Diving into the Data

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Jointly sponsored By VAA, VTRC and VDOT

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Shooting Range Practice

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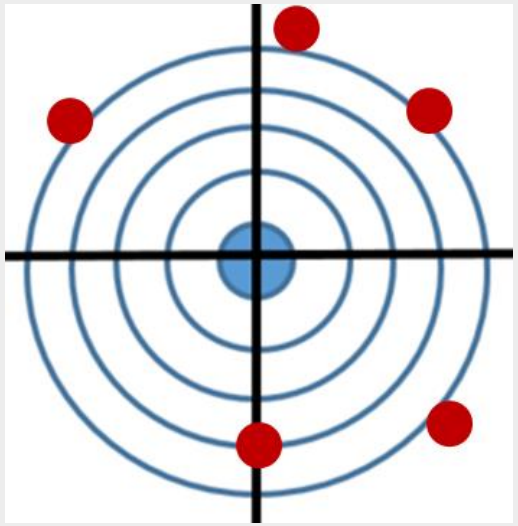

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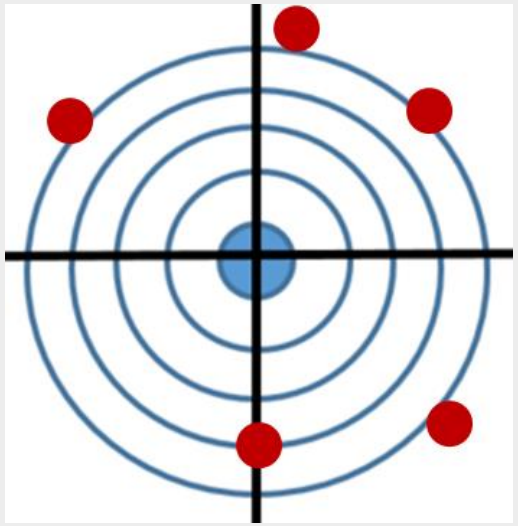
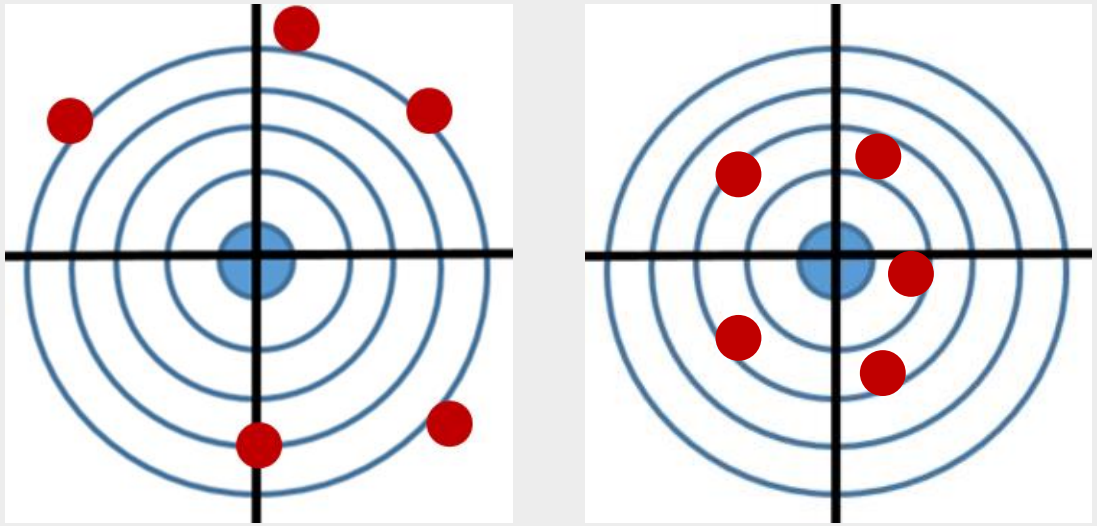


Poor Precision
Poor Accuracy

Shooting Range Practice



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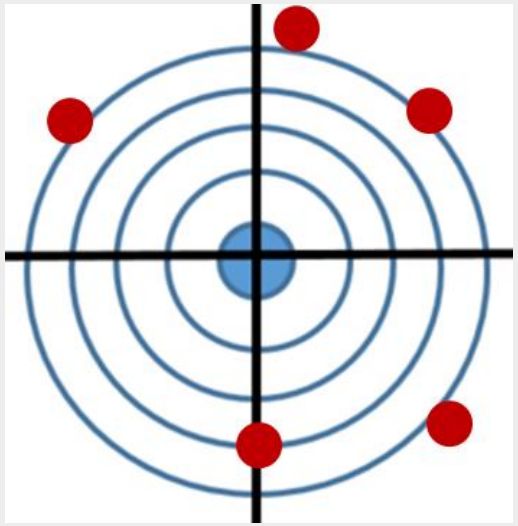

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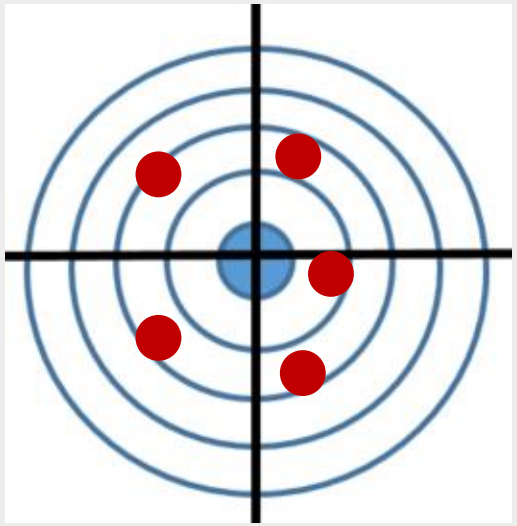

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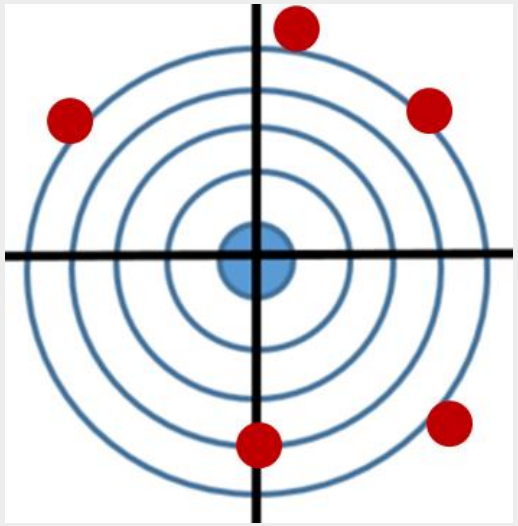

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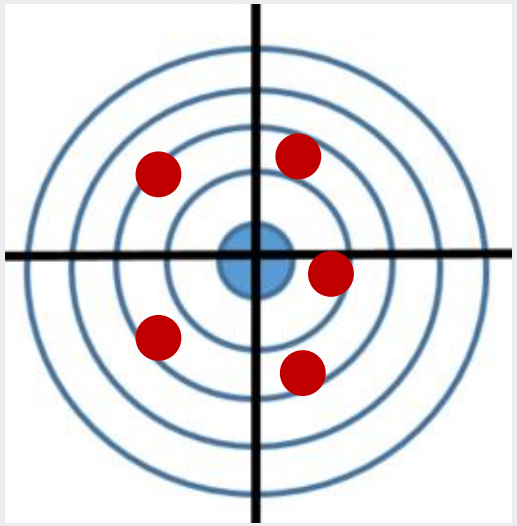

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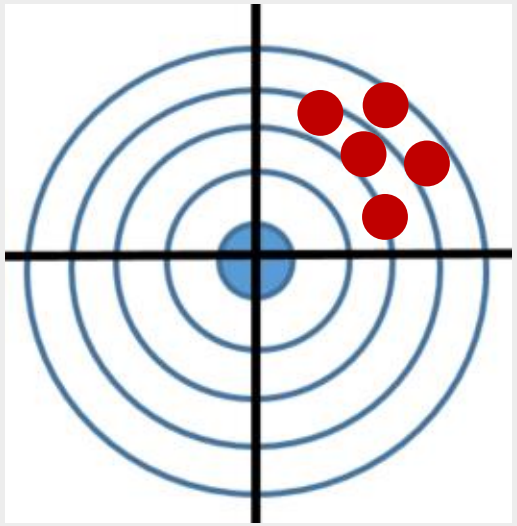

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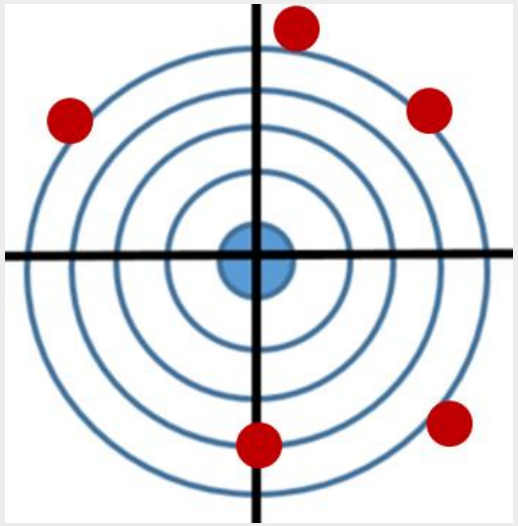

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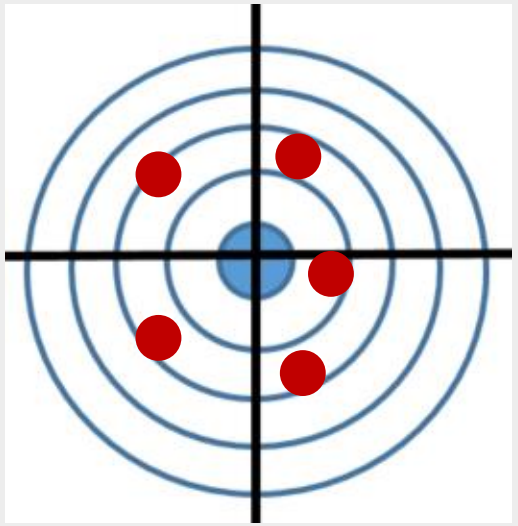

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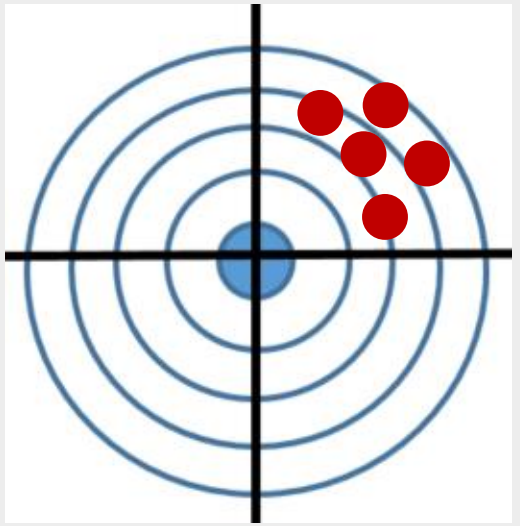

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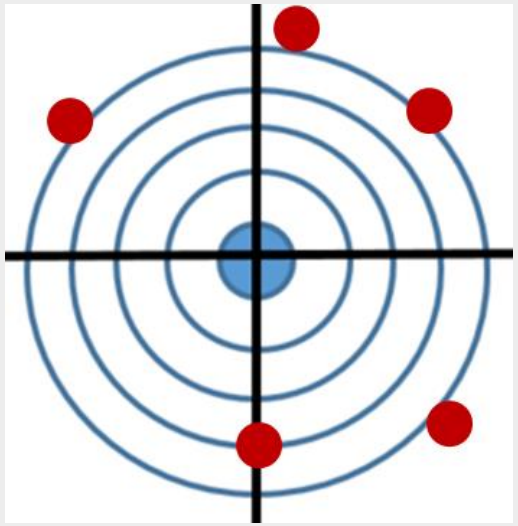

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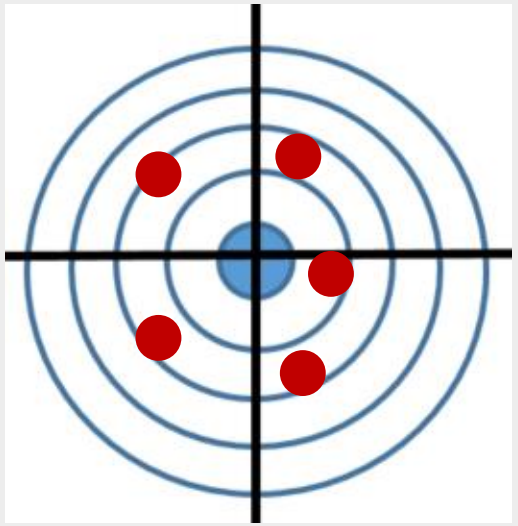

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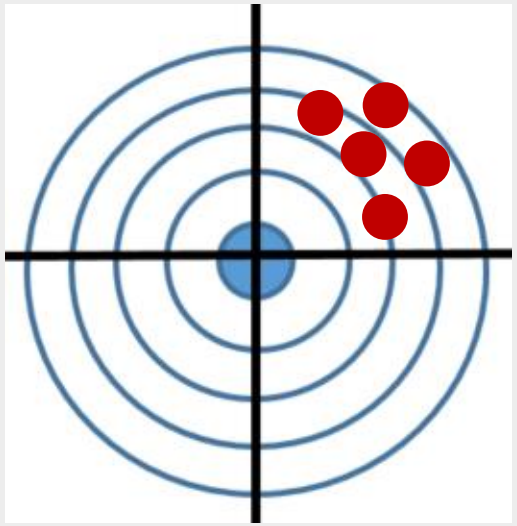

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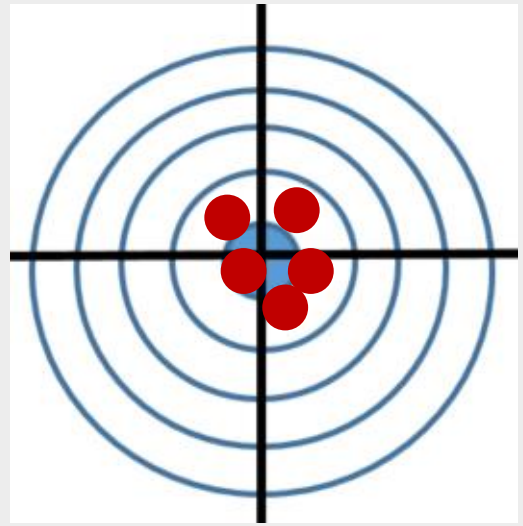

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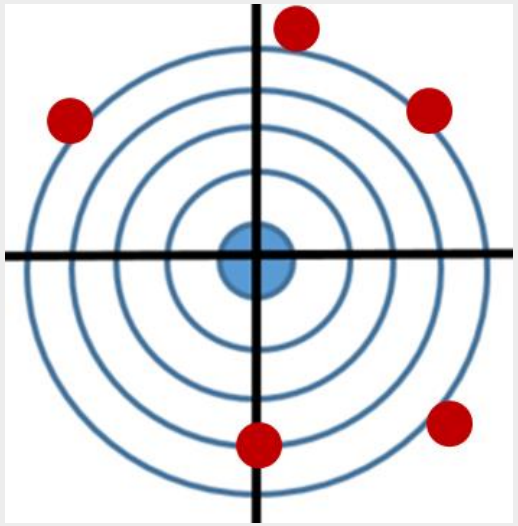

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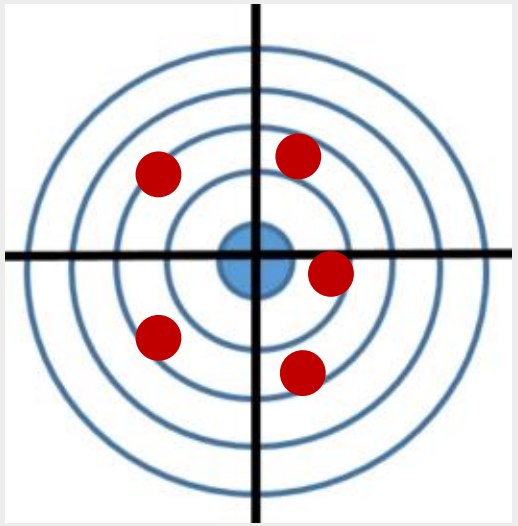

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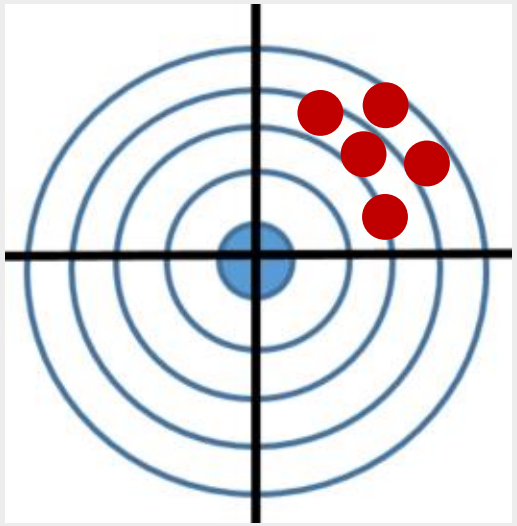

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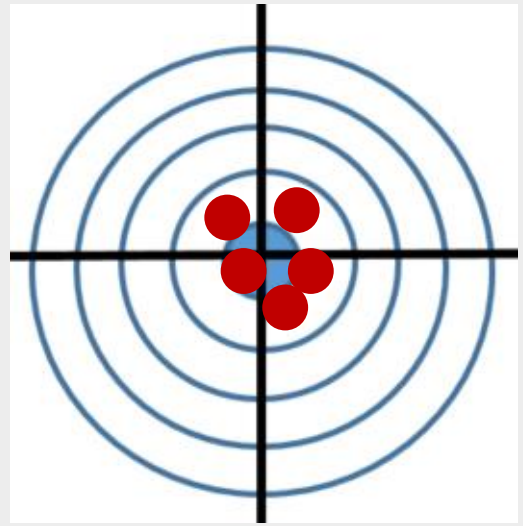

Good Precision
Good Accuracy

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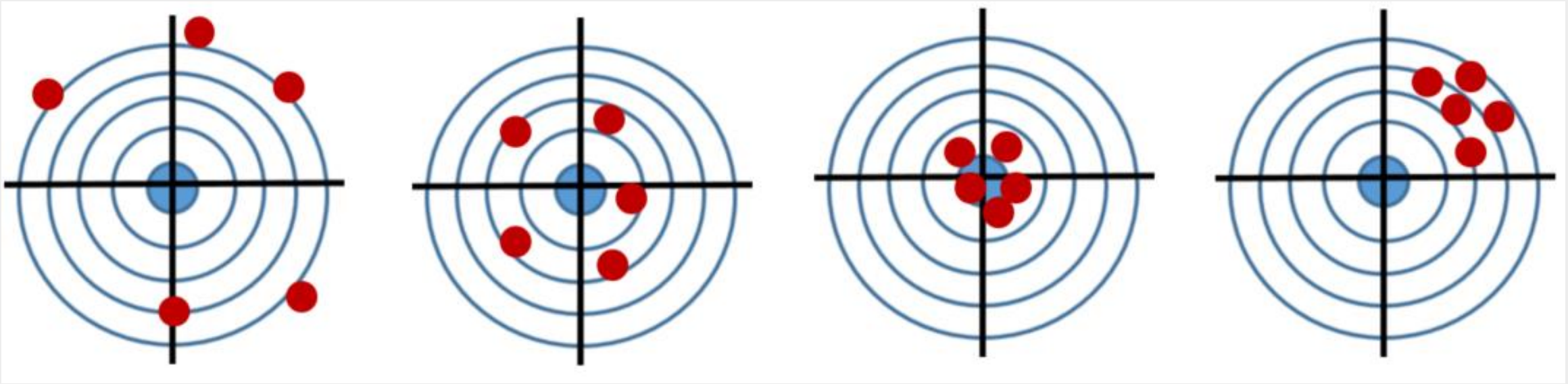
Shooting Range Practice

- Need to quantify the precision (repeatability and reproducibility)!



Interlaboratory (Round Robin) Study

A designed practice to obtain precision estimates for a test method, involving multiple laboratories, each generating replicate test results on one or more materials

This Presentation

Precision estimates already exist for these parameters!

- To see how precise we are in terms of:
  - Theoretical maximum specific gravity (Gmm)
  - Bulk specific gravity (Gmb)
  - Asphalt content-post ignition
  - Aggregate gradation
- Precision: Repeatability (single-operator) and Reproducibility (multi-lab)
  - Gmm and Gmb
- Consistency (relative to the data)
  - All parameters

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Definitions

- Standard deviation: a measure of variation of a dataset
- Coefficient of variation: a measure of variation of a dataset relative to its average
- Low magnitudes indicate the values are close to the average

Single-operator Precision (Repeatability)

- Single-operator indexes of precision
  - Standard deviation (1s) or coefficient of variation (1s%)
  - Standard deviation (d2s) or coefficient of variation (d2s%)
- Indication of variability of a group of test results by the same operator on the same/identical test specimens
- Guide to acceptable performance for workmanship/materials quality

Multi-laboratory Precision (Reproducibility)

- Multi-laboratory indexes of precision
  - Standard deviation (1s) or coefficient of variation (1s%)
  - Standard deviation (d2s) or coefficient of variation (d2s%)
- Indication of the variability of a group of test results obtained by different laboratories for identical test specimens
- Guide to acceptable performance for workmanship/materials quality

Precision Indexes

The difference limit (d2s or d2s%) are usually used as the appropriate index of precision!

- 1s: Standard deviation repeatability or reproducibility
- 1s%: Coefficient of variation repeatability or reproducibility
- d2s: the maximum acceptable difference between **two** results
- d2s%: the maximum acceptable difference between **two** results as a percentage of their average

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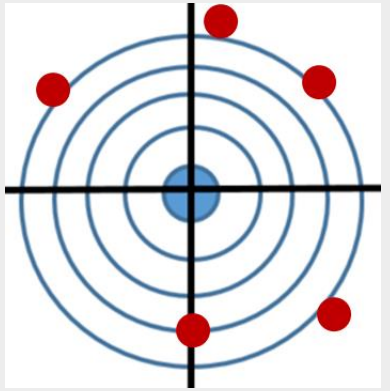
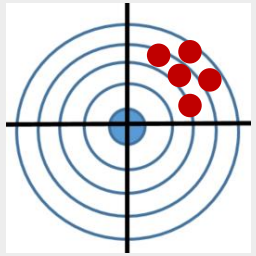
Exceeding Precision Estimate Limits

- Error has occurred if the limits exceeded, review circumstances:
  - Material heterogeneity
  - Sampling variability
  - Test method variability (equipment maintenance and calibration, environment etc.)
  - Operator variability



- Consistent (single-operator) but erroneous results: uniform misunderstanding of instructions, incorrect specimen preparation, and maladjustment of equipment



- Hitting the 5% probability being outside of the limits

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Example Statement

Single-Operator Precision—The single-operator coefficient of variation was 18.3%. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ from each other by more than 51.1%[A] of their average.

Multi-Laboratory Precision—The multi-laboratory coefficient of variation was 21.3%. Therefore, results of two properly conducted tests by two different laboratories on specimens of the same material are not expected to differ from each other by more than 59.7%[A] of their average.

[A]These numbers represent the difference limits in percent (d2s%) as described in Practice ASTM C670.

Note X—These precision statements are based on an interlaboratory study that involved 14 laboratories (16 data sets), two materials with CT index values ranging from 44 to 162, and five replicate tests per operator.

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Theoretical Max Specific Gravity (Gmm)

- Gmm: Asphalt mixture with no air voids
- Performed as per AASHTO T209 or ASTM D2041 (both has PEs)
- VDOT requires multi-laboratory standard deviation of 0.024 (d2s)

*Pictures from pavementinteractive.org

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Interlaboratory Study (ILS) for Gmm

- 47 Laboratories: DOT, Contractor, University, and Consultant
- Two dense-graded mixtures with Gmm of 2.499 and 2.713
- Two replicates

*Pictures from pavementinteractive.org

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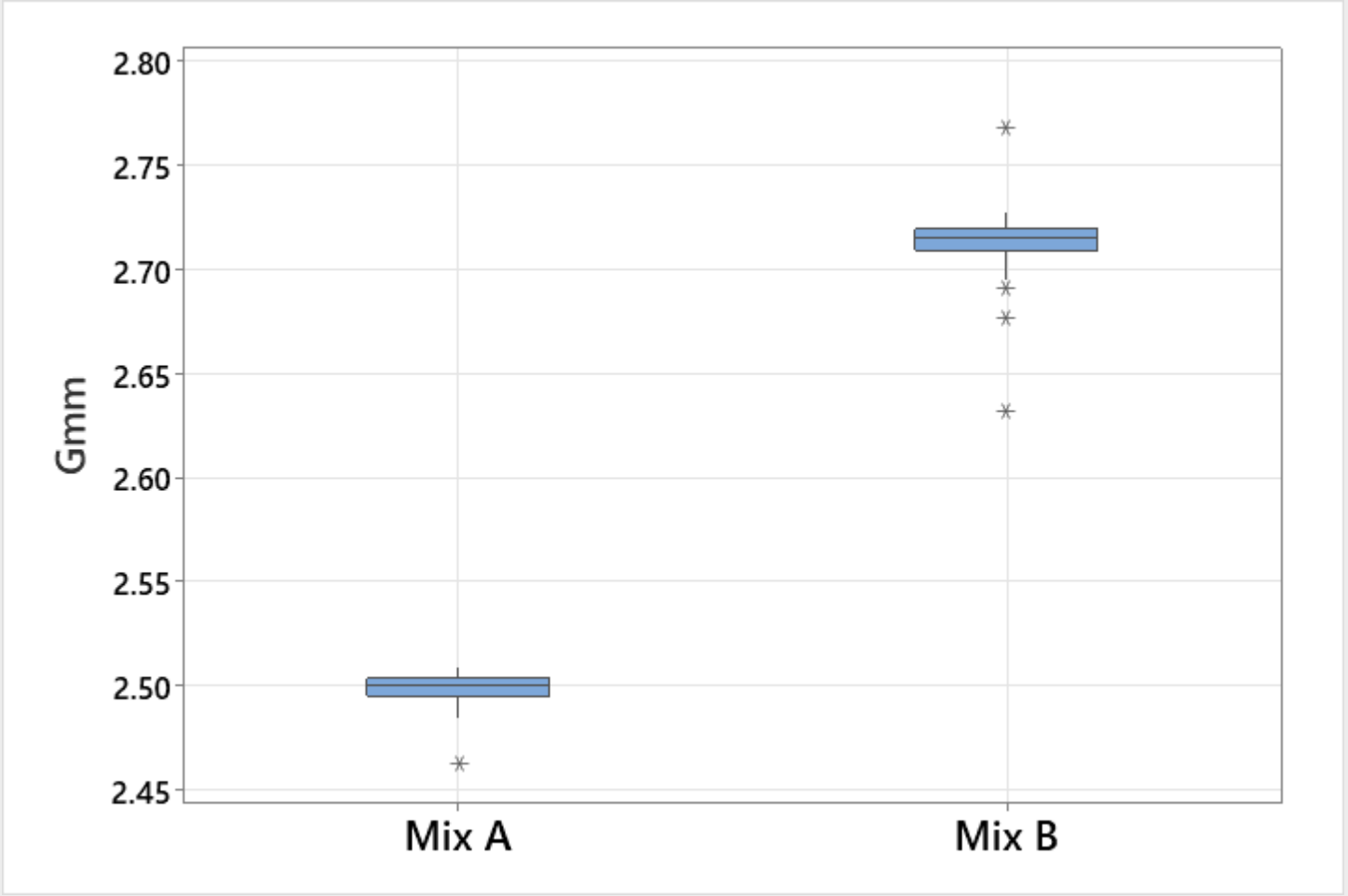
Data Range



Consistency

- Inconsistent labs within the dataset

Back to the Basics					
Within Lab			Between Labs		
Mix A	Mix B	Both	Mix A	Mix B	Both
P15	P20	-	P51	P20; P51	P51

Precision Estimates

- Gmm: Based on standard deviation

References	Back to the Basics		VDOT		AASHTO T209	
Type Index	**1s**	**d2s**	**1s**	**d2s**	**1s**	**d2s**
Single-operator precision	0.0050	0.0139	N/A	N/A	0.0046	0.0131
Multi-laboratory precision	0.0082	0.0231	0.0086	0.0240	0.0068	0.0193

- T209: 4 to 4.8% asphalt content

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Single-operator Variability

- Labs exceeding single-operator PE (1s) as per AASHTO T209

29.8% for Mix A

38.3% for Mix B

14.9% for Both

Mix A		Mix B		Both
P2	P40	P1	P21	P2
P11	P47	P2	P27	P15
P12	P49	P6	P28	P20
P15	P50	P7	P35	P21
P20	P51	P9	P36	P50
P21	P53	P14	P50	P51
P37	P55	P15	P51	P55
		P16	P52	
		P20	P55	

Mix B
Higher AC (5.8%)
Higher Agg. SG
12.5 NMAS

Is PE from T209 applicable here?

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Single-operator Variability

- Labs <u>exceeding</u> single-operator PE (1s) as per <u>back to the basics</u>

27.7% for Mix A

31.2% for Mix B

12.7% for Both

Mix A		Mix B		Both
P2	P50	P1	P27	P2
P11	P51	P2	P28	P15
P12	P53	P6	P36	P20
P15	P55	P7	P50	P21
P20		P9	P51	P50
P21		P15	P52	P51
P40		P16		
P47		P20		
P49		P21		

Mix B
Higher AC (5.8%)
Higher Agg. SG
12.5 NMAS

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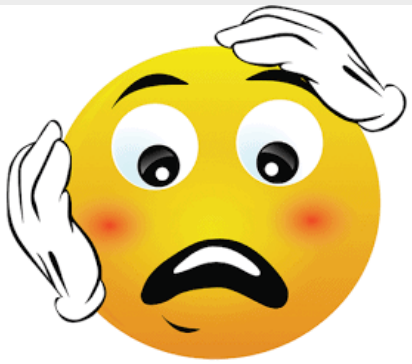
Multi-laboratory Variability

- Labs <u>exceeding</u> multi-lab PE (d2s) as per <u>VDOT limit</u> (0.024)

Mix A	Mix B		Both
P51	P20	P49	P51
	P39	P51	

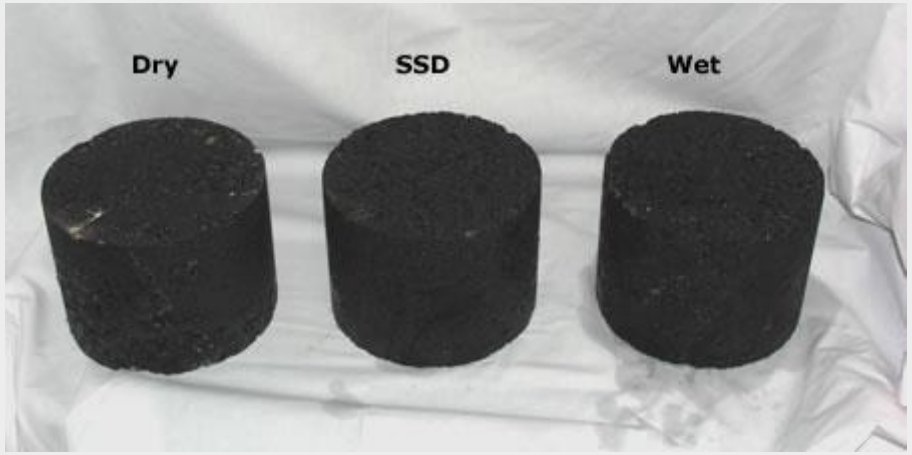


Extent of Precision Estimates

- Gmb = 2.327, Gmm = 2.499, Single-operator variability of 0.005:
  - Air void: 6.9% → Lower end: 6.7% and Higher end: 7.1%
- Gmb = 2.327, Gmm = 2.499, multi-lab variability of 0.024:
  - Air void: 6.9% → Lower end: 6.0% and Higher end: 7.8%

Bulk Specific Gravity (Gmb)

- To determine volumetric quantities (e.g. air voids and VMA)
- Performed as per AASHTO T166, T275, T331, and ASTM D2726
- VDOT requires multi-laboratory standard deviation of 0.042 (d2s)



*Picture from pavementinteractive.org

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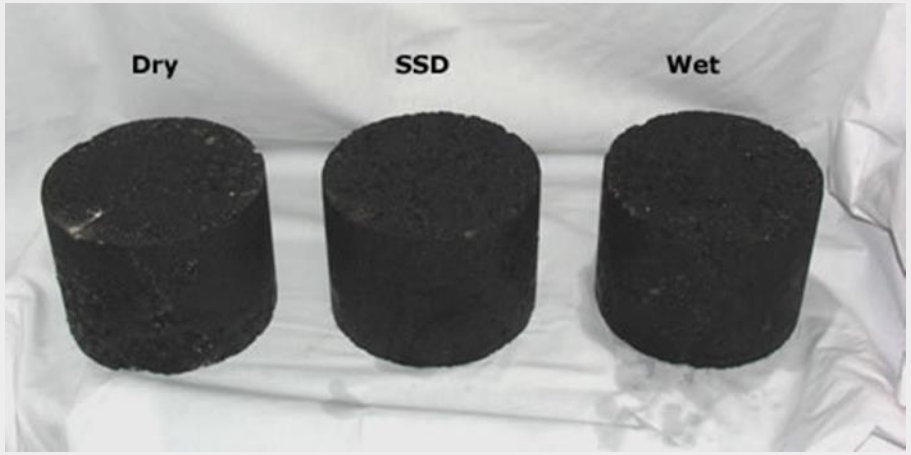
Interlaboratory Study (ILS) for Gmb

- 50 Laboratories: DOT, Contractor, University, and Consultant
- Two dense-graded mixtures with Gmb of 2.326 and 2.528
- Five replicates



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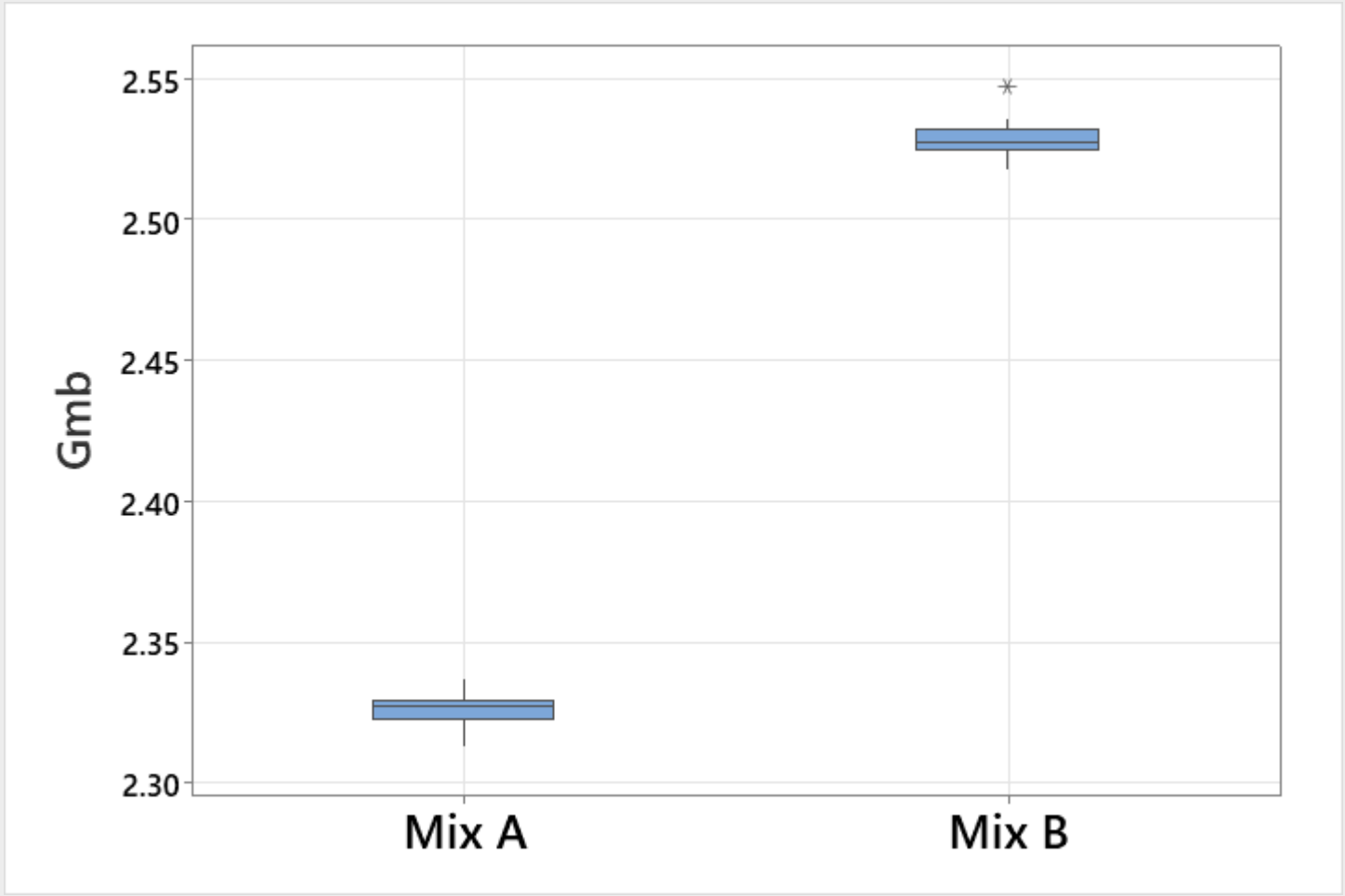

Consistency

- Inconsistent labs within the dataset

Back to the Basics					
Within Lab			Between Labs		
Mix A	Mix B	Both	Mix A	Mix B	Both
P19	P19; P49	P19	-	P19	-

Precision Estimates

- Gmb: Based on standard deviation

References	Back to the Basics		VDOT		AASHTO T166	
Type Index	**1s**	**d2s**	**1s**	**d2s**	**1s**	**d2s**
Single-operator precision	0.007	0.018	N/A	N/A	0.002	0.006
Multi-laboratory precision	0.008	0.021	0.015	0.042	0.006	0.017

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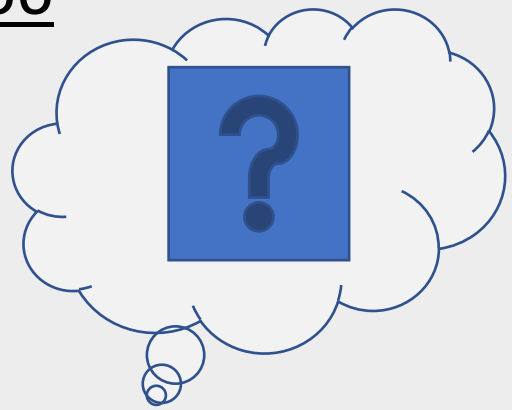
Single-operator Variability

- Labs **meeting** single-operator PE (1s) as per AASHTO T166

Mix A	Mix B	Both
P7; P14; P54	P7; P16; P30	P7



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Single-operator Variability

- Labs **exceeding** single-operator PE (1s) as per back to the basics

34% for Mix A

34% for Mix B

16% for Both

Mix A		Mix B		Both
P5	P32	P17	P39	P17
P8	P37	P18	P40	P18
P9	P39	P19	P41	P19
P10	P40	P20	P43	P39
P17	P43	P21	P49	P40
P18	P44	P23	P50	P43
P19	P49	P24	P52	P49
P25	P50	P33	P55	P50
P28		P36		

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Multi-laboratory Variability

- Labs exceeding multi-lab PE (d2s) as per AASHTO T166 (0.017)
- Reference to the third party lab
- No issues with the VDOT and back to the basics limits!

Mix A	Mix B	Both
-	P19	-

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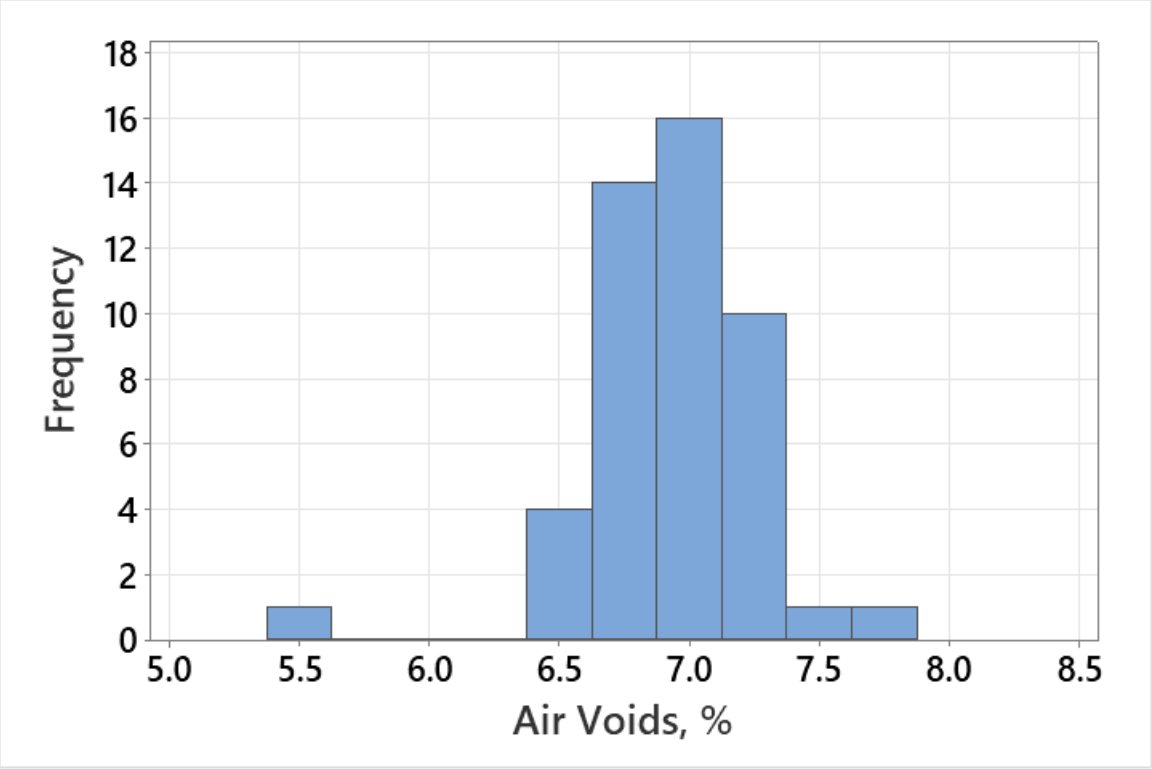
Extent of Precision Estimates

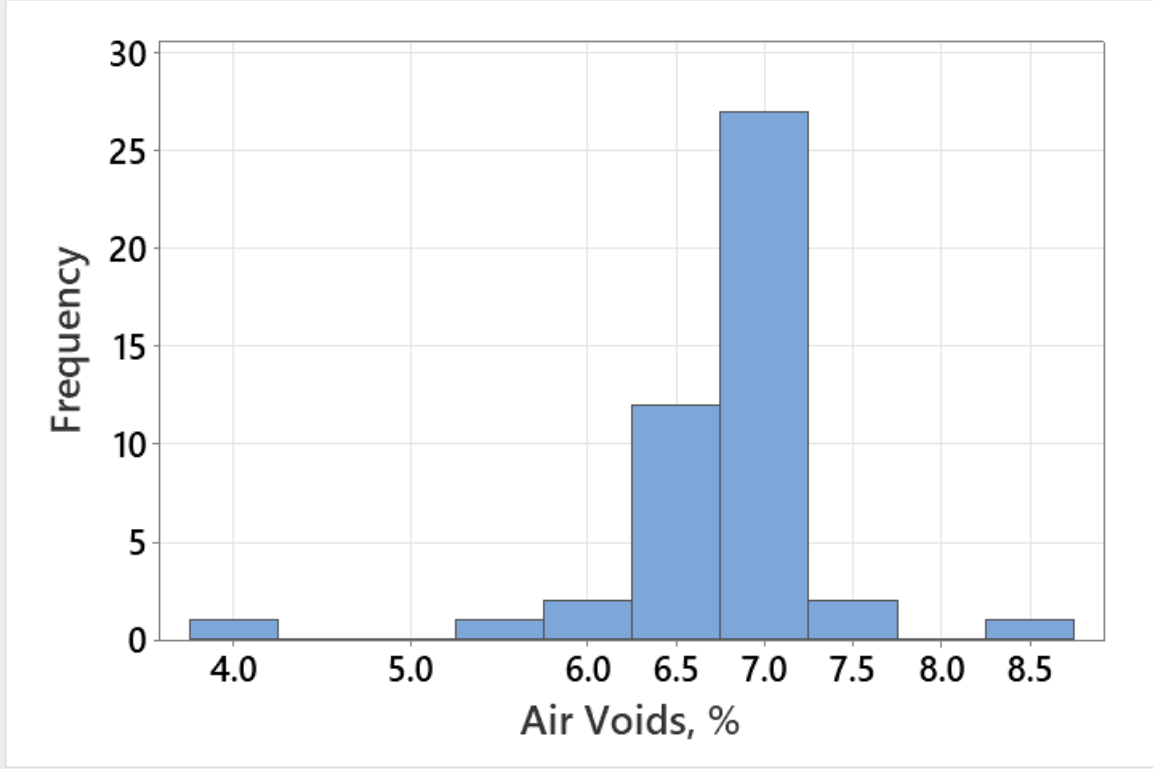
- Gmm = 2.499, Gmb = 2.326, Single-operator variability of 0.007
  - Air void: 6.9% → Lower end: 6.6% and Higher end: 7.2%
- Gmm = 2.499, Gmb = 2.326, multi-lab variability of 0.042:
  - Air void: 6.9% → Lower end: 5.2% and Higher end: 8.6%

Air Voids

Mix A



Mix B



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Air Voids

What about the impact on volumetric properties?

- Labs **exceeding** air void range of 7±0.5%

Mix A	Mix B	Both
P28; P51	P9; P15; P19; P20; P39; P49; P51	P51

4.3% for Mix A

15.2% for Mix B

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Thank you!

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