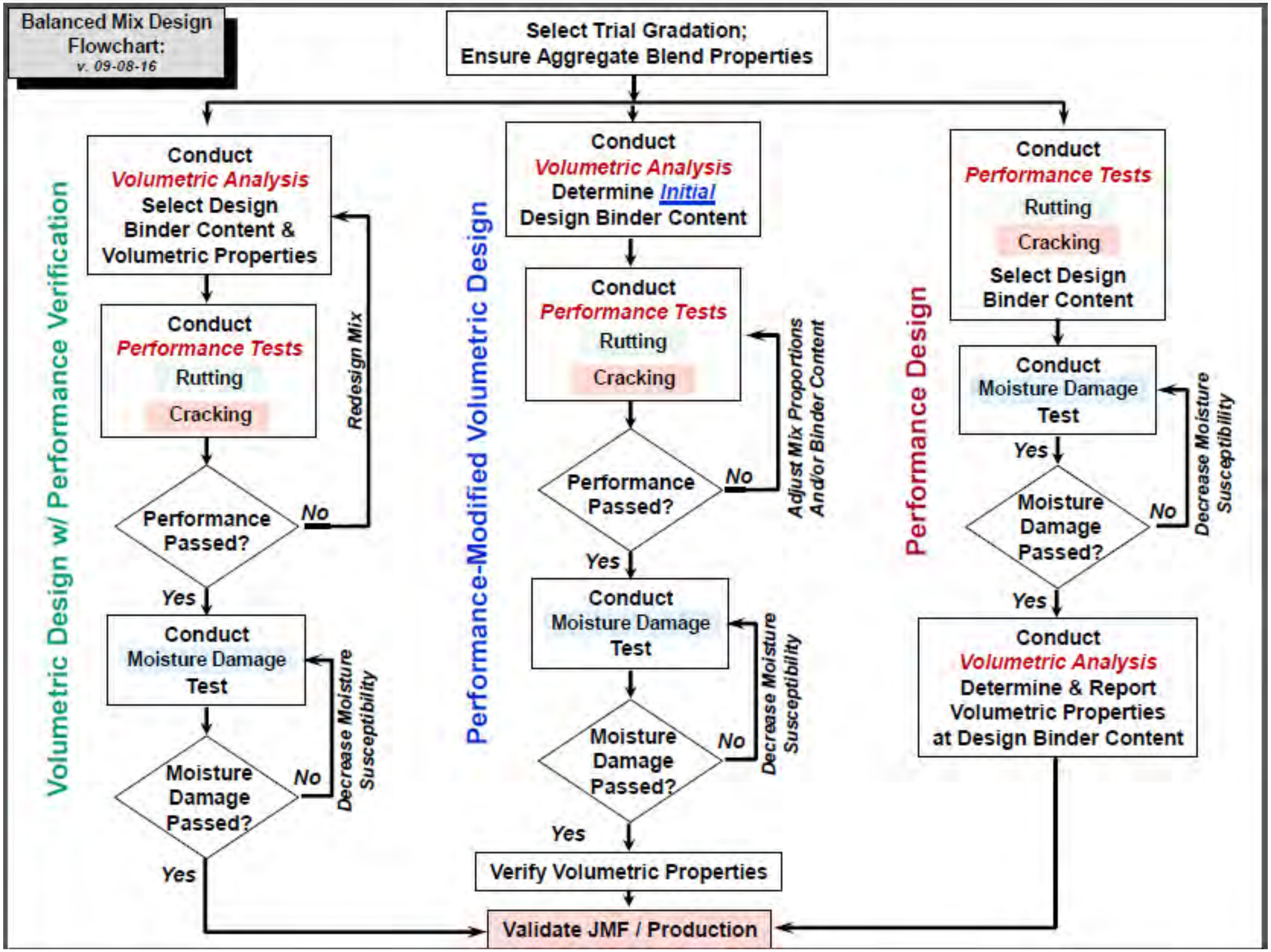
Pavement Performance Goals

- Achieving Balanced Mixture Performance is Key to a Long Lasting Pavement

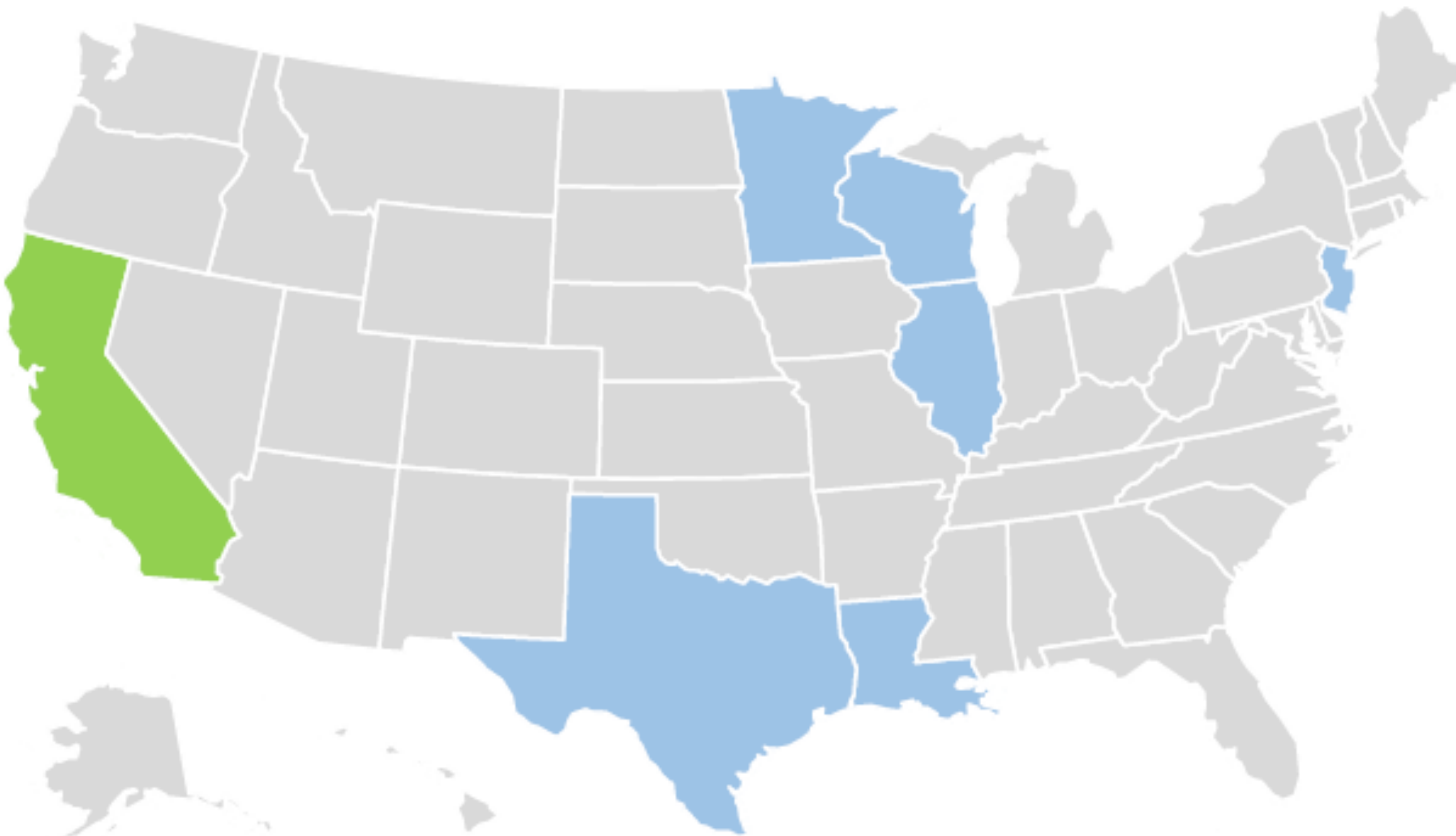


Buchanan, 2017 (NESMEA)

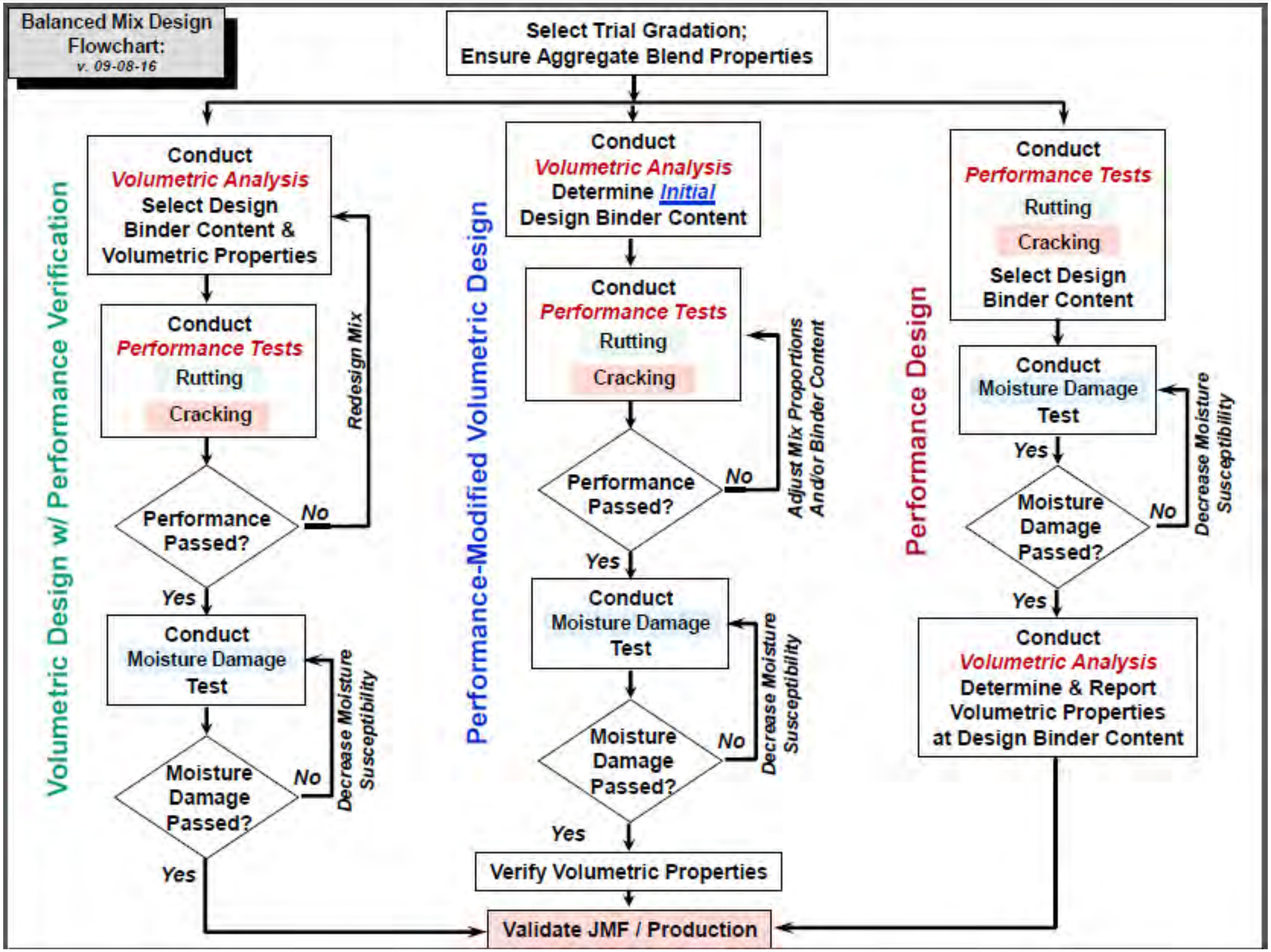
Balanced Mixture Design Approaches (FHWA Mix ETG)



Agencies Practicing a Version of Balanced Mixture Design



Balanced Mixture Design Approaches (FHWA Mix ETG)



Balanced Mixture Design Approaches (FHWA Mix ETG)

Common Performance Tests for Performance Related Specifications

Bending Beam Fatigue

Texas Overlay Test

SCB
- LTRC – Jc
- IFIT

Direct Tension Cyclic Fatigue, S-VECD

Disk Shaped Compact Tension (DCT)

Hamburg Wheel Test (HWT)

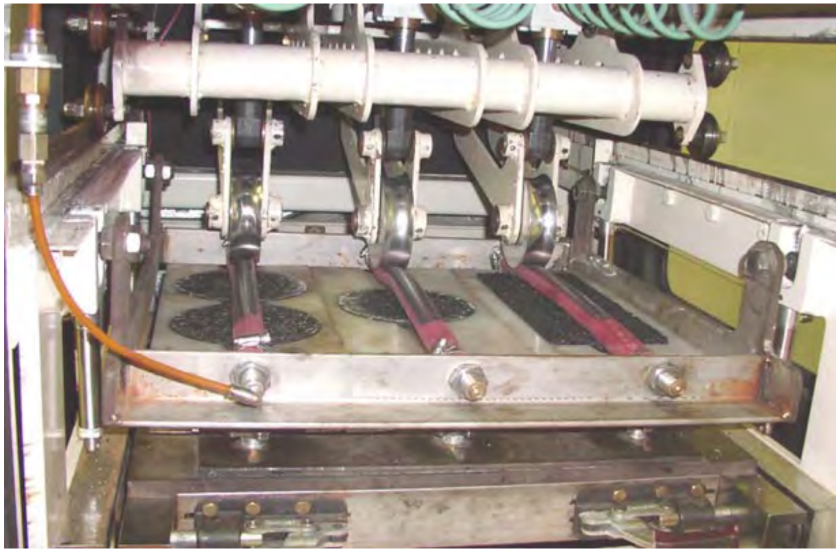
Asphalt Pavement Analyzer (APA)

AMPT Flow Number

New Jersey's Experience

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

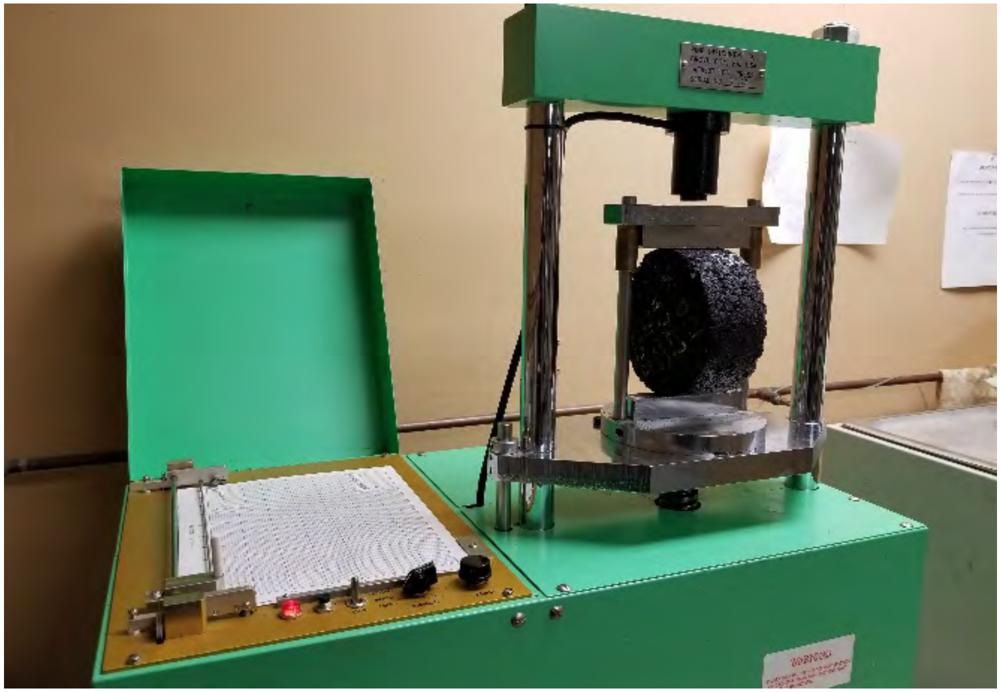
- Implementing Performance Related Specifications (PRS) and Balanced Mixture Design (BMD)
  - Mixture Design
    - Easy to implement – production held until completed; testing at NJDOT/Rutgers Laboratories
  - Production (?)
- Asphalt suppliers' comments regarding PRS testing;
  - "Too expensive to purchase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

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



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

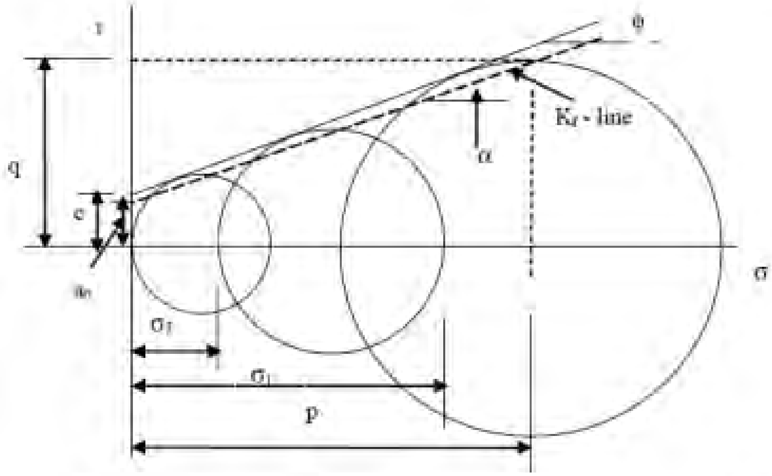
Surrogate Testing

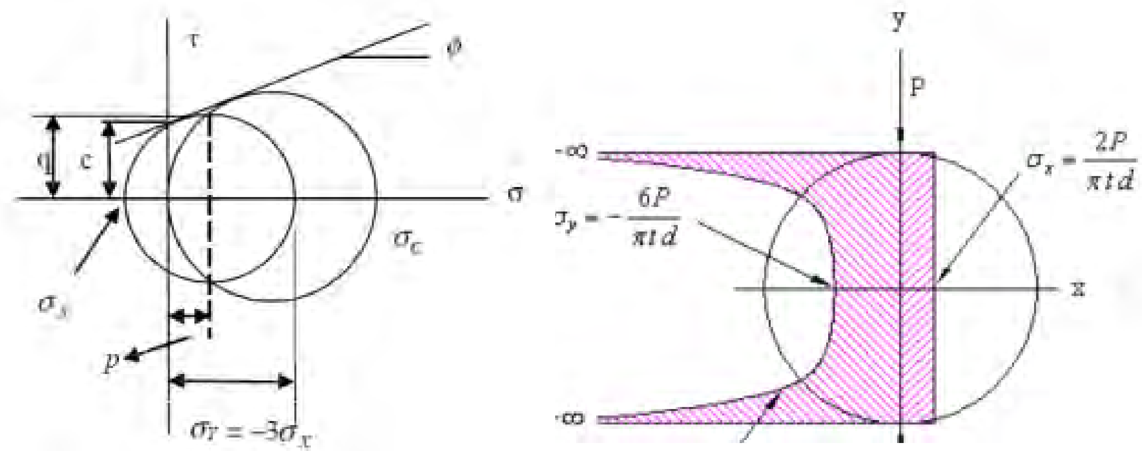
- For NJ's condition, performance testing in place for mix design – lack of speed for QC plant work
  - Surrogate testing needed for QC
- To implement Surrogate Testing in NJ, need to develop relationship between existing test methods and IDT
  - For state agencies without testing, IDT methods could 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 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

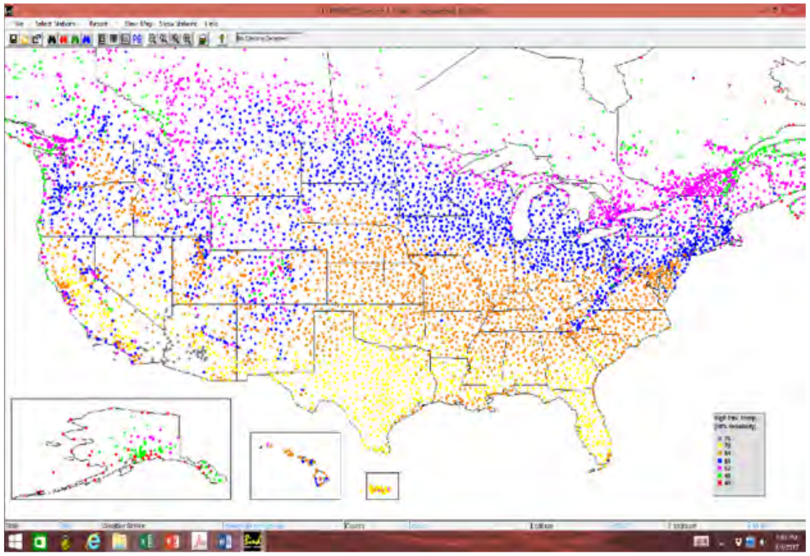


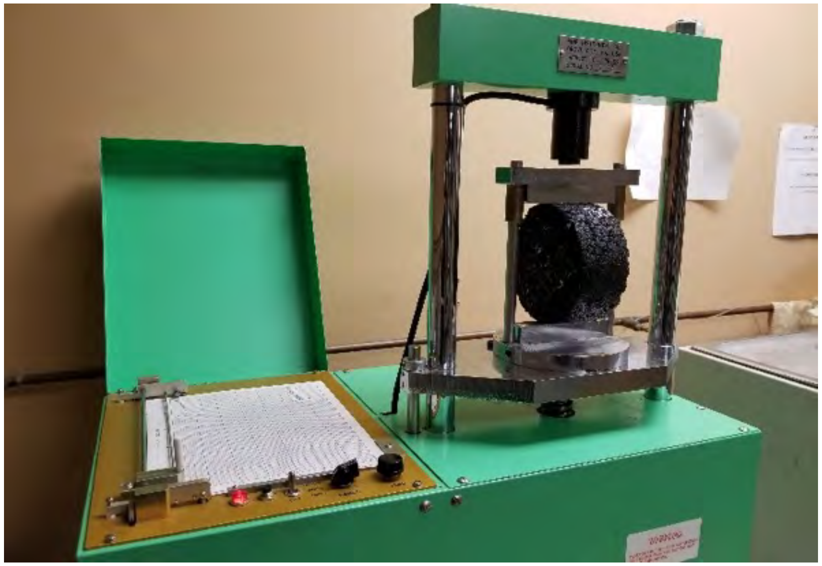


Christensen et al. (E-Circular, 2004)
Pellinen and Xiao (AAPT, 2005)

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





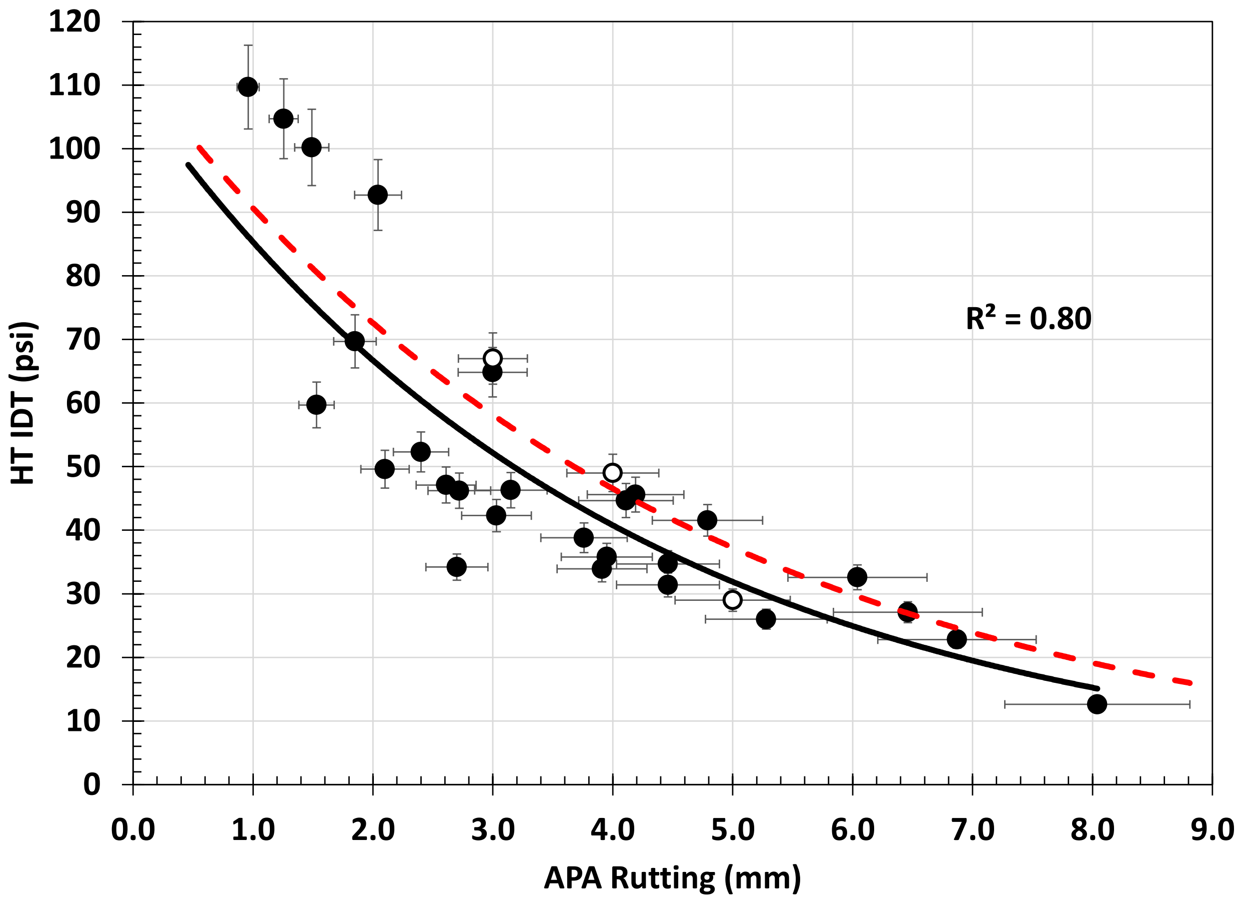
HT-IDT Laboratory Evaluation

- Compared variety of lab and plant produced HMA using APA and HT-IDT
  - RAP, WMA, NMAS, binder grades
- Used NJDOT PRS criteria for rutting (APA) for criteria development

NJDOT PRS Asphalt Mixture	Asphalt Pavement Analyzer Rutting Requirement
High Performance Thin Overlay (HPTO)	< 4 mm
Bituminous Rich Intermediate Course (BRIC)	< 6 mm
High RAP - Surface Course	< 4 mm
High RAP - Inter/Base Course	< 7 mm

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 of Asphalt Mixtures

- Rutgers has been evaluating a number of fatigue cracking test methods for use within PRS, BMD, and Quality Control
  - Compared test methods to field performance
  - Results showed Overlay Tester and SCB Flexibility Index had best comparison
    - Similar findings at TTI, U. of Illinois
    - Similar recommendations in NCHRP 9-57
- For NJDOT, although Overlay Tester provides good data, test procedure is time consuming for Quality Control

Fatigue Cracking Laboratory Evaluation

- Compared variety of lab produced mixes
  - NMAS, binder grades, aged conditions, asphalt contents
- Used NJDOT PRS criteria for fatigue cracking (Overlay Tester) for criteria development
- Compared 2 potential test methods for potential Overlay Tester surrogate

NJDOT PRS Asphalt Mixture	Overlay Tester Fatigue Cracking Requirement
High Performance Thin Overlay (HPTO)	> 700 cycles
Bituminous Rich Intermediate Course (BRIC)	> 700 cycles
High RAP - Surface Course	> 175 cycles
High RAP - Inter/Base Course	> 100 cycles

SCB Flexibility Index (AASHTO TP124)

Standard Method of Test for Determining the Fracture Potential of Asphalt Mixtures Using Semicircular Bend Geometry (SCB) at Intermediate Temperature

AASHTO Designation: TP 124-16[1]

AASHTO

Technical Section: 2d, Proportioning of Asphalt –Aggregate Mixtures

Release: Group 3 (August 2016)

1. SCOPE

1.1. This test method covers the determination of the fracture energy (G_f) of asphalt mixtures using the semicircular bend (SCB) geometry at an intermediate test temperature. The method also includes procedures for calculating other relevant parameters derived from the load-displacement curve. These parameters, in conjunction with field performance, can be used to develop a Flexibility Index (FI) to predict an asphalt mixtures' damage resistance. The index can be used as part of the asphalt mixture approval process.

1.2. These procedures apply to test specimens having a nominal maximum aggregate size (NMAS) of 19 mm or less. Lab compacted and field core specimens can be used. Lab compacted specimens shall be 150 ± 1 mm in diameter and 50 ± 1 mm thick. When field cores are used, specimens shall be 150 ± 8 mm in diameter and 25 to 50 mm thick. A thickness correction factor may be applied for field cores tested at thickness less than 45 mm.

1.3. A vertical notch parallel to the loading axis shall be cut on the SCB specimen. The SCB specimen is a half disc with a notch parallel to the loading and the vertical axis of the semicircular disc.

1.4. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish and follow appropriate health and safety practices and determine the applicability of regulatory limitations prior to use.*

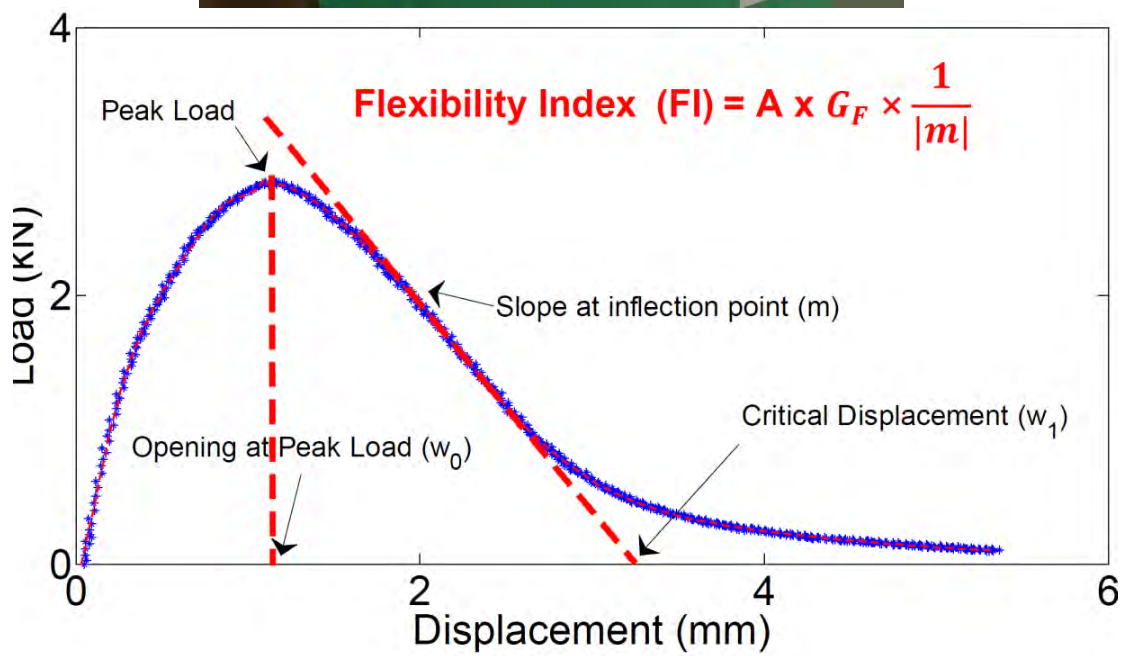
2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards:*

- T 166, Bulk Specific Gravity (G_{mb}) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
- T 283, Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage
- T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
- TP 105, Determining the Fracture Energy of Asphalt Mixtures using Semicircular Bend Geometry (SCB)

2.2. *ASTM Standards:*

- D3549/D3549M, Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
- D5361/D5361M, Standard Practice for Sampling Compacted Bituminous Mixtures for Laboratory Testing



SCB Flexibility Index Sample Prep

(1)

(2)

(3)

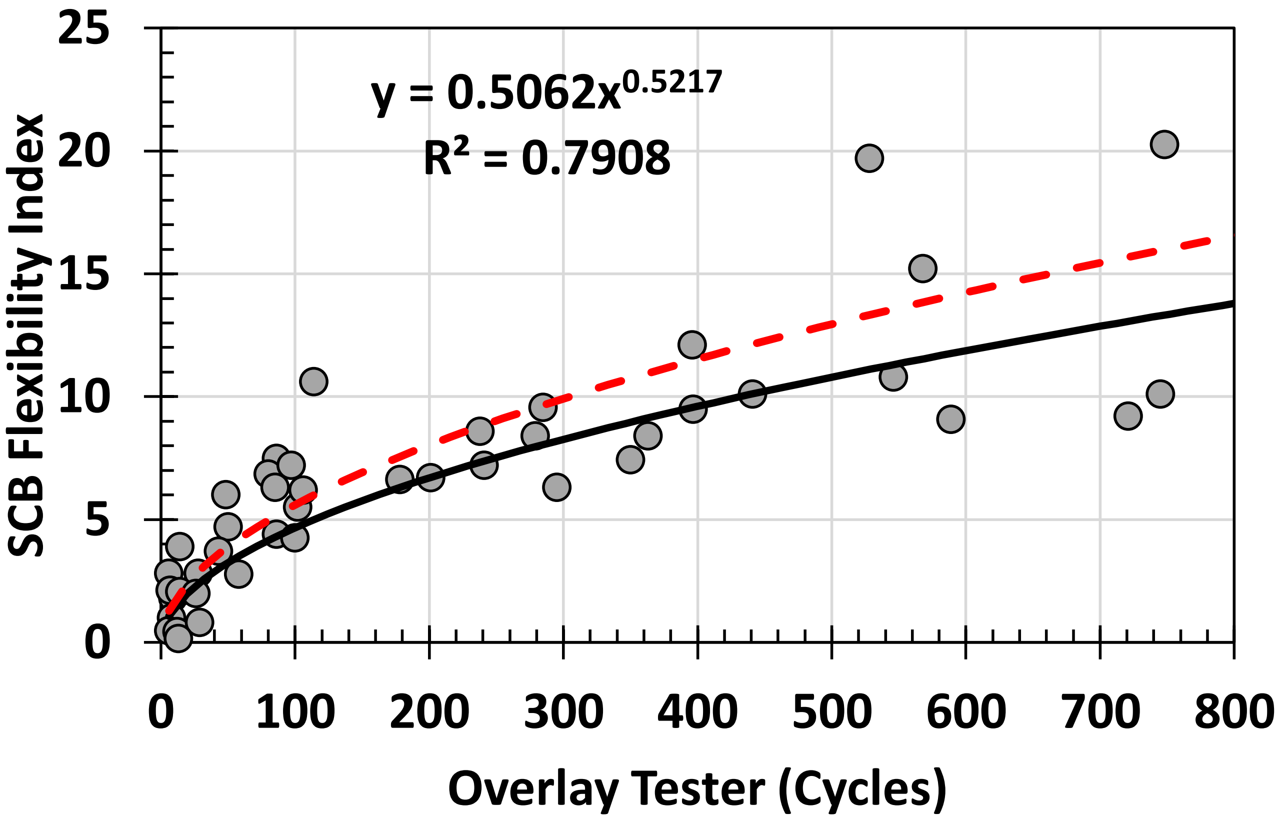
(1)

(2)

(3)

Overlay Tester vs SCB FI – Preliminary Guidance Values

- Error bars represents average COV
  - OT = 24.5 %; SCB FI = 23.2%



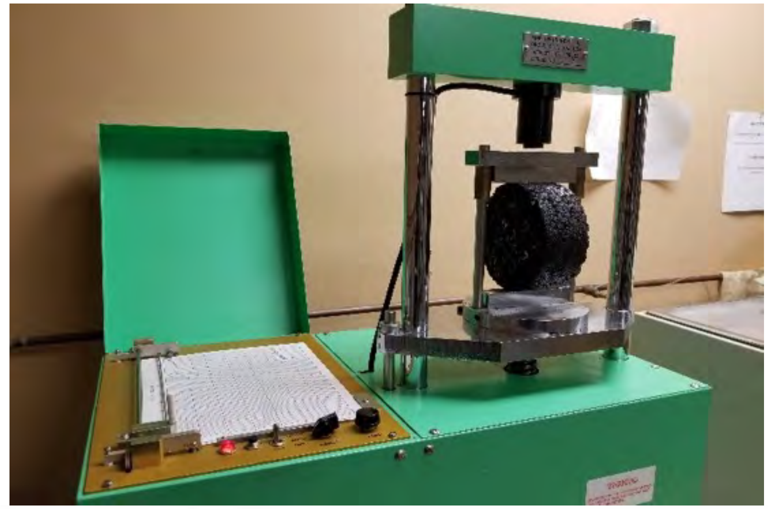
Black line correlation
Red dotted line is proposed Pass/Fail criteria that includes SCB-FI COV%

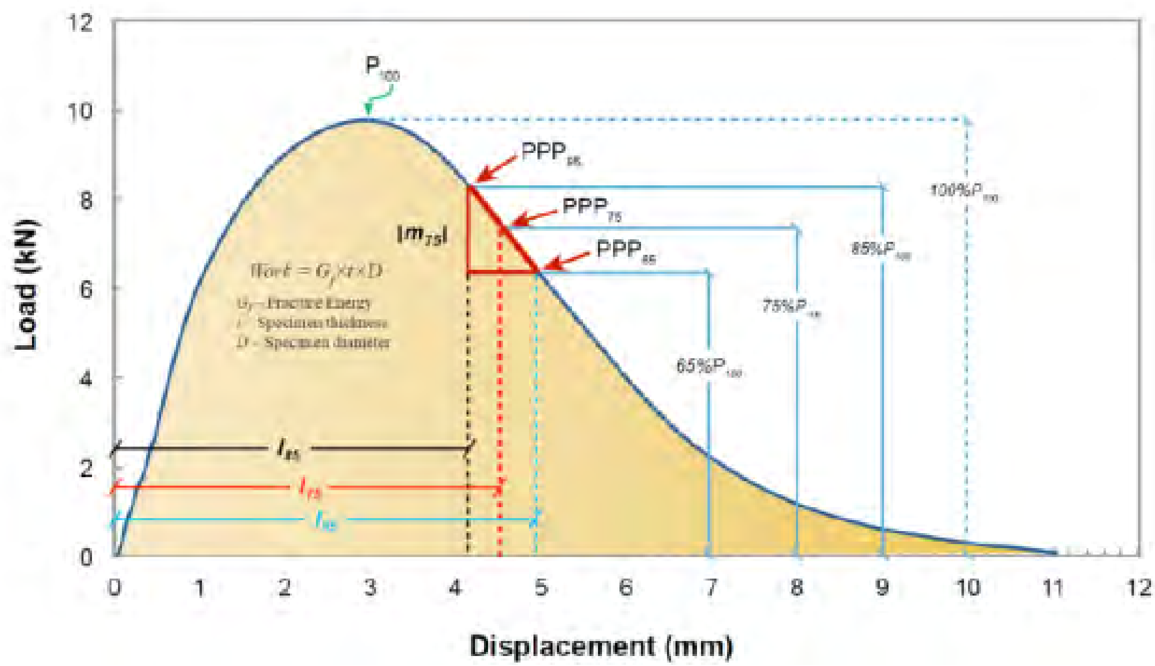
Overlay Tester vs SCB FI

- Advantages of SCB FI over Overlay Tester for Quality Control testing
  - Quicker testing time
  - Inexpensive equipment
  - Quicker specimen prep time (no gluing)
  - Less specimens (OT needs 5 gyratories; SCB FI needs 2 gyratories)
- Some drawbacks of SCB FI for Quality Control
  - Requires wet saw in lab
  - Requires sawing and notching for sample prep
  - Some data analysis required – Spreadsheets available

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

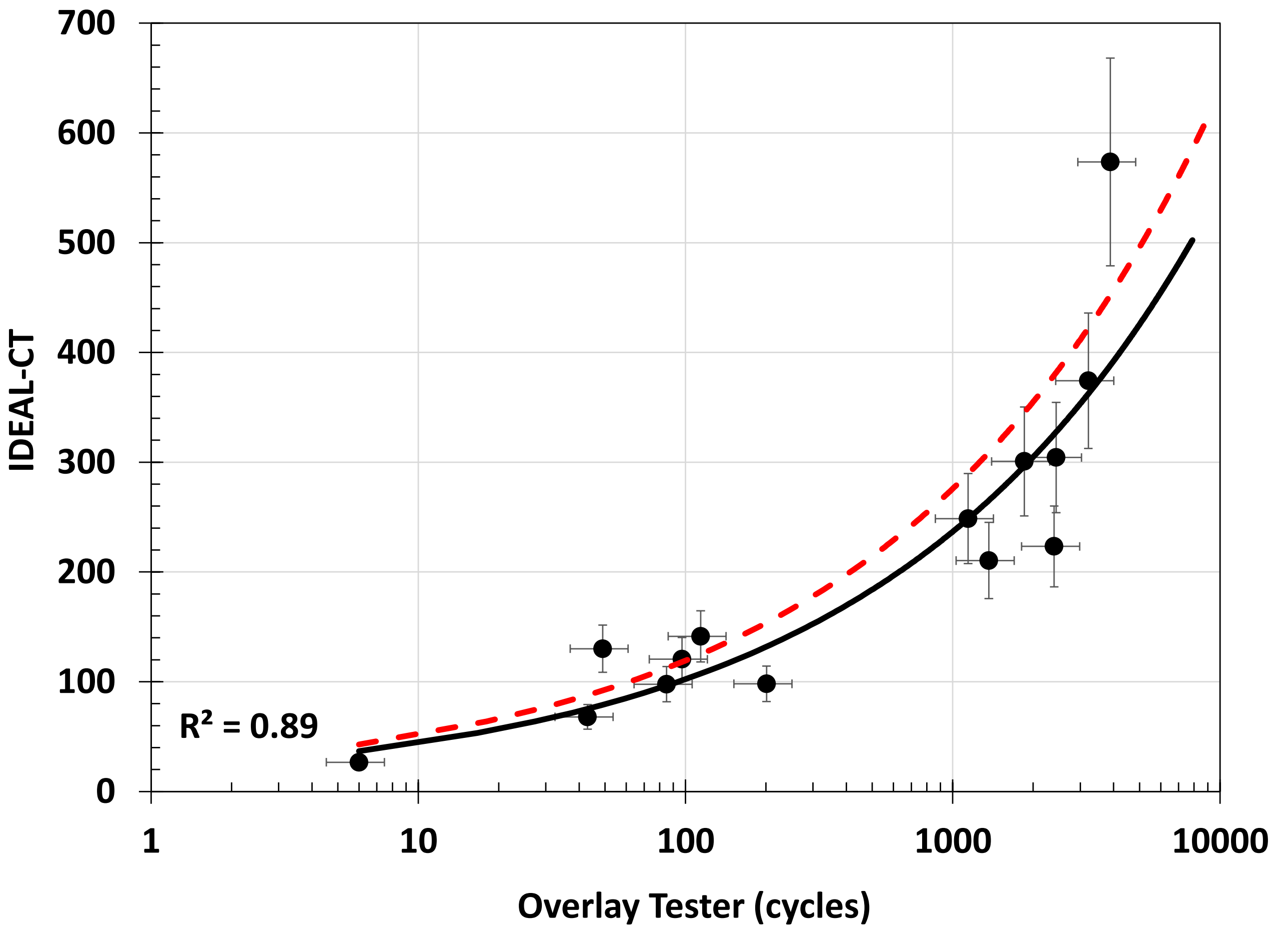
- Fatigue Cracking (IDEAL-CT Recommendations)
  - Uses TSR IDT frame with Lottman head (used for TSR; AASHTO T283)
  - Gyratory compacted samples (set air void level to specified)
  - 50 mm/min (2 inch/min) deformation rate
  - Test temperature is 25°C





IDEAL-CT vs Overlay Tester Fatigue Cracking – Preliminary Guidance Values

- Error bars represents average COV
  - OT = 24.5 %; IDEAL-CT = 16.5%



- Black line correlation
- Red dotted line is proposed Pass/Fail criteria that includes IDEAL-CT COV%

Overlay Tester vs 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
  - Data analysis required – Spreadsheets available

Resultant Fatigue Cracking Criteria

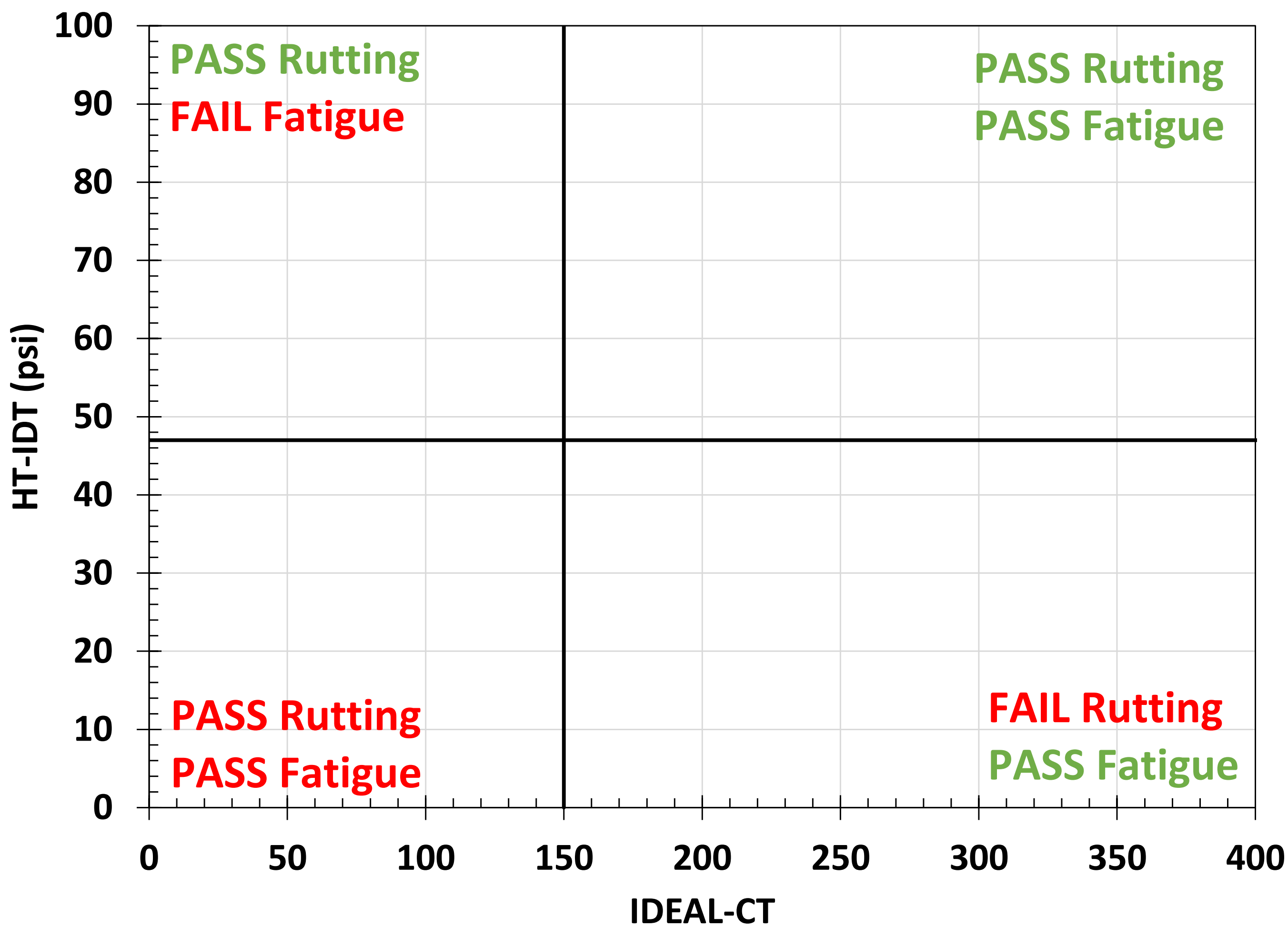
NJDOT PRS Asphalt Mixture	Overlay Tester Fatigue Cracking Requirement	SCB Flexibility Index	IDEAL-CT Fatigue Cracking Requirement
High Performance Thin Overlay (HPTO)	> 700 cycles	> 18	> 245
Bituminous Rich Intermediate Course (BRIC)	> 700 cycles	> 18	> 245
High RAP - Surface Course	> 175 cycles	> 11	> 150
High RAP - Inter/Base Course	> 100 cycles	> 9	> 120

Proposed "Balanced" IDT Performance

NJDOT PRS Asphalt Mixture	HT-IDT Strength Requirement	IDEAL-CT Fatigue Cracking Requirement
High Performance Thin Overlay (HPTO)	> 47 psi	> 245
Bituminous Rich Intermediate Course (BRIC)	> 30 psi	> 245
High RAP - Surface Course	> 47 psi	> 150
High RAP - Inter/Base Course	> 25 psi	> 120

Proposing IDT Performance Space for Quick QC Reference

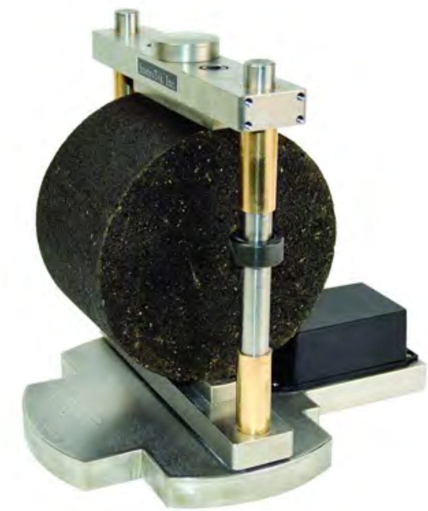
- Example: High RAP, Surface, High Traffic



Other IDT Items

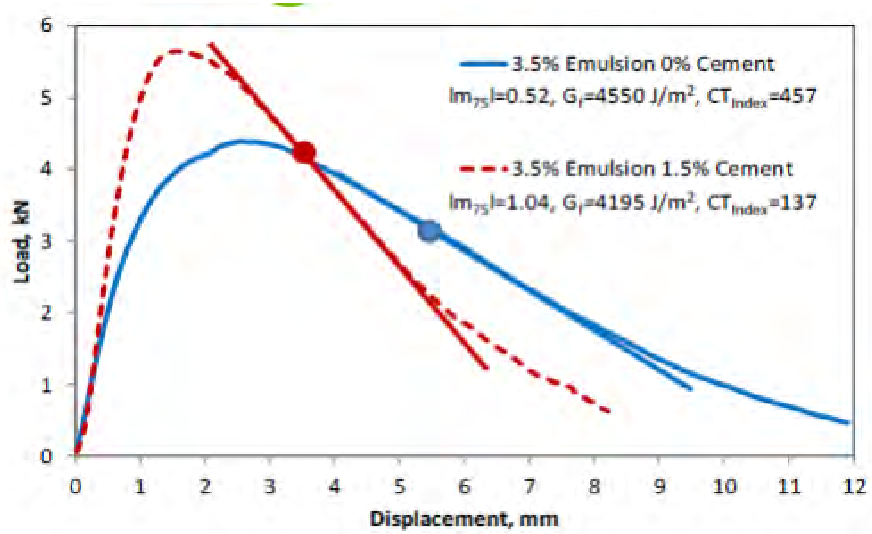
Automated IDT?

- For those Marshall machine users with no data acquisition/computer
  - InstroTek's "SMART TSR"
    - Wireless/Bluetooth to computer/tablet/phone
    - Has its own load cell and LVDT's
    - Software calculates IDT strength and IDEAL-CT value
    - Load cell only ≈ $2k
    - Load cell + 2 LVDT's ≈ $4k



Other Potential Applications of IDT Performance Testing

- Cold In-Place Recycling (CIR) Materials
  - TRB 2018 Paper, "Proposed Tests for Cold Recycling Balanced Mixture Design with Impact of Varying Emulsion and Cement Contents"

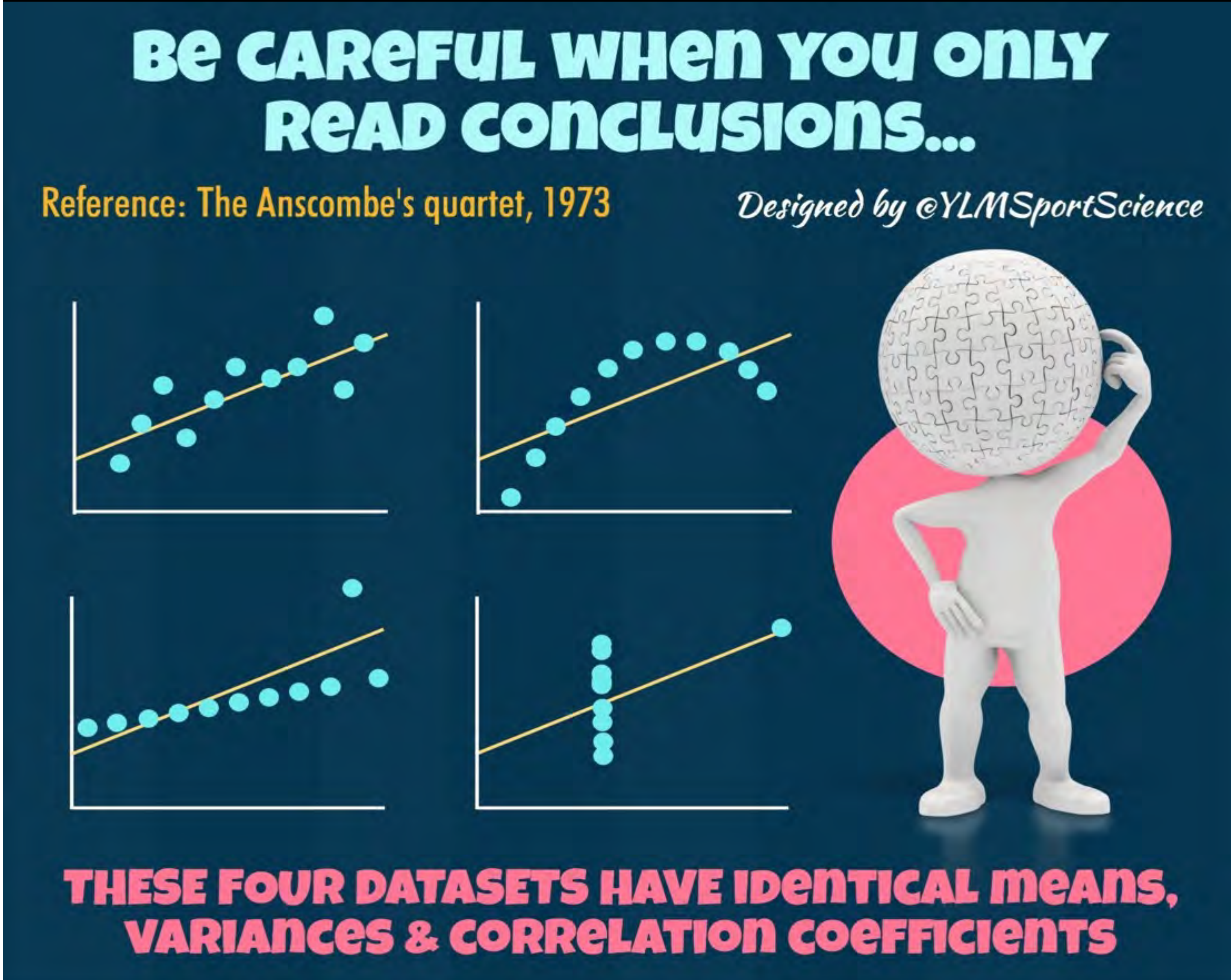


Areas Currently Evaluating

Areas Needing Further Work

- Temperature Conditioning
  - Water vs Forced Air
- Field Cores
  - Height to Diameter ratio (H/D)?
    - Correction for IDEAL-CT appropriate for Thin Lifts?
- Different HT IDT requirement for SMA?
  - Generally lower high temperature IDT strengths

Thank you for your time! Questions?



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