Back to Basics Workshop

Interlaboratory Study:

Indirect Tensile Cracking Test (IDT-CT) at Intermediate Temperature

Jhony Habbouche, Ph.D., P.E.
Senior Research Scientist
Virginia Transportation Research Council

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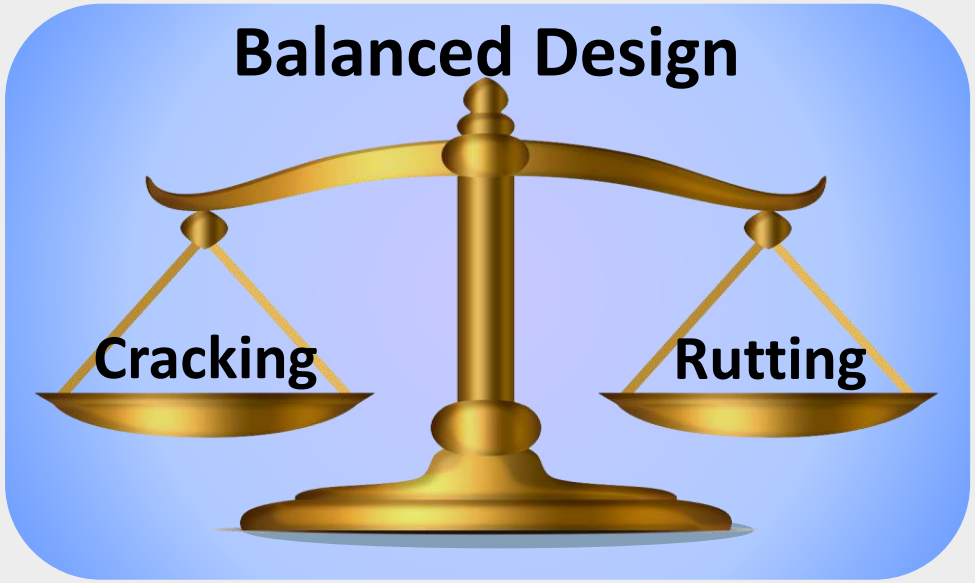
Jointly sponsored By VAA, VTRC and VDOT

Virginia's BMD Specifications

Cracking

Indirect Tensile (IDT) Test (ASTM D8225)

CT index ≥ 70



Rutting

Asphalt Pavement Analyzer (APA) Rut Test (AASHTO T 340)

RD ≤ 8.0 mm

Durability

Cantabro Mass Loss Test (AASHTO T 401)

CML ≤ 7.5 %

Moisture Damage

Tensile Strength Ratio Test (AASHTO T 283)

TSR ≥ 80 %

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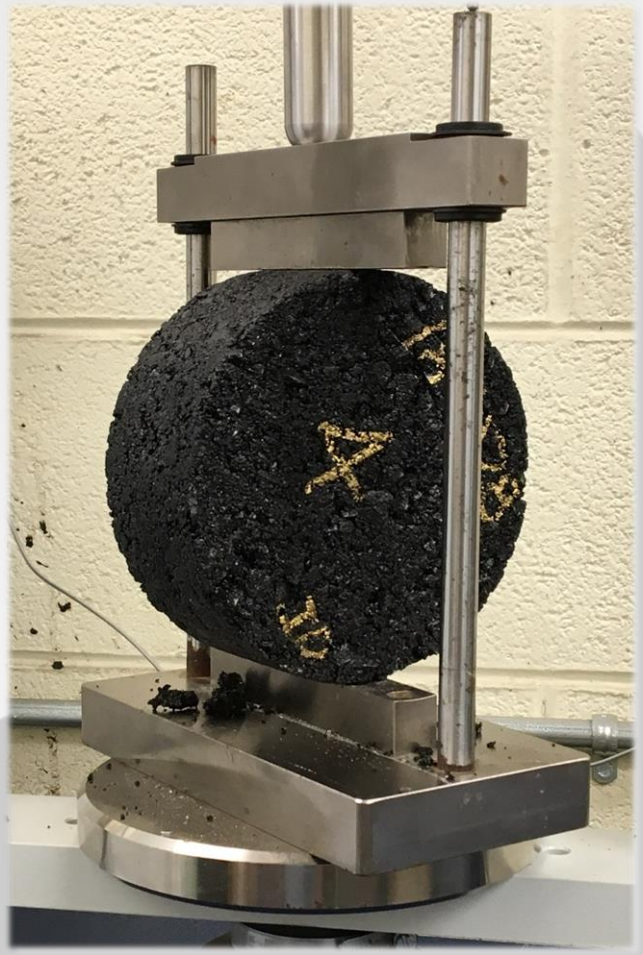
IDT Cracking Test (IDT-CT / IDEAL-CT)

- **Performed as per ASTM D8225**
  - Testing Temperature: **25°C**
  - Air Voids Content: **7 ± 0.5%**
  - Loading Rate: **50 ± 2 mm/min**
  - Specimen Thickness: **62 ± 1 mm**
  - Specimen Diameter: **150 ± 2 mm**



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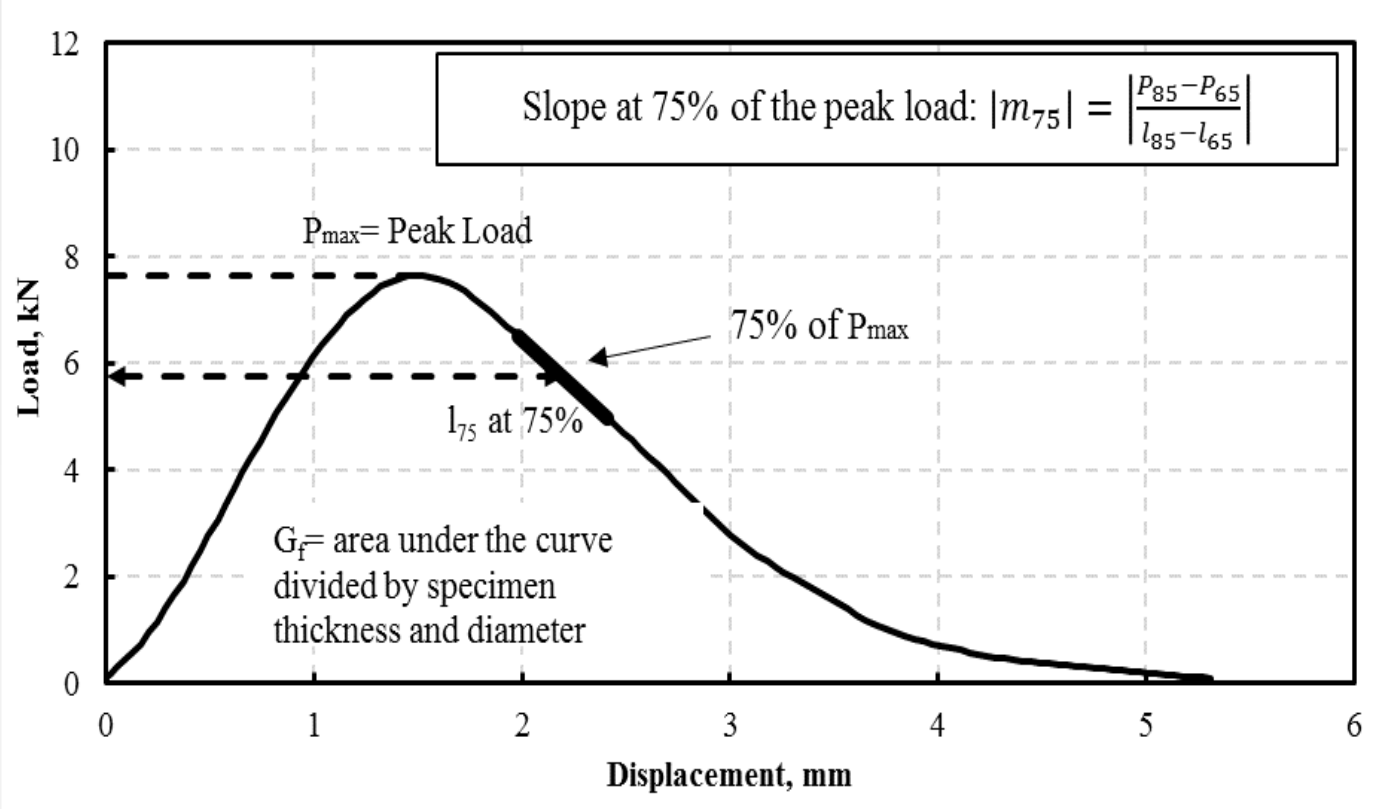
IDT Cracking Test (IDT-CT / IDEAL-CT)

$$CT\ index = \frac{G_f}{|m_{75}|} * \frac{l_{75}}{D} * \frac{t}{62}$$

- D = specimen diameter, mm
- t = specimen thickness, mm
- G_f = total area under the curve divided by the product of [D] and [t]
- $m_{75} = |\frac{p_{85}-p_{65}}{l_{85}-l_{65}}|$
- l_{75}= displacement corresponding to 75% of P_{max} at the post-peak stage (p_{75}), kN

Cracking Tolerance Index (CT index) - Calculation



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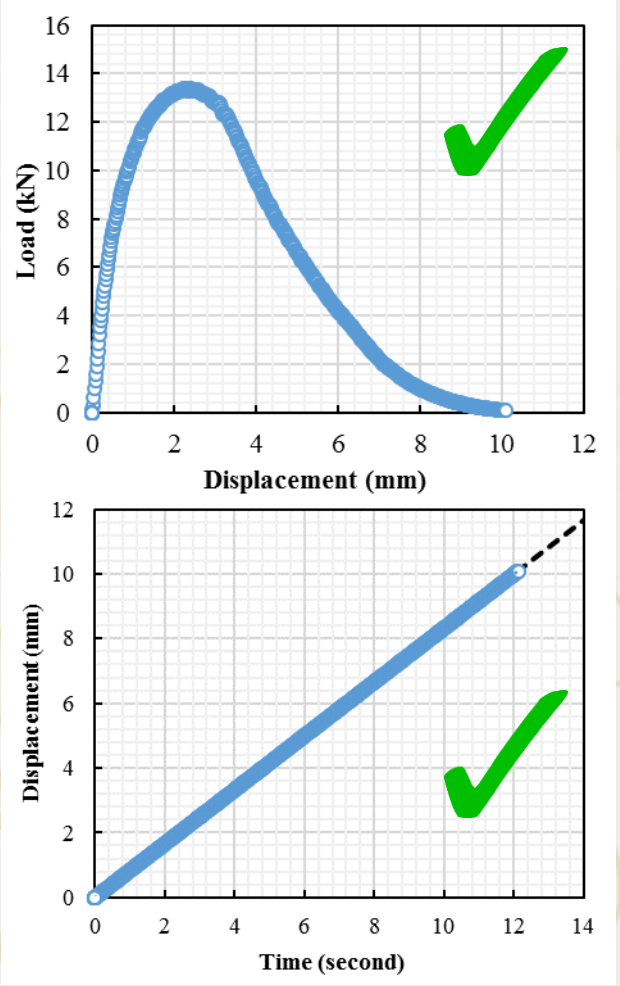
Data Quality Evaluation

- **Testing with Good / Compliant Data**
  - No seating load
  - Test ends when load reaches 0.1 kN or less
  - No irregularities in the curves
  - Constant loading rate of 50 ± 2 mm/min



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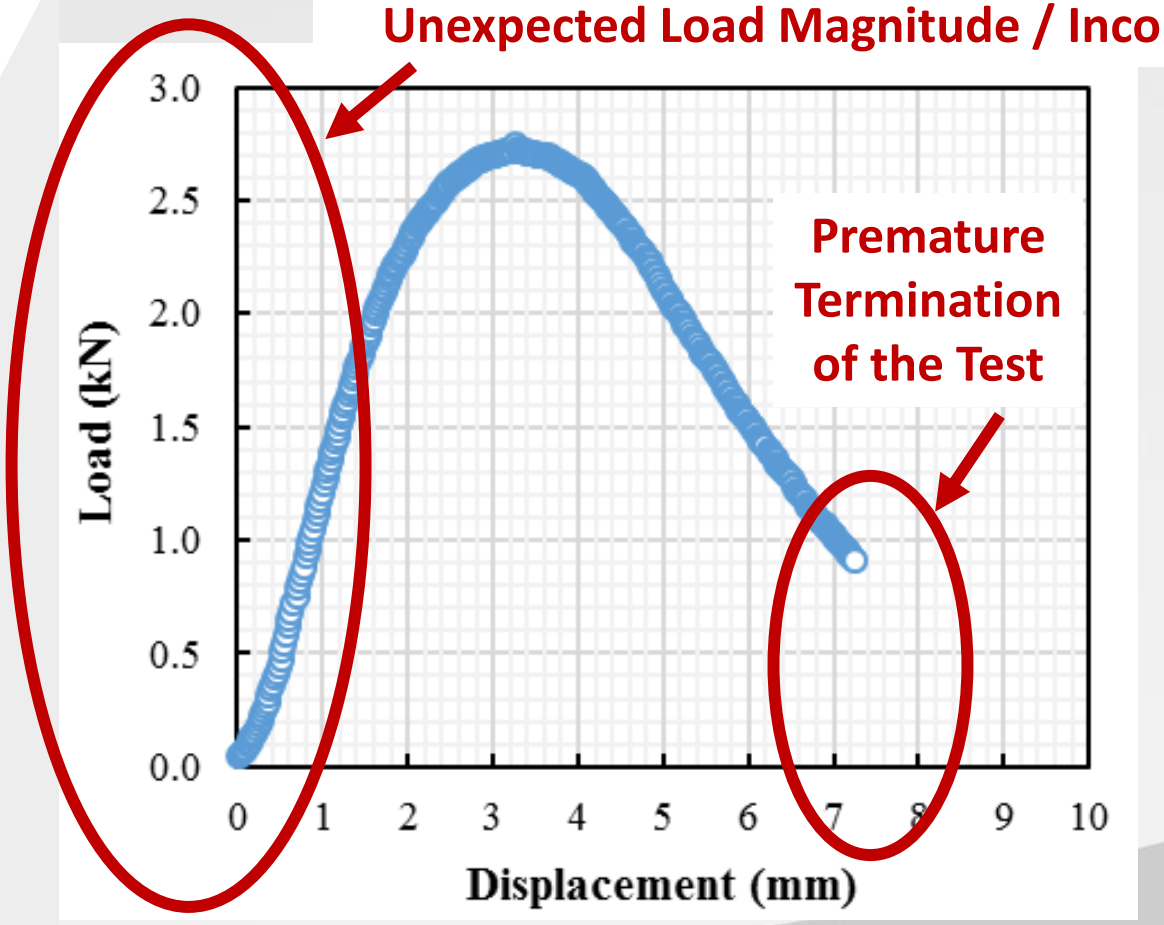
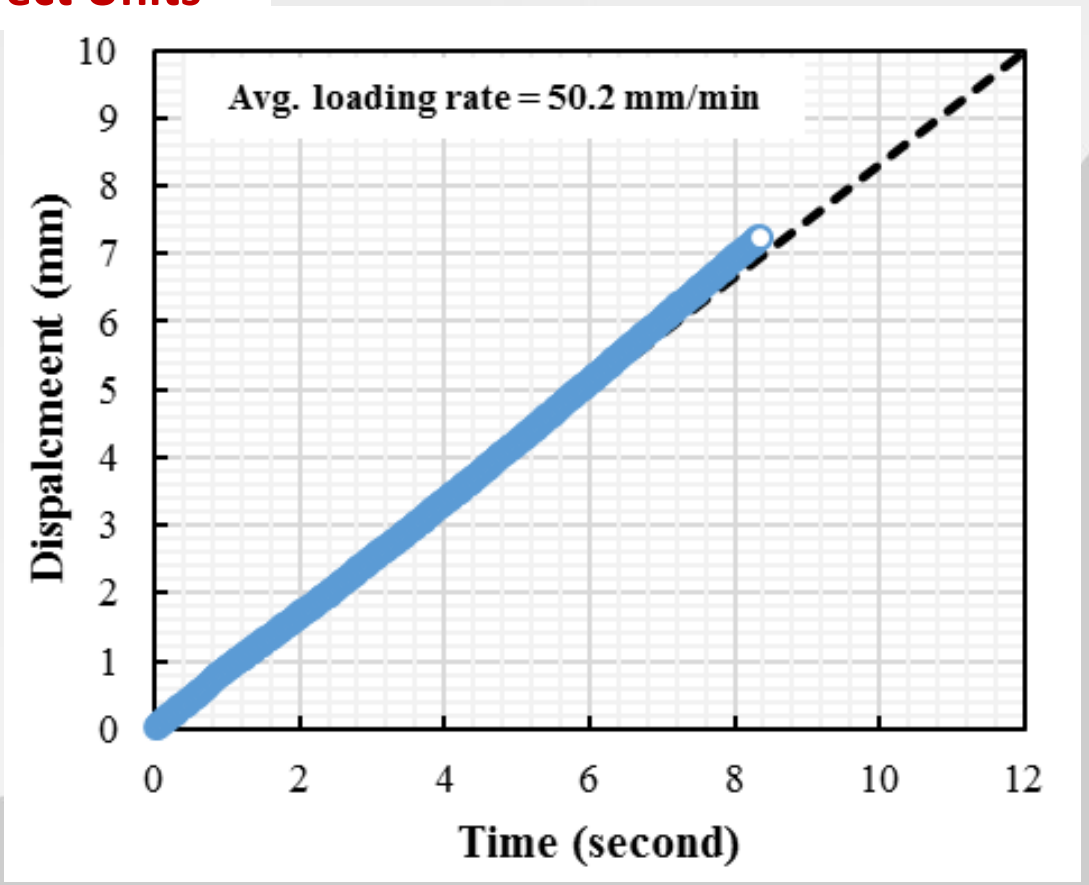
Data Quality Evaluation





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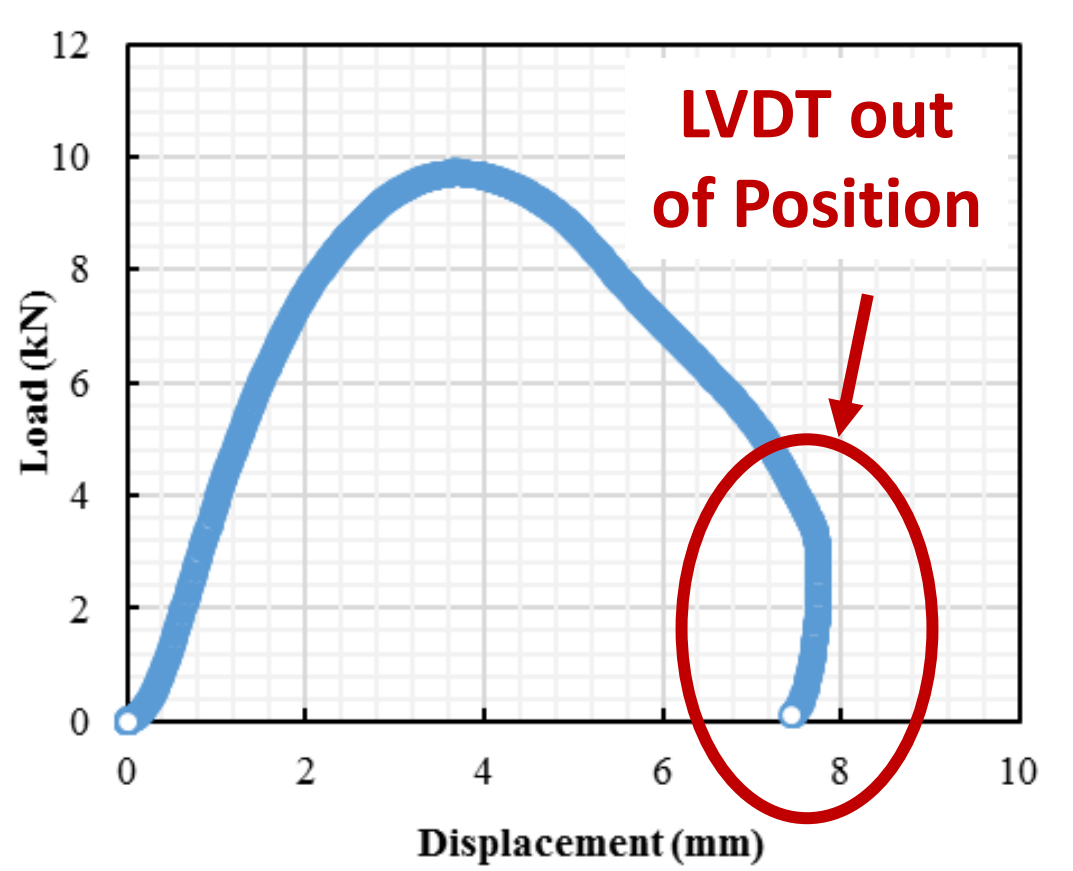
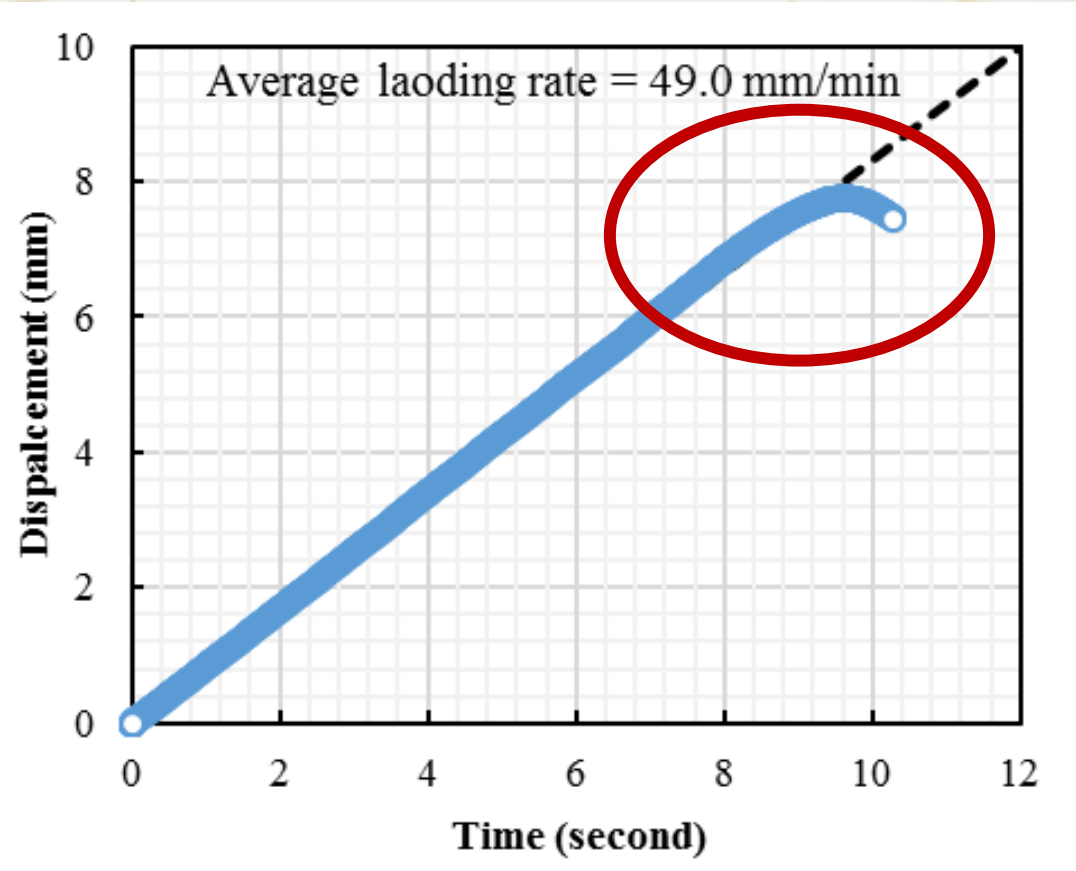
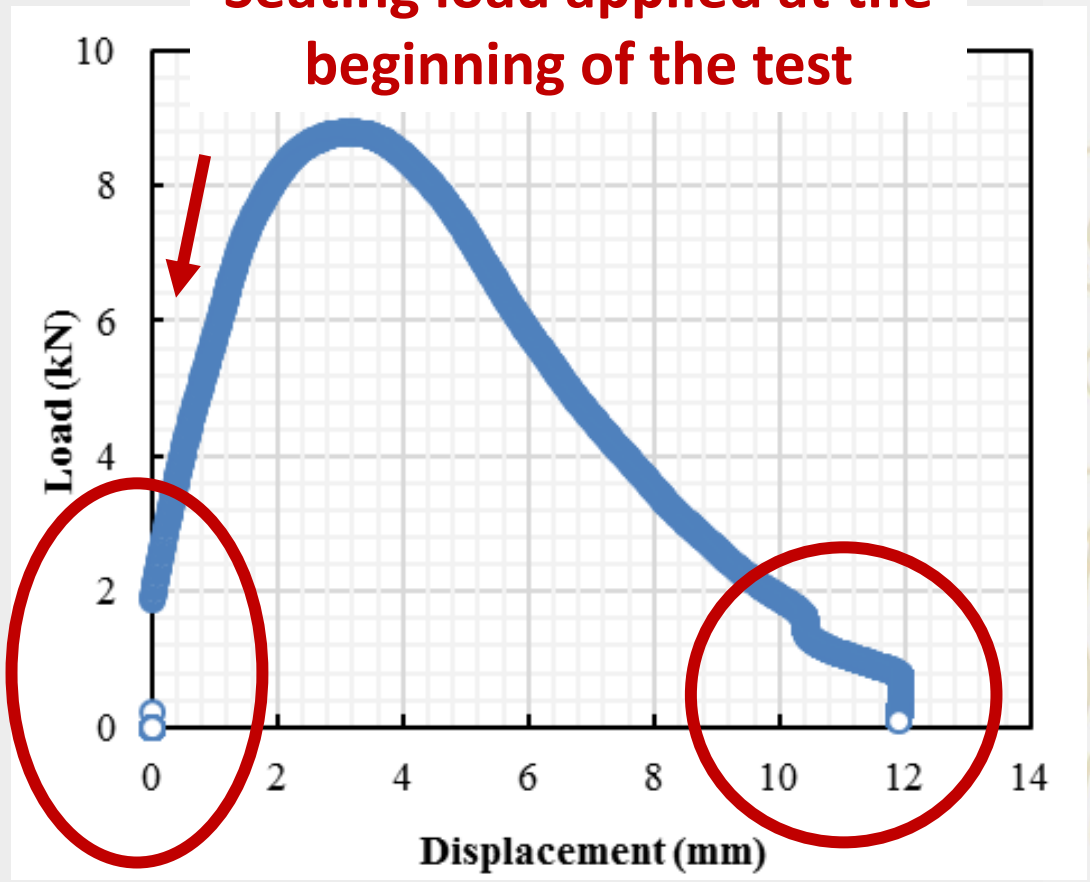
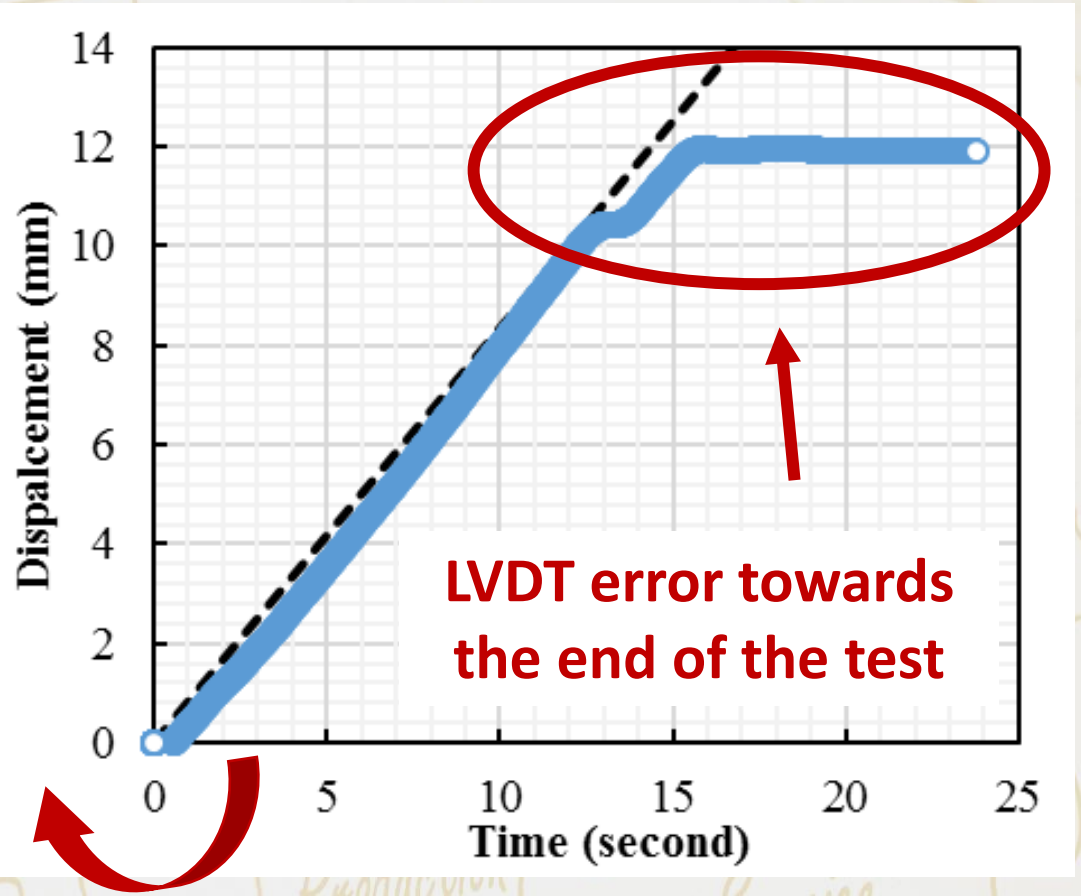
Data Quality Evaluation





Data Quality Evaluation





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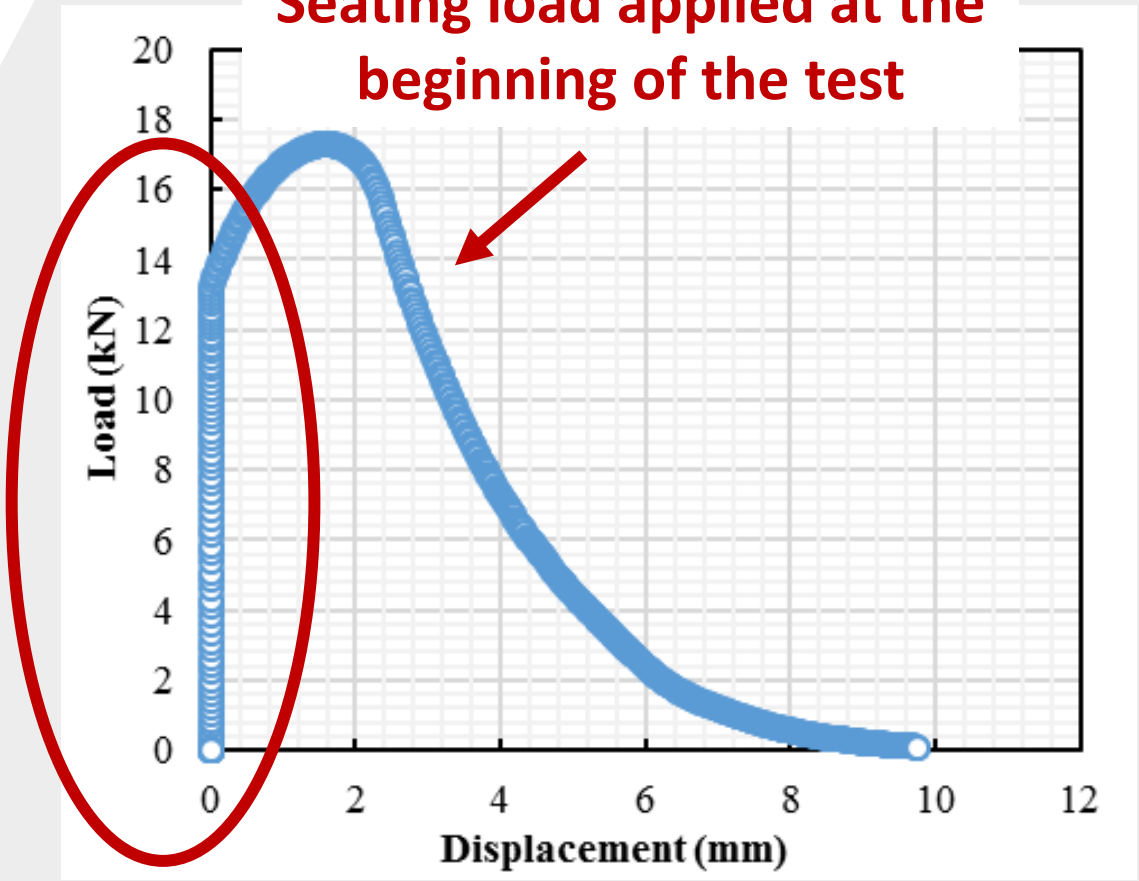
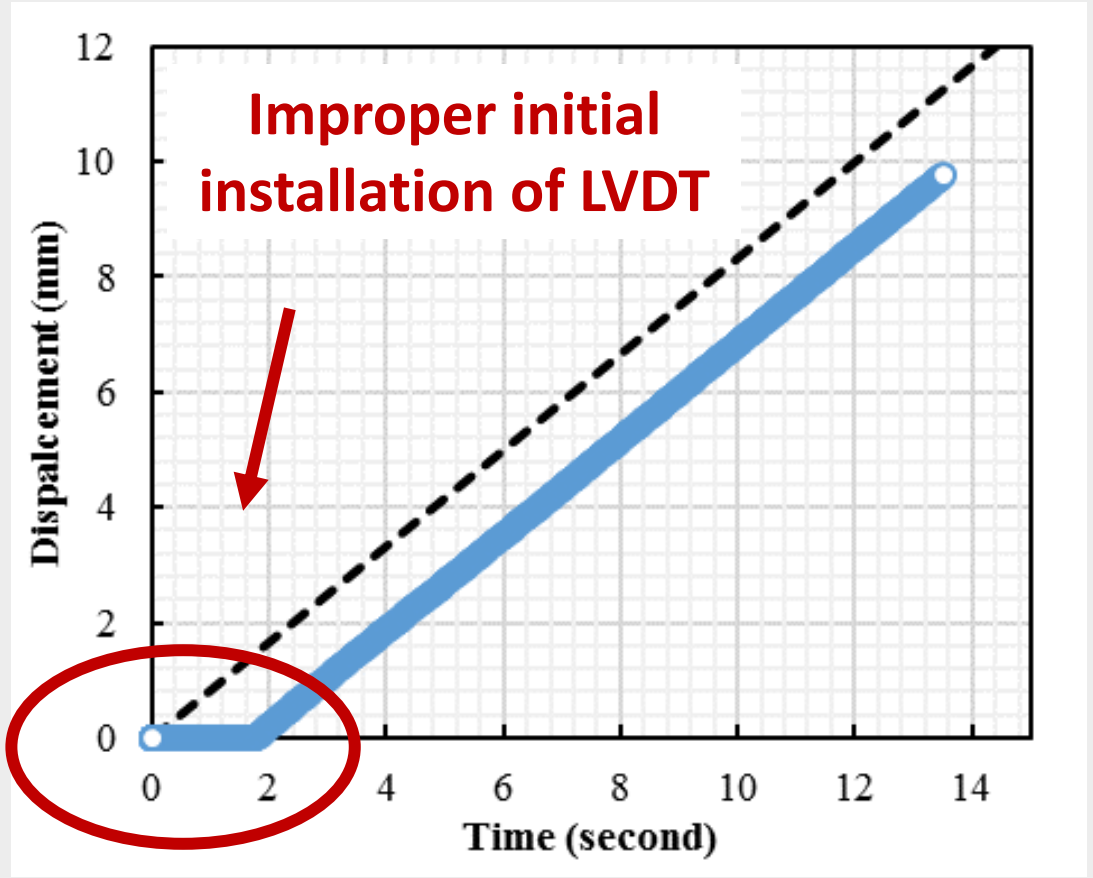
Data Quality Evaluation





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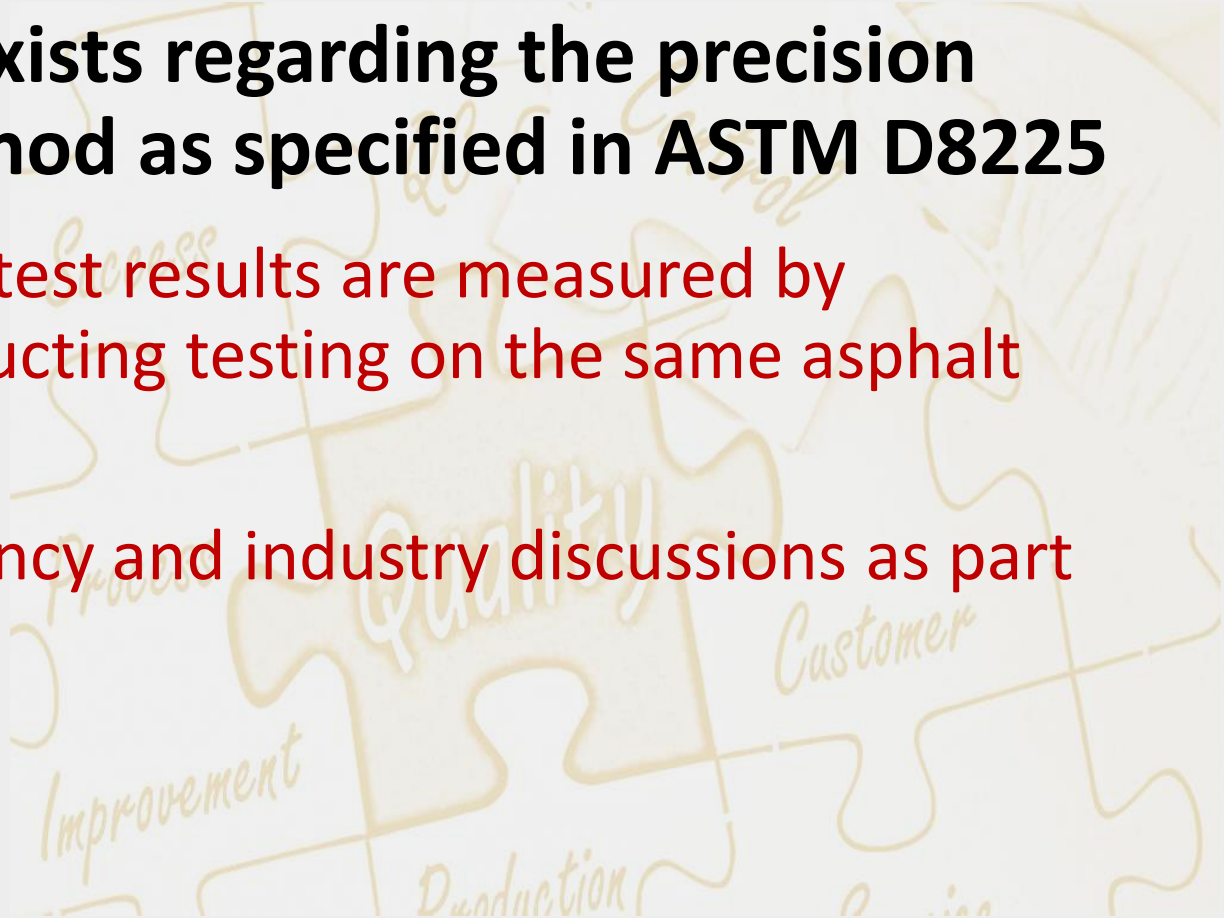
Problem Statement

- **No information currently exists regarding the precision and bias of the IDT-CT method as specified in ASTM D8225**
  - Potential issues if different test results are measured by individual laboratories conducting testing on the same asphalt mixture.
  - Topic of interest during agency and industry discussions as part of BMD implementation.



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Phase I – Objectives

- **To establish the acceptable variability of the test method: "repeatability" and "reproducibility".**
  - ➢ Determine and develop precision estimates and statements for the IDT-CT indices ***(e.g., CT index)***
- **Assess the effect of equipment type and loading rate on the selected IDT-CT indices.**
- **Preliminary assess the impact of shelf life of compacted specimens on the selected IDT-CT indices.**

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Phase I – Scope of Work

- **Phase I: Evaluation of specimens fabricated and compacted by a 3rd party laboratory and sent to participants for *testing only (as per ASTM E691)***
  - **Stage 1:** Focus on non-VDOT laboratories **(Spring 2020)**
  - **Stage 2:** Focus on VDOT laboratories **(Spring 2021)**

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Phase I – Evaluated Mixtures

- **Mixture A**
  - Asphalt Binder: PG76-22
  - RAP Content: 30%
  - N_{design} = 65
  - NMAS = 9.5mm
  - Binder Content = 5.3%
  - CML = 6.1%
  - APA RD = 1.350 mm
  - CT index < 100

- **Mixture B**
  - Asphalt Binder: PG64-22
  - RAP Content: 0%
  - N_{design} = 50
  - NMAS = 12.5mm
  - Binder Content = 5.8%
  - CML = 3.8%
  - APA RD = 4.160 mm
  - CT index > 100

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Phase I.1 – Experimental Program

- **Participants**
  - ➢ 41 participants and 46 sets of tested specimens
    - ○ 3 laboratories with multiple devices
- **Testing Instructions**
  - ➢ Provided for consistency + all testing happened on dry specimens
  - ➢ Conditioning in a chamber or leaked proof plastic bags placed in water

Challenges reported in keeping the specimens dry because of frequent water leaks due to tearing of the plastic bags!!!

→ Does testing dry or wet specimens make a difference?

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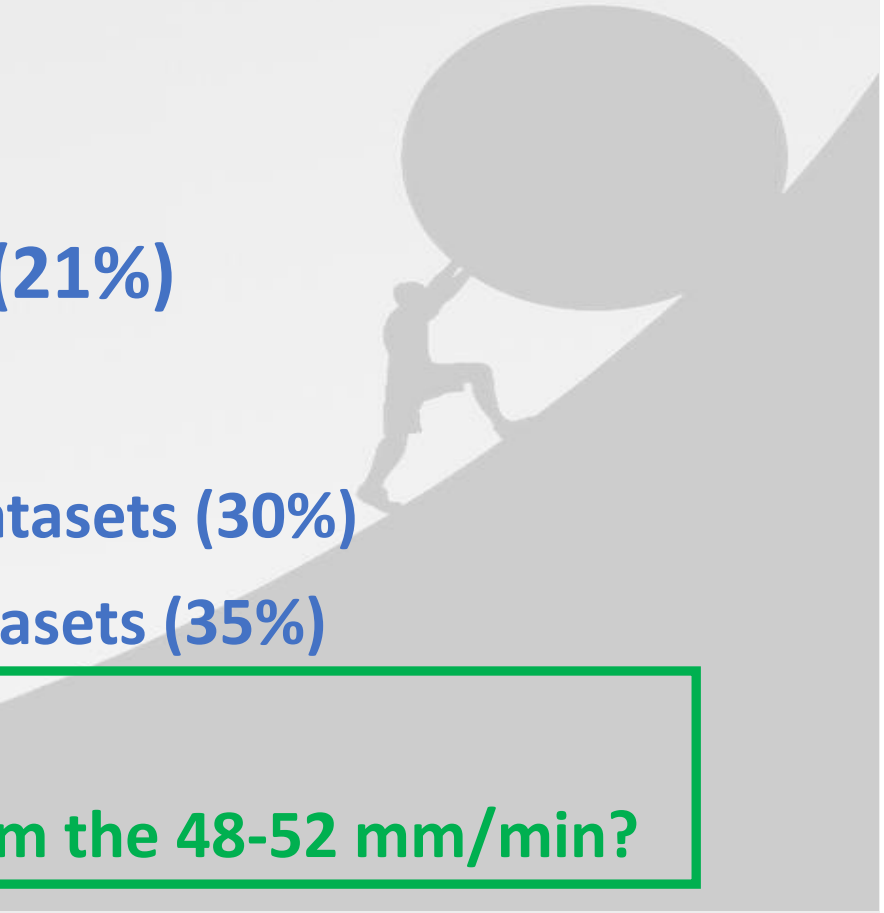
Phase I.1 – Status of Submitted Data

- **Machine-related issues: 3 datasets (7%)**
- **No raw data: 3 datasets (7%)**
- **Did not meet ASTM D8225: 10 datasets (21%)**
- **Testing Instructions**
  - Loading rate **outside** 50 ± 2 mm/min: **14 datasets (30%)**
  - Loading rate **within** 50 ± 2 mm/min: **16 datasets (35%)**

➢Need for training?

→Quantify the impact of small deviation from the 48-52 mm/min?



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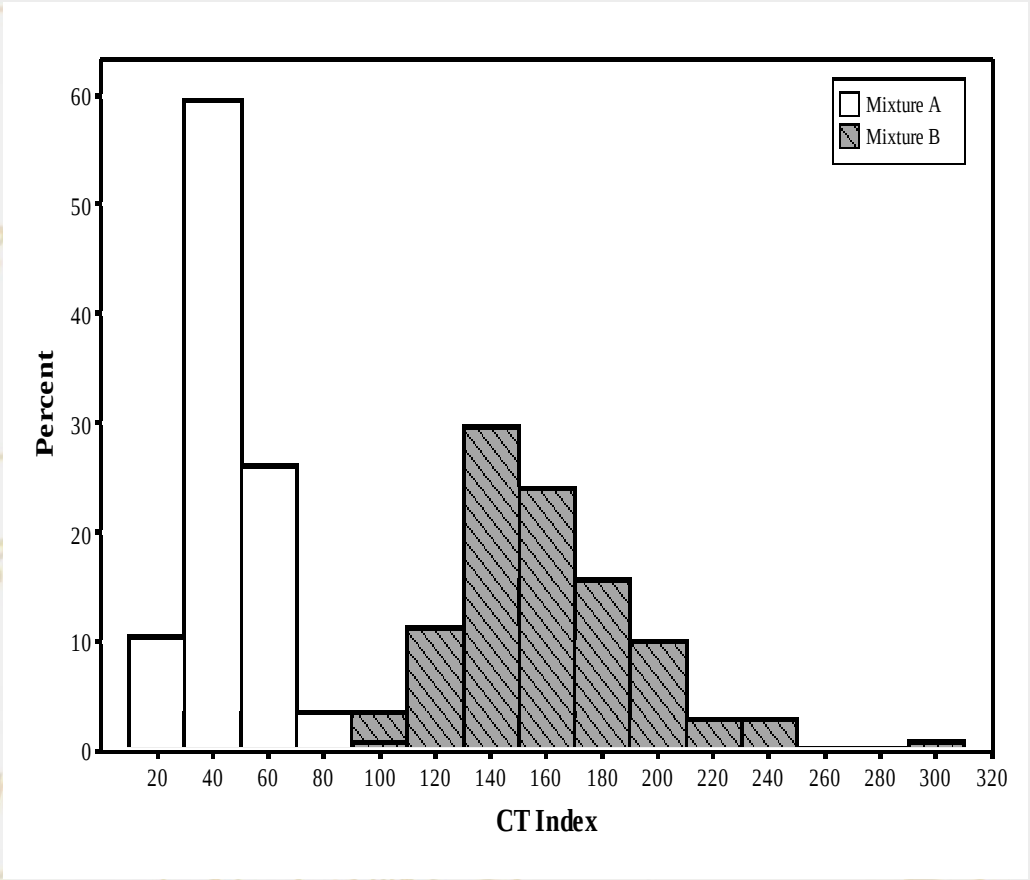
Phase I.I: Database and Analysis Approaches

- **Database**
  - Category (i): 16 datasets
  - Category (ii): 30 datasets (16+14)
- **Analysis Approaches**
  - Original / Untrimmed
  - Trimmed



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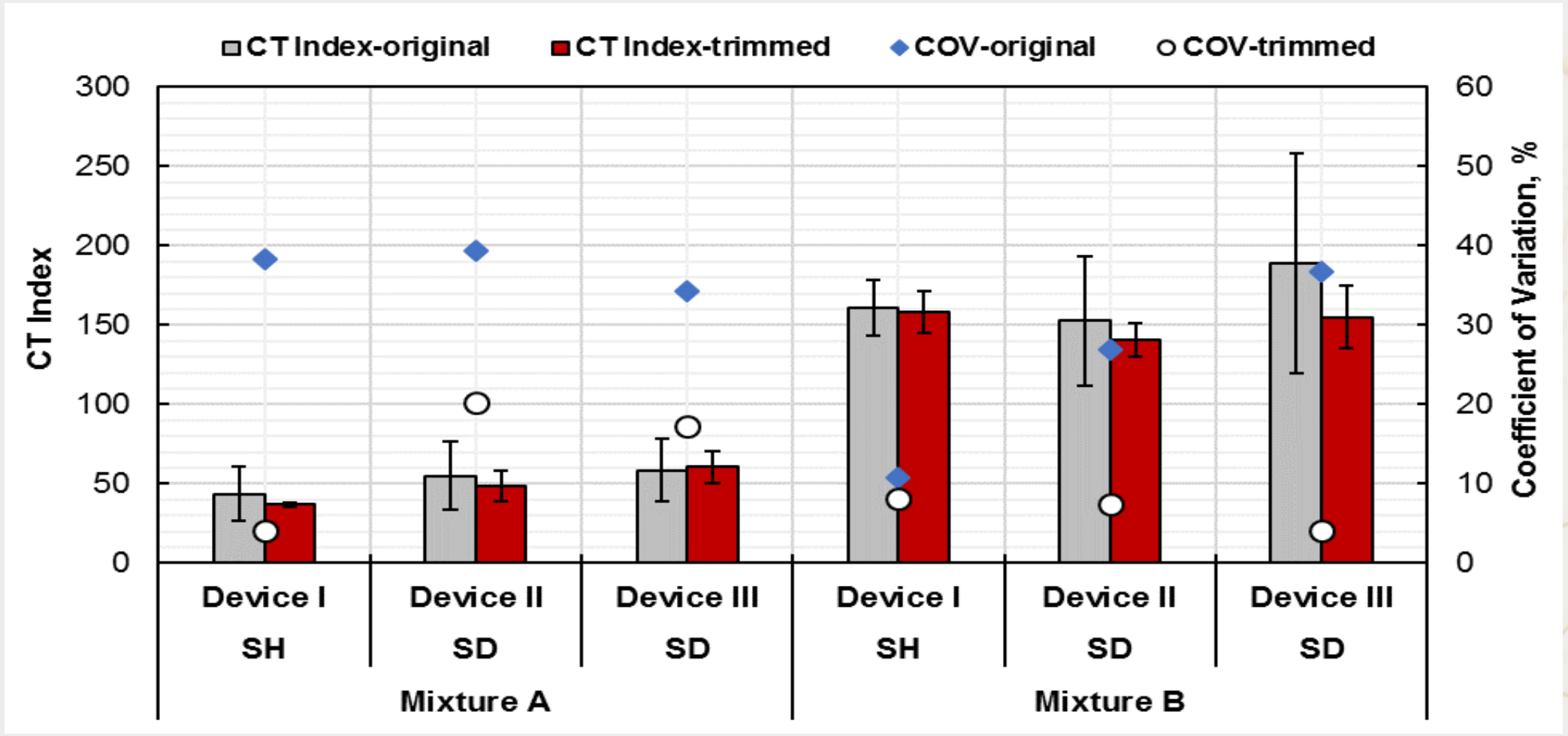
Phase I.I: Effect / Impact of Devices



SH = servo hydraulic; SD = screw-drive

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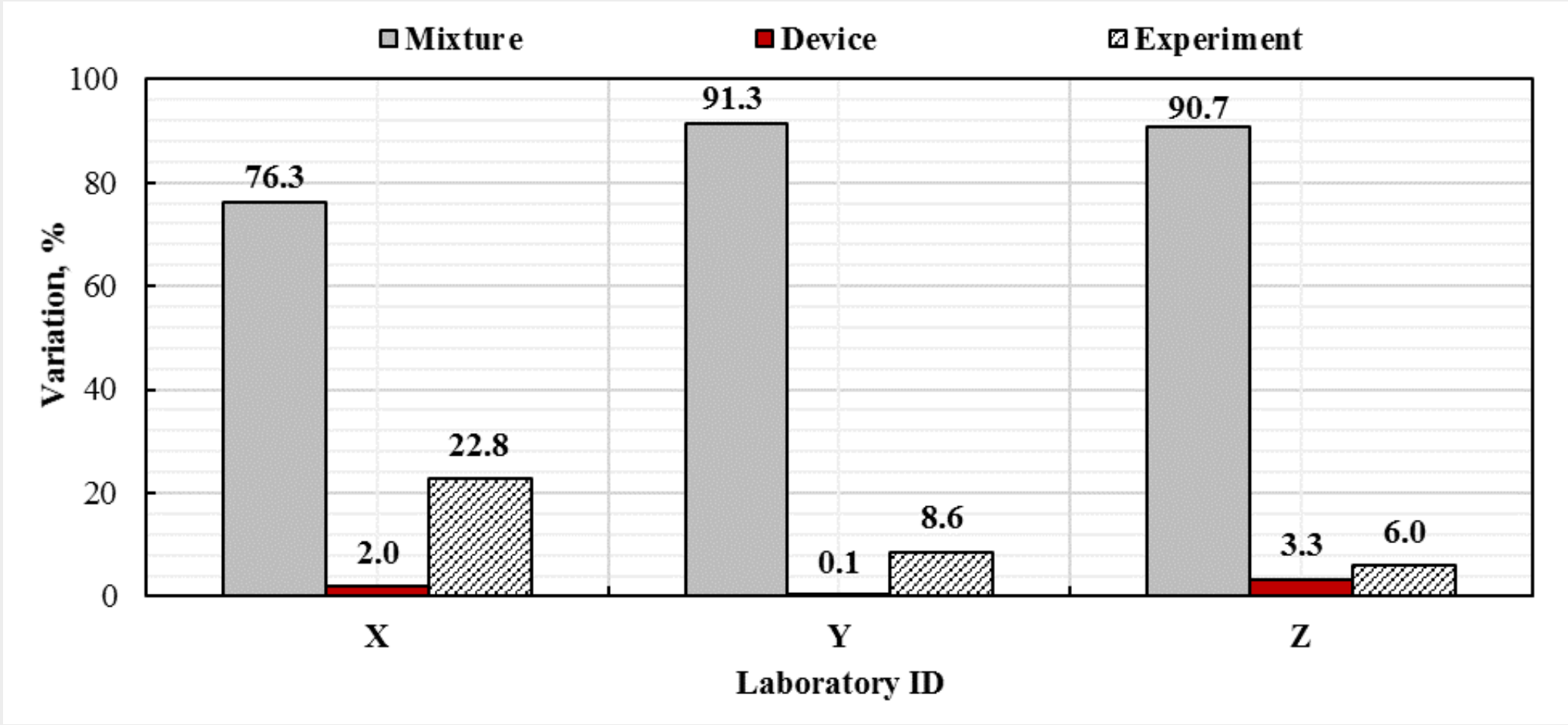
Phase I.I: Effect / Impact of Devices *(2)*



→ **Actual Variability vs. Practical Variability?**

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Phase I.I: Database and Analysis Approaches

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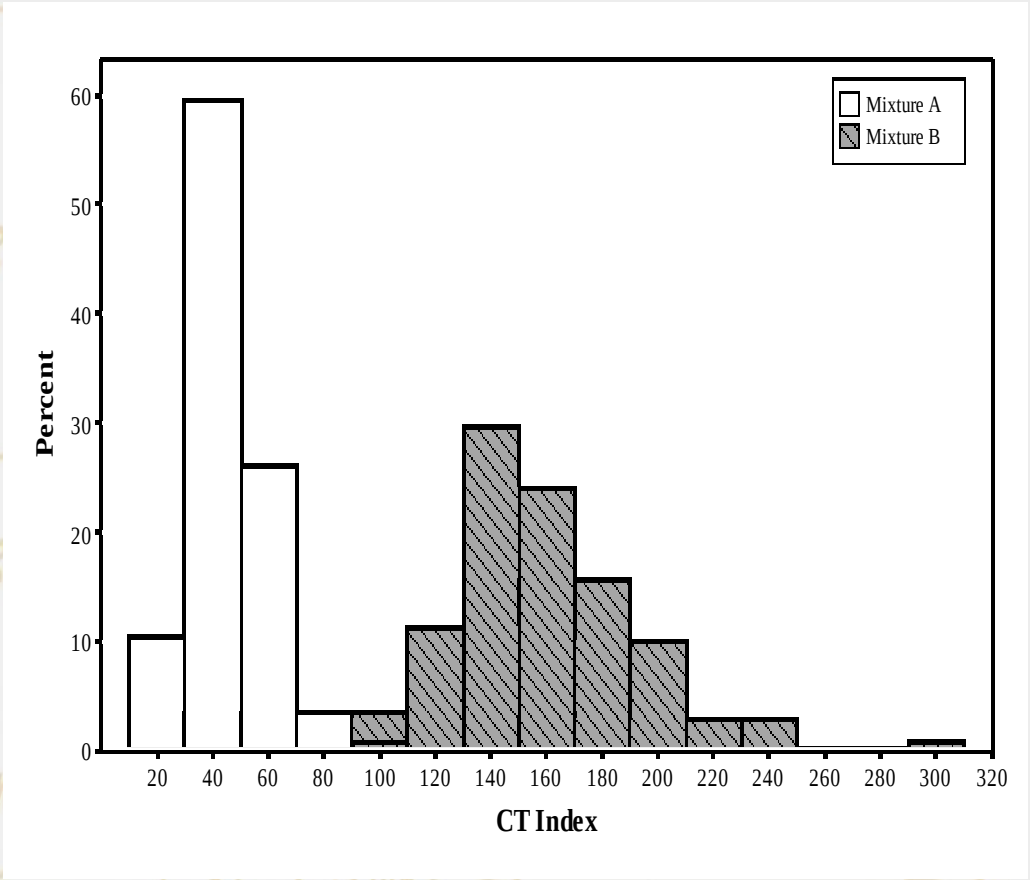

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Phase I.1 – Precision Estimates

Study			Precision Estimates, COV, %	
			Single-Operator	Multi-Operator
VTRC	16 data sets per mix	**Original Data *(5)***	**18.3%**	**21.3%**
		Trimmed Data *(3)*	11.2%	15.9%
	30 data sets per mix	**Original Data *(5)***	**20.7%**	**21.9%**
		Trimmed Data *(3)*	12.8%	16.9%
NCAT			18.8%	20.2%
Rutgers			15.2%	23.0%

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Phase I.1 – Numerical Example

Sample	Set 1 Lab A	Set 2 Lab B
1	75	69
2	99	74
3	107	92
4	87	51
5	102	46
Average CT index	94 ✓	67 ✗
COV	13.8% ✓	27.7% ✗
Required Average CT index	70	
Single Operator COV	18.3%	

What about among laboratories?

d2s	33.6%
Multi Operator d2s	59.7%
COV	12.0%
Multi Operator COV	21.3%

✓

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Phase I.2 – Precision Estimates

Stage ID	Approach	Precision Estimates	
		Single-Operator	Multi-Laboratory
I (focus on NON-VDOT Labs)	**Original data (Five replicates)**	18.3%	21.3%
	Trimmed data (Three replicates)	11.2%	15.9%
II (focus on VDOT Labs)	**Original data (Five replicates)**	23.4%	23.8%
	Trimmed data (Three replicates)	14.8%	15.8%

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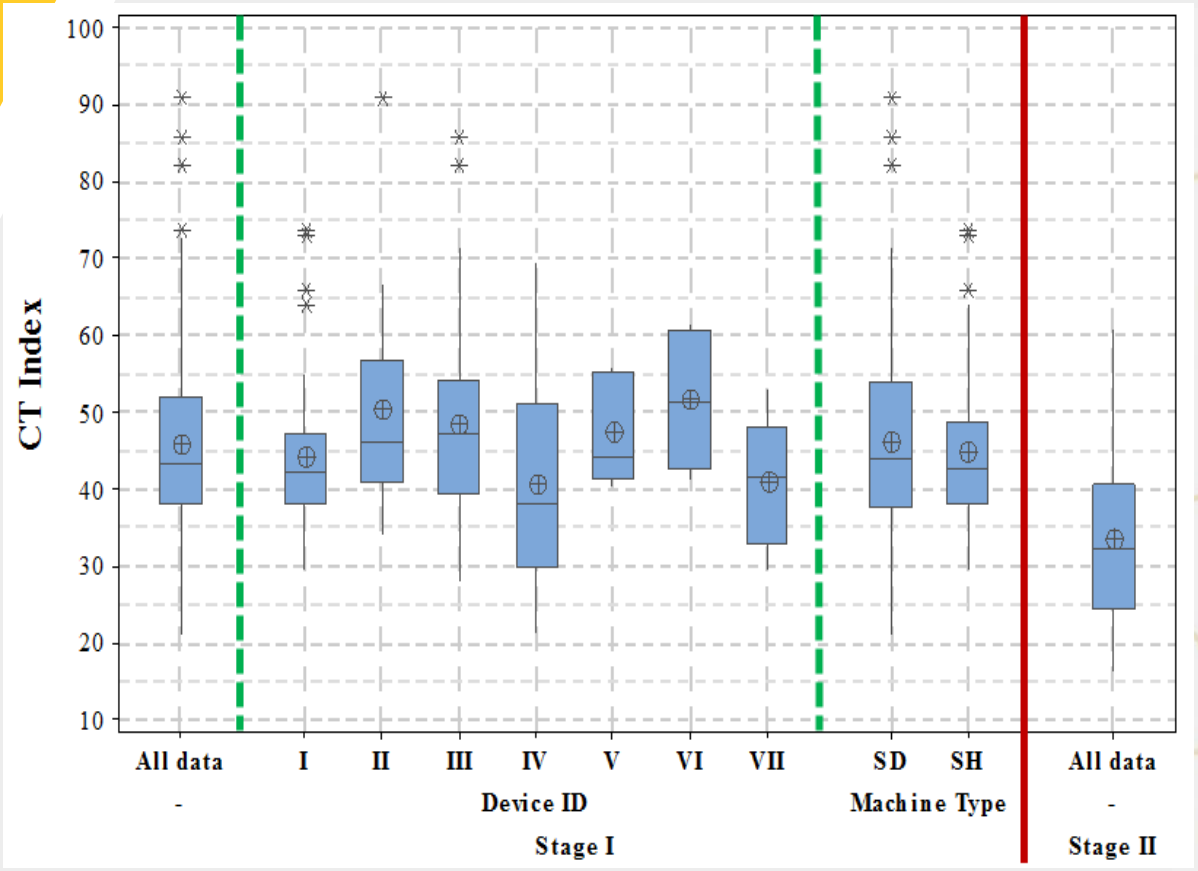
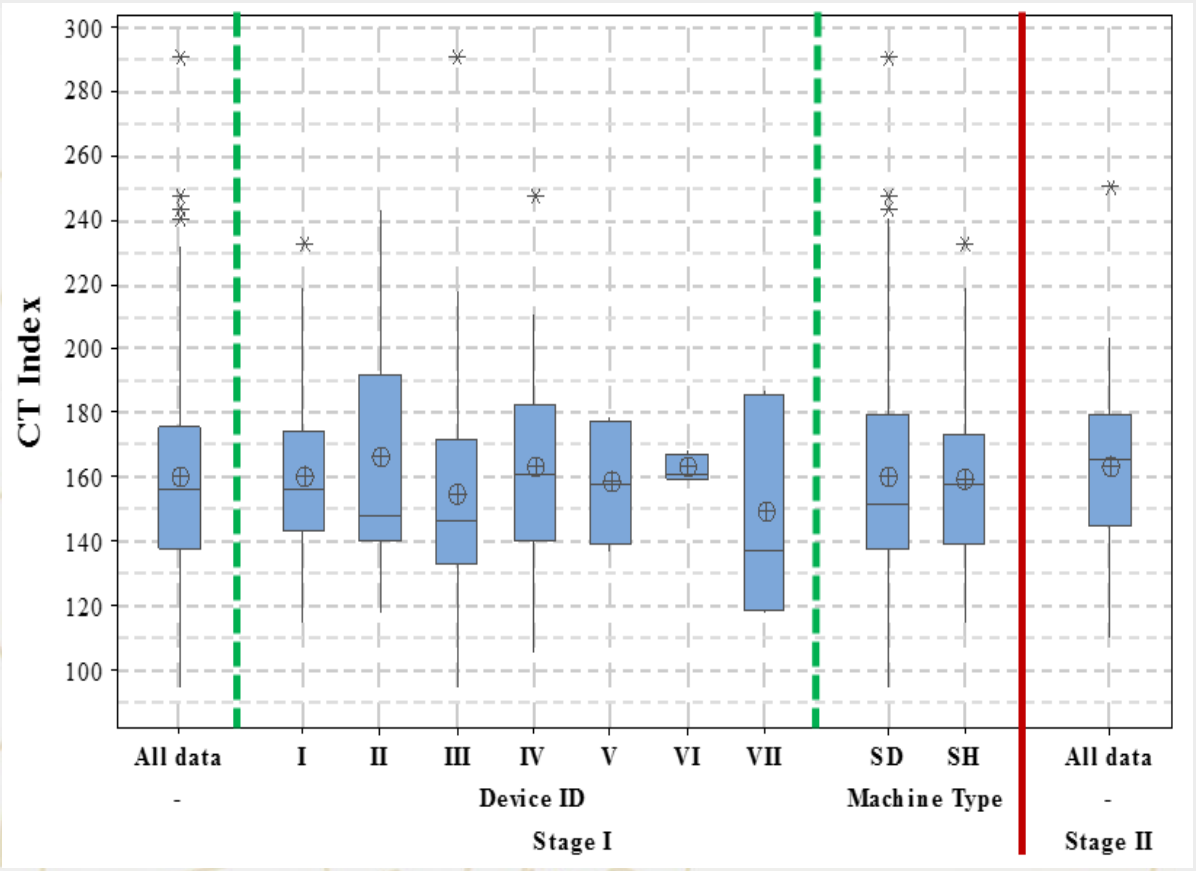
Phase I – Impact of Shelf Life on CT index



Mixture A



Mixture B

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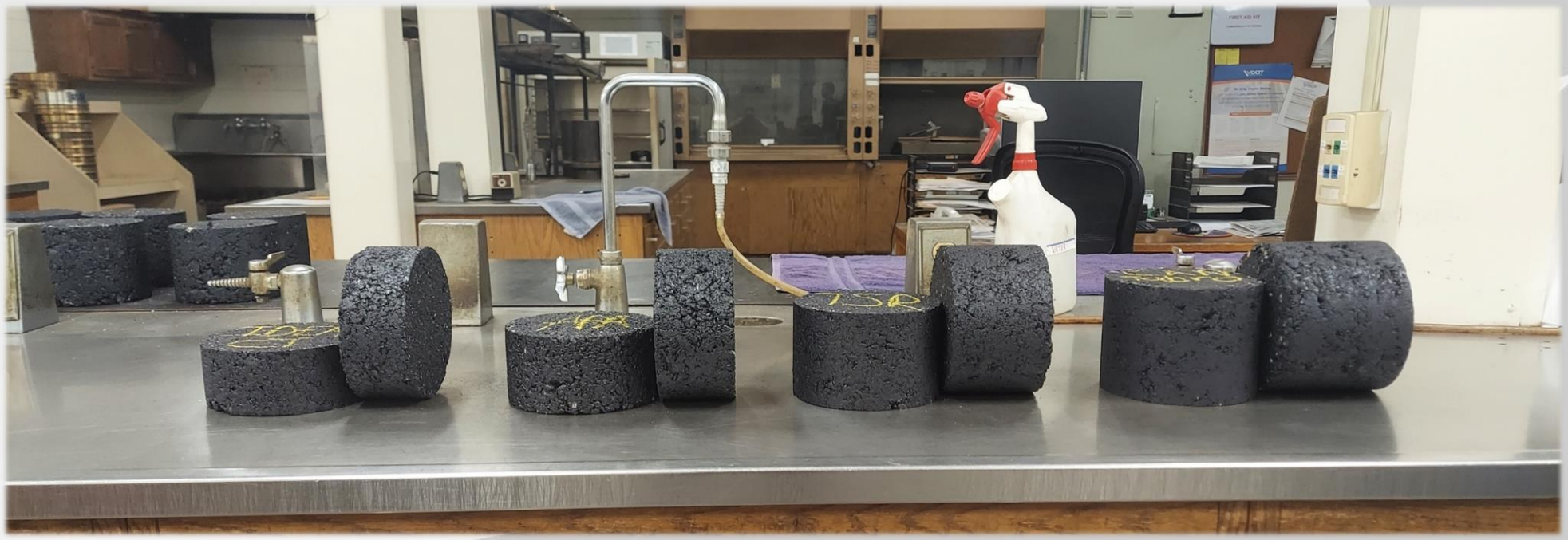
What Do We Need More?

- **Is Phase I *ENOUGH* for *Fair* Implementation**
  - What about the variability induced due to specimen preparation??



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Phase II – Objectives

- **Stage 1 - Assess the impact of variability induced because of specimens preparation**
  - ➢ Evaluate the impact of generating a smaller number of replicates
- **Stage 2 - Assess the impact of specimen conditioning (dry vs. wet)**
  - ➢ Evaluate the feasibility of performing IDT-CT on wet specimens
- **Stage 3 - Assess the impact of loading rate and data collection frequency on the test results.**

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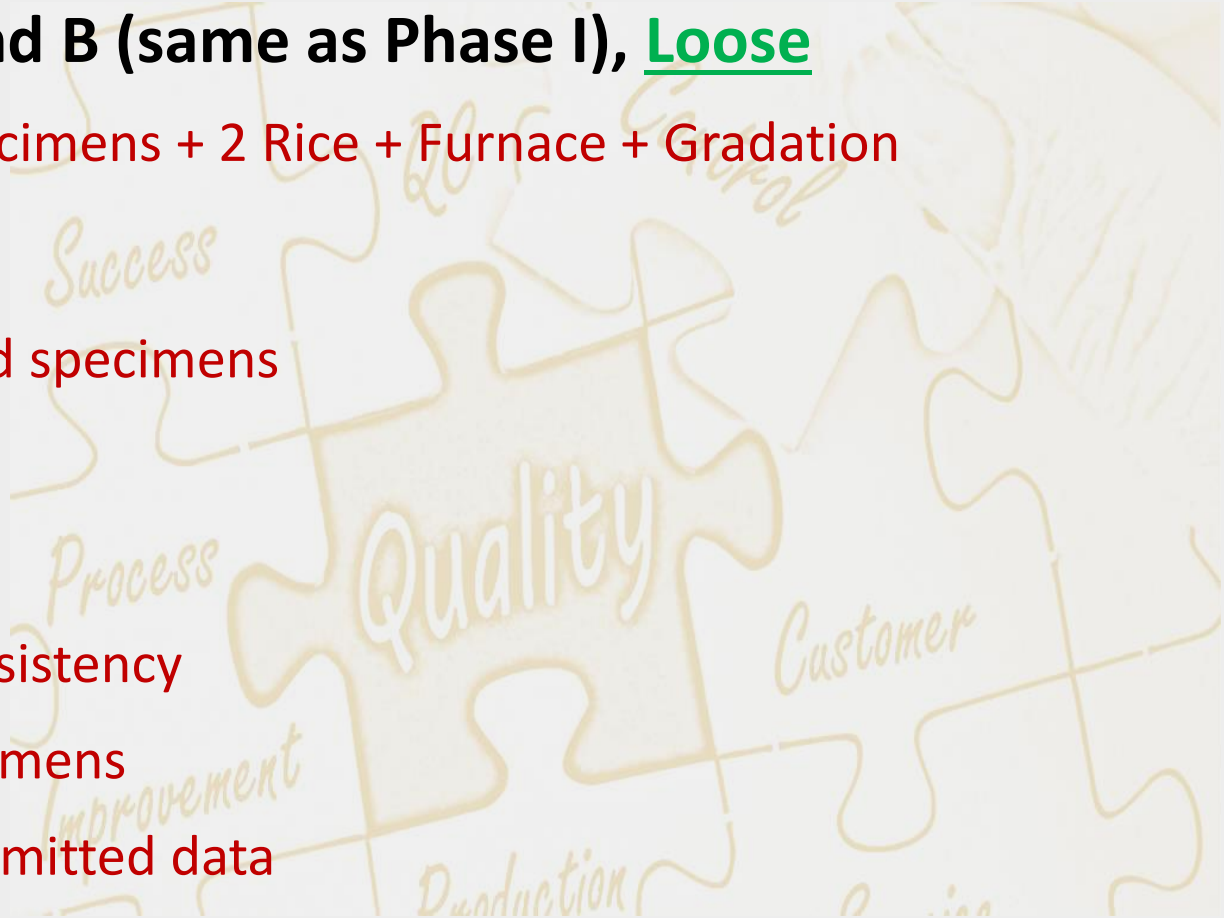
Phase II.1 – Experimental Program

- **Evaluated Mixtures: Mixture A and B (same as Phase I), Loose**
  - Compact at least 5 IDT-CT good specimens + 2 Rice + Furnace + Gradation
- **Participants**
  - 50 participants and 55 sets of tested specimens
    - 3 laboratories with multiple devices
- **Data collection**
  - Testing instruction provided for consistency
  - Testing was performed on **dry** specimens
  - Data quality was checked for all submitted data



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Phase II.1 – Status of Submitted Data

- **Machine-related issues: 4 datasets (7%)**
- **No raw data: 3 datasets (5%)**
- **Did not meet ASTM D8225: 7 datasets (13%)**
- **Testing Instructions**
  - Loading rate **outside** 50 ± 2 mm/min: **12 datasets (21%)**
  - Loading rate **within** 50 ± 2 mm/min: **30 datasets (54%)**

→ **Phase I vs. Phase II: improvement in the quality of collected data**

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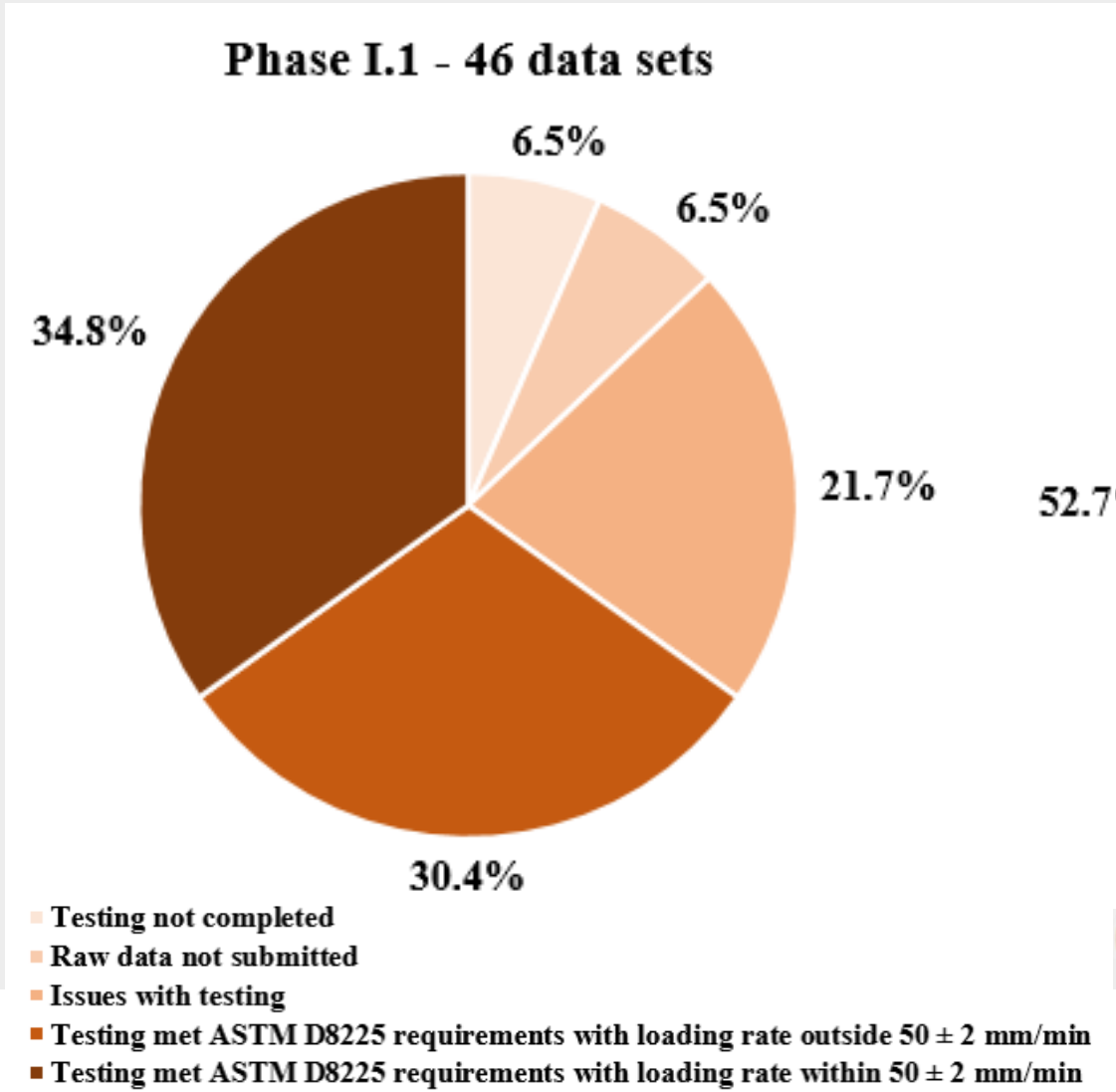
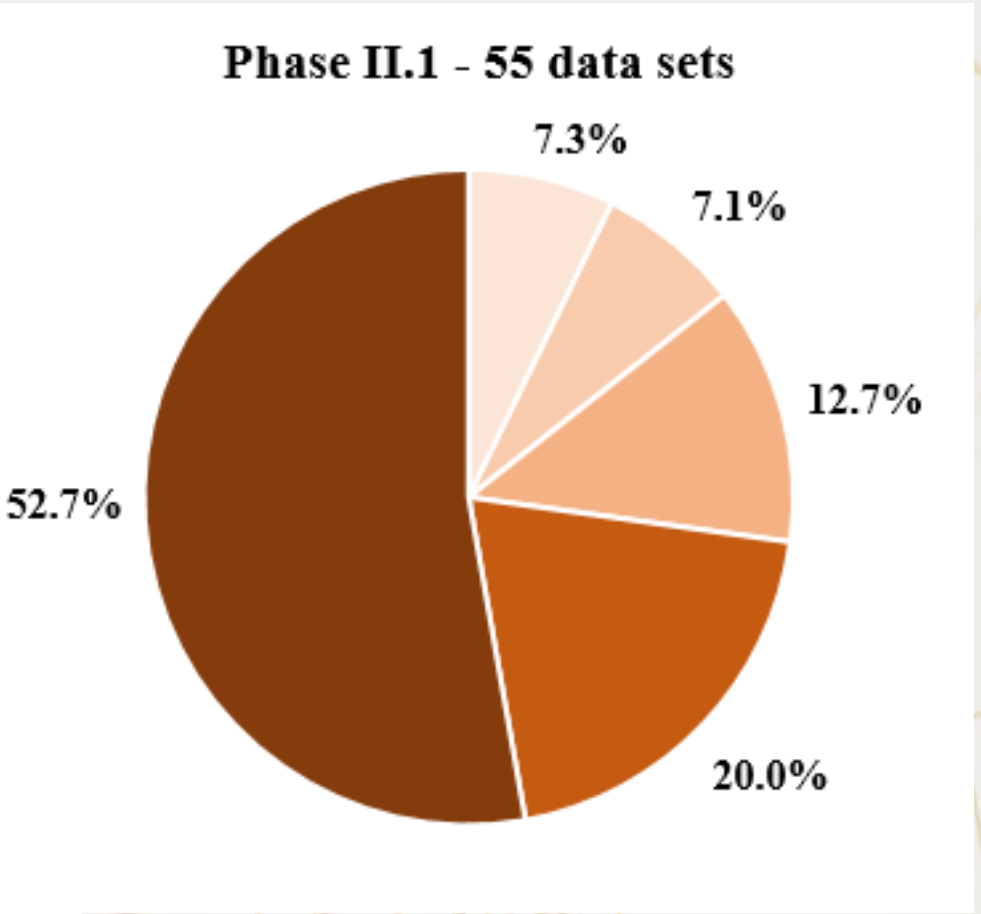
Phase I.1 vs. Phase II.1 - Status





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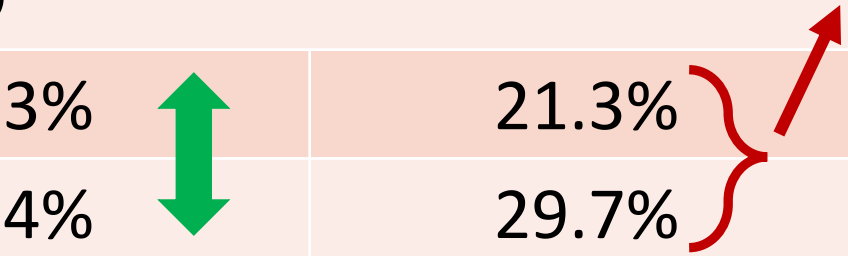
Phase II.1 – Precision Estimates

Study		Precision Estimates, COV, %	
		Single-Operator	Multi-Operator
Loading rate IN accordance with ASTM D8225-19			
50±2 mm/min	**Phase I**	18.3%	21.3%
	Phase II	20.4%	29.7%
Loading rate NOT in accordance with ASTM D8225-19			
50±3 mm/min	**Phase I**	20.7%	21.9%
	Phase II	20.5%	29.4%



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What if ? - Reduction of Specimen Replicates

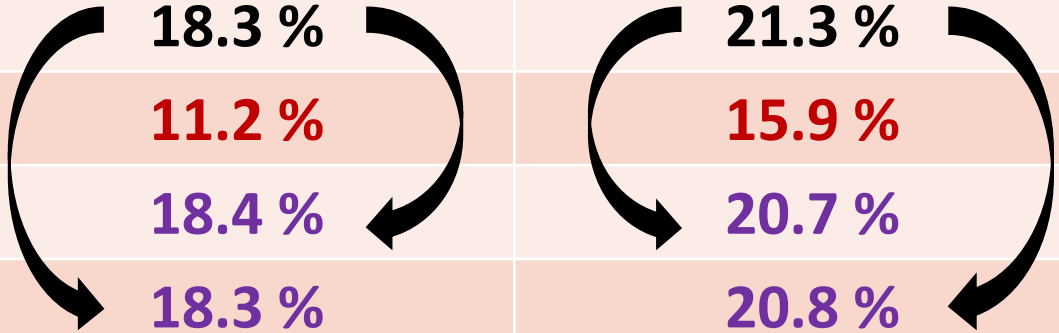
- What if some of the non-reheats QA/QC IDT-CT specimens did not meet 7.0 ± 0.5%?
- What if some of the IDT-CT specimens were mishandled and damaged at any point?
- What if there were machine- and/or operator-related issues during testing of the compacted IDT-CT specimens?

→ This could result in specimens sets consisting of fewer than five replicates for Quality Control or Assurance testing

Reduction of Specimen Replicates

- **Impact on Precision Estimates**

Number of Replicates	Description	Precision Estimates, COV, %	
		Single-Operator	Multi- Laboratory
5	Data used as collected	18.3 %	21.3 %
3	After trimming	11.2 %	15.9 %
4	Combinations of 4 of 5	18.4 %	20.7 %
3	Combinations of 3 of 5	18.3 %	20.8 %



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Phase II.2 – Dry vs. Wet Testing

- **Dry Testing**
  - Conditioning in a chamber or leaked proof plastic bags placed in water.
- **Wet Testing**
  - Placing specimens in a water bath for 2 hours, removing, and drying them until they reach saturate surface dry conditions.
- **Experimental Program**
  - Two Mixtures A and B; Specimens prepared by 3rd party laboratory
  - Five participants with ONLY Servo Hydraulic based machines

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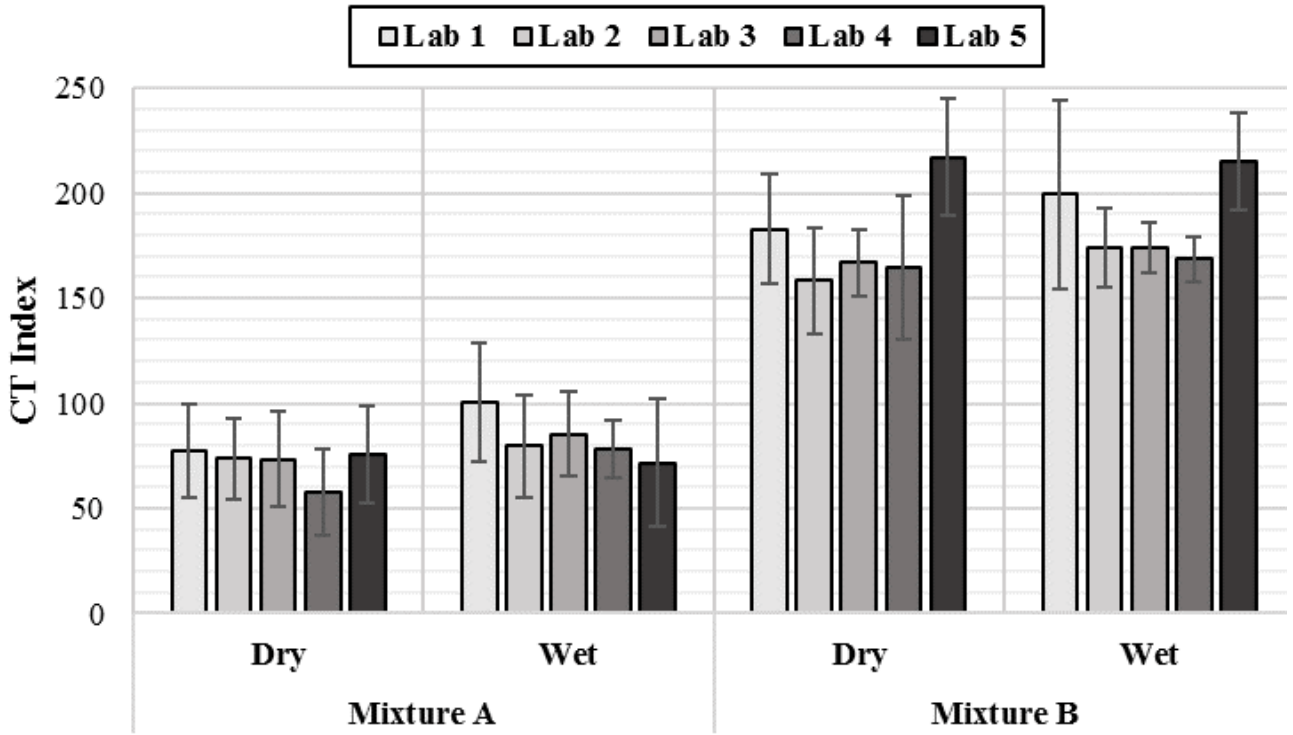
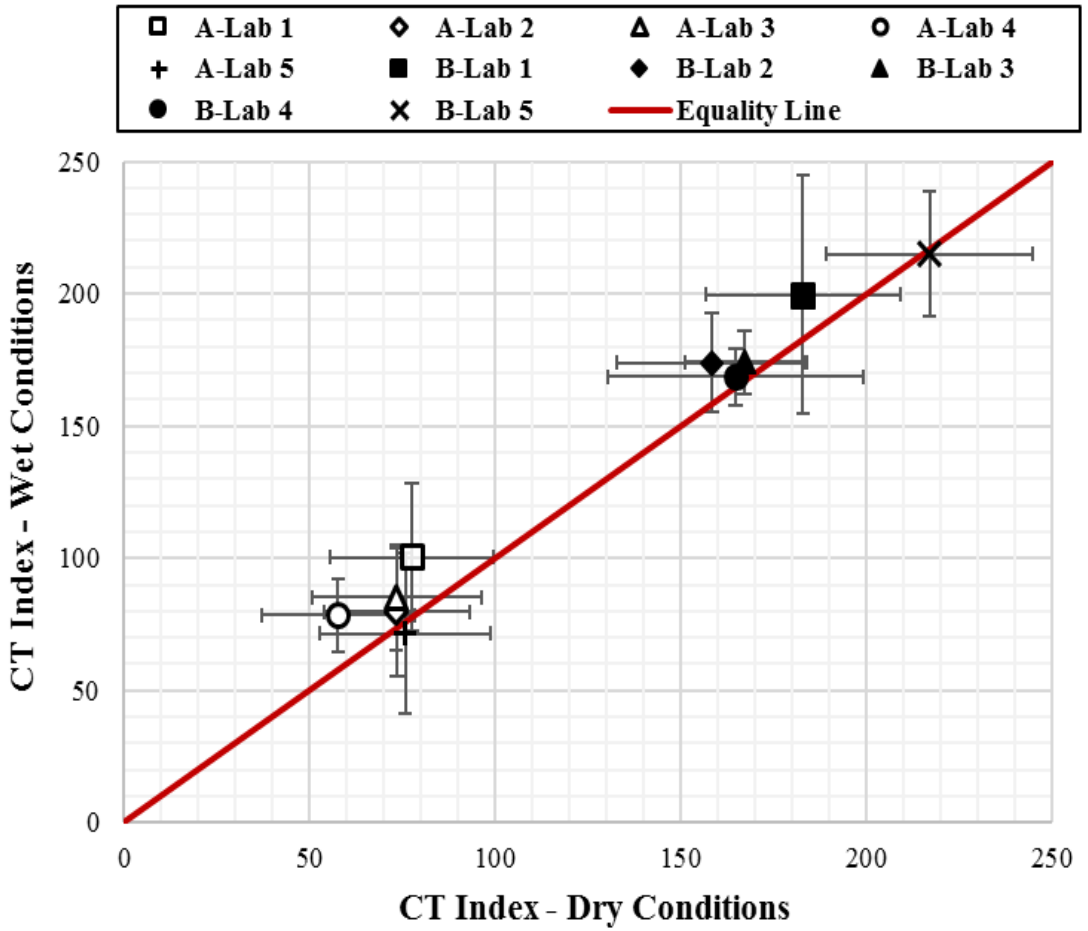
Phase II.2 – Dry vs. Wet Testing





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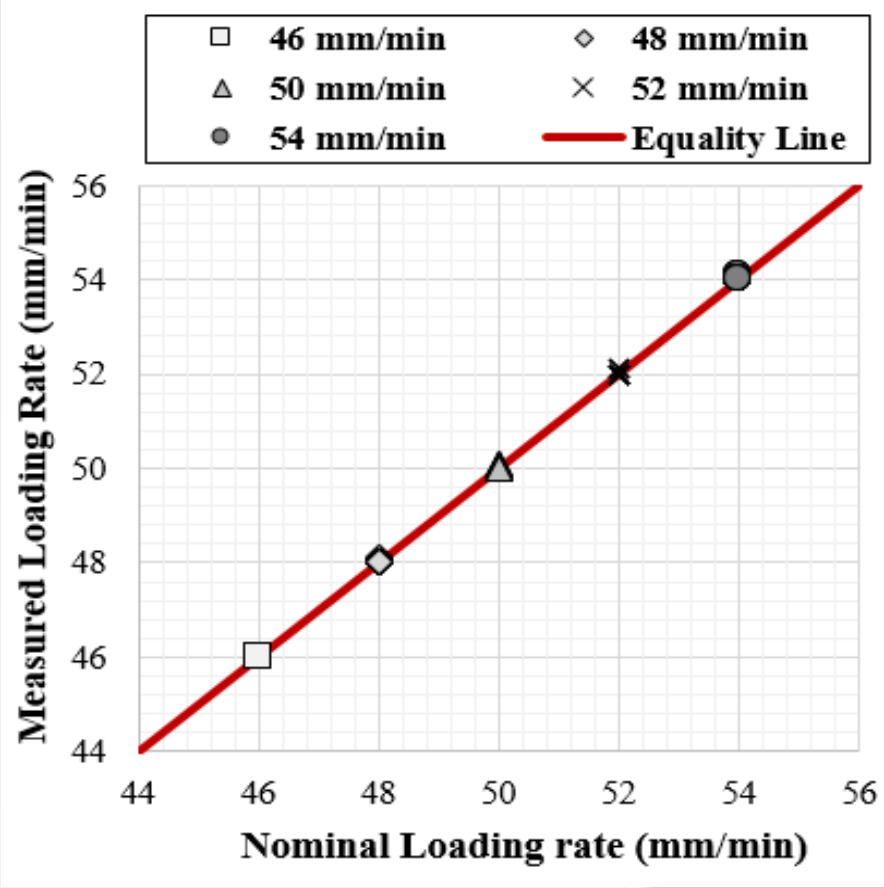
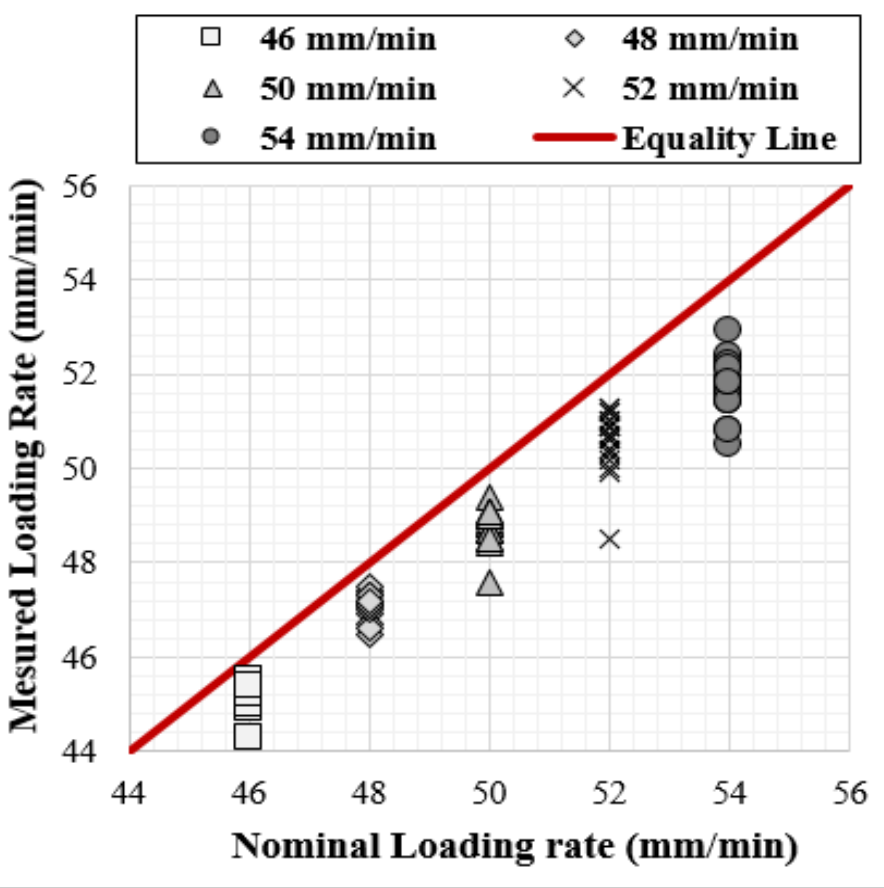
Phase II.3 – Impact of Loading Rate

- **Experimental Program**
  - Four Mixtures A, B, C, and D; Specimens prepared by 3rd party laboratory
  - Five loading rates: 46, 48, 50, 52, and 54 mm/min
  - Servo Hydraulic vs. Screw-Drive machines
  - Multiple frequency to collect data: 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 Hz

Phase II.3 – Impact of Loading Rate

Servo-Hydraulic





Screw-Drive

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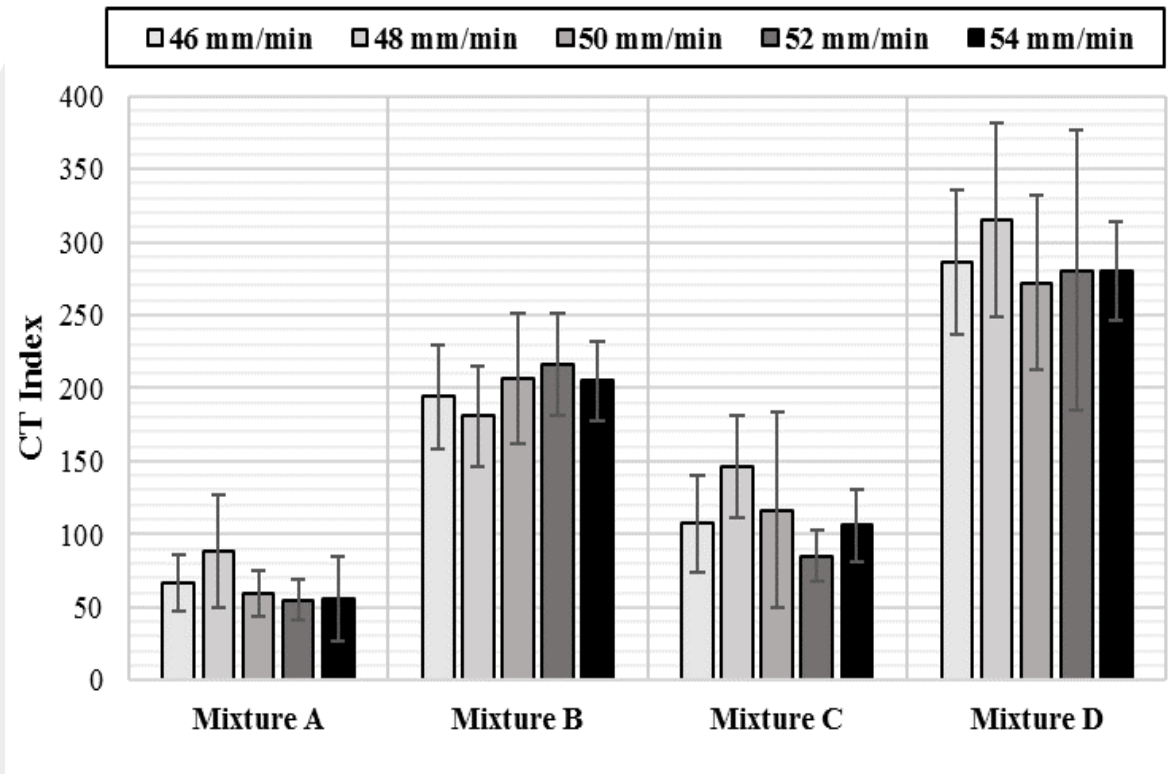
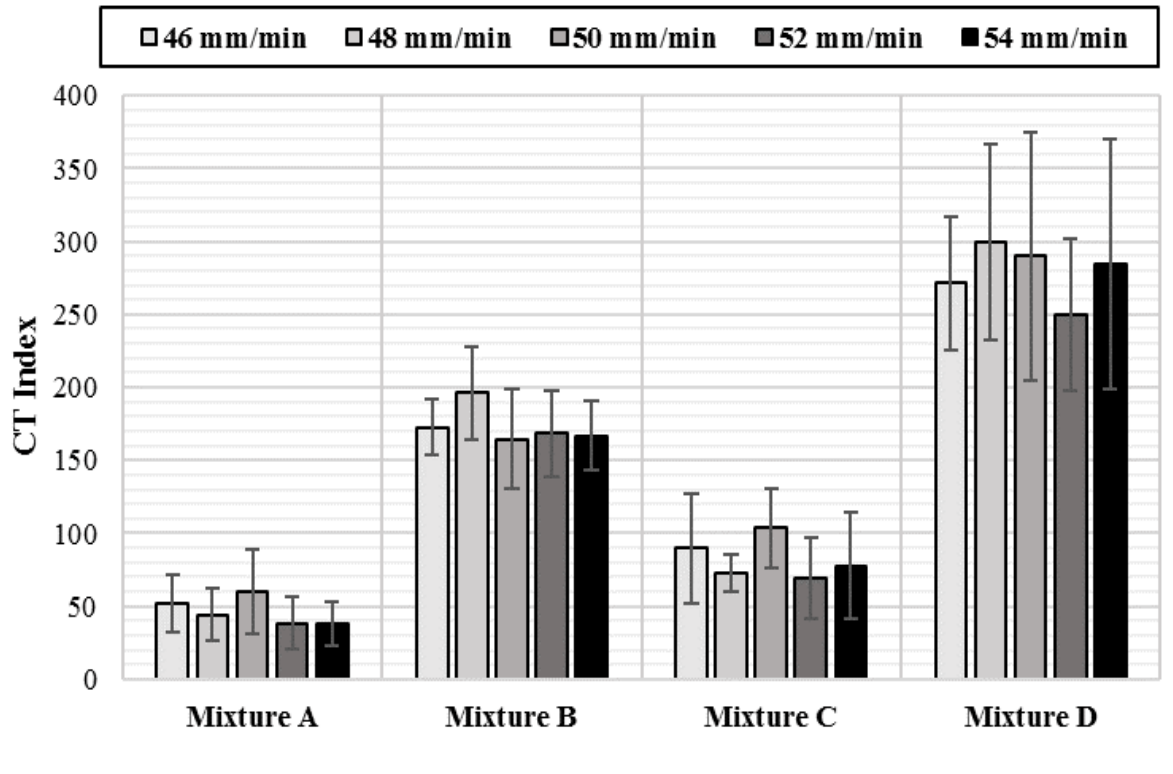
Phase II.3 – Impact of Loading Rate

Servo-Hydraulic



Screw-Drive



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Phase II.3 – Impact of Loading Rate

- **Observations**
  - Servo-hydraulic has better control of loading rate
  - Can widen the **50 ± 2 mm/min** to **50 ± 3 mm/min**
  - No impact on data collection frequency
  - Device type may be a significant factor or mixtures with relatively low CT index values

  → **may raise a significant concern for long-term aged asphalt mixtures**

Numerical Example – Mix Design

Sample ID	Short-Term Aged Specimens			Long-Term Aged Specimens
	OBC – 0.5%	OBC	OBC + 0.5%	OBC
1	71.9	147.4	211.8	40.4
2	109.3	127.6	143.8	41.6
3	53.0	120.2	162.6	38.7
4	70.9	111.4	159.0	35.2
5	41.2	178.7	227.1	24.9
Analysis Using Original Untrimmed Data				
Average CT Index	69	137	181	36
Required Average CT index		70		N/A
Pass/Fail	Fail	Pass	Pass	N/A
COV, %	37.3	19.5	20.1	18.7
Single-Operator COV, %			18.3	
Pass/Fail	Fail	Fail	Fail	Fail

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Numerical Example - Production

Sample ID	Non-Reheated Specimens		Reheated Specimens	
	Contractor	VDOT	VDOT	VTRC
1	176.8	239.7	188.3	121.6
2	198.3	237.5	124.7	110.6
3	210.1	189.7	152.5	141.5
4	195.9	237.9	183.4	150.0
5	175.9	161.0	219.8	225.6
Analysis Using Original Untrimmed Data				
Average CT Index	191	213	174	150
Required Average CT index	95		70	
Pass/Fail	Pass	Pass	Pass	Pass
Single-Operator COV, %	7.7	16.9	20.9	30.1
Required Single-Operator COV, %	18.3			
Pass/Fail	Pass	Pass	Fail	Fail
Multi-Laboratory COV, %	3.8		5.3	
Required Multi-Laboratory COV, %	21.3			
Pass/Fail	Pass		Pass	

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Keys Take Away

- Perform IDT-CT testing according to ASTM standard
  - Data quality check is very important !!!
- "Variability" of performance testing is very important during both mix design and production stages.
- No difference between IDT-CT testing on "Dry" vs. "Wet" .
- Allowable loading rate can be extended to 50 ± 3 mm/min
- Hands-on training and workshops are always needed!

Questions?!

Jhony.habbouche@vdot.virginia.gov

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