Aggregate Friction

July 24th, 2024

Materials & Asphalt Technology Research Summit

- Richard Izzo
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Presentation outline

1. Background of the Study
2. Variability Study of Aggregates Friction
3. Friction Characterization of Texas Aggregates
4. Prediction Models of Aggregate Friction

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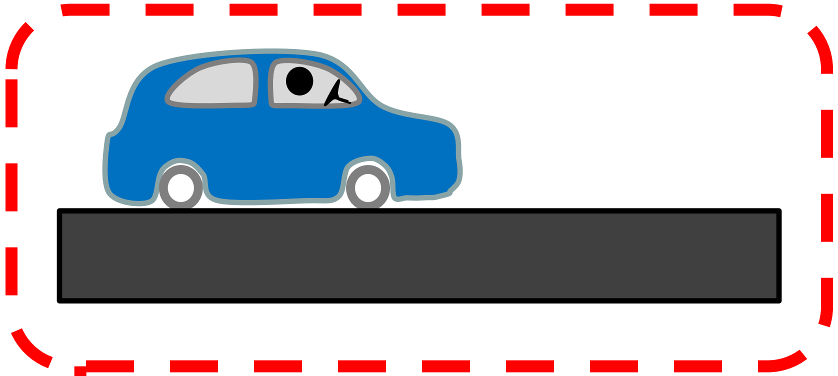
Skid



Surface
(Skid resistance)

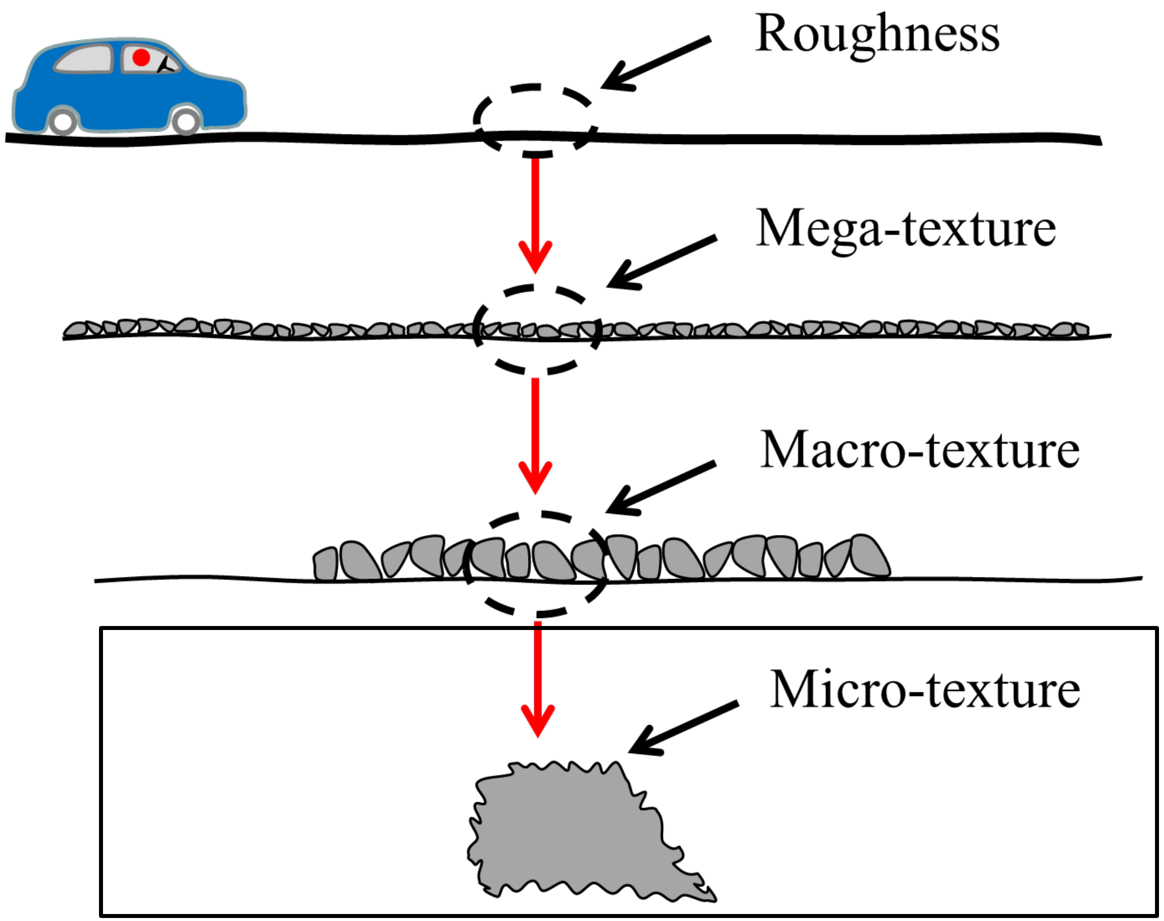
Driver
- Speeding
- Vision
- Condition etc.

Vehicle
- Braking efficiency
- Rubber hardness
- Tire groove depth etc.

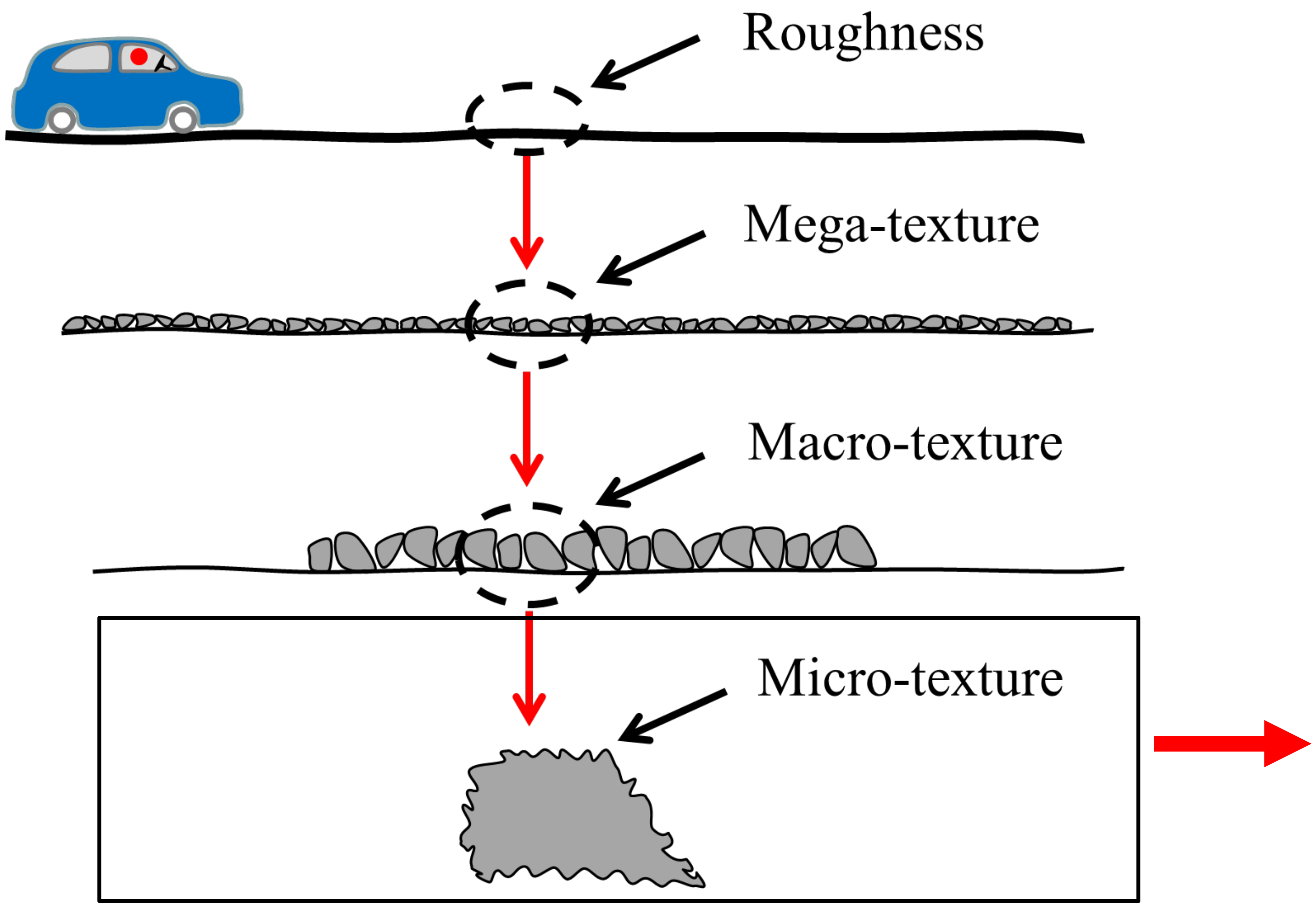
Environmental
- Snow fall
- Rain
- Fog etc.

Geometrical
- Sight distances
- Horizontal curves
- Downward slope etc.

Surface Factors Influencing Skid Resistance

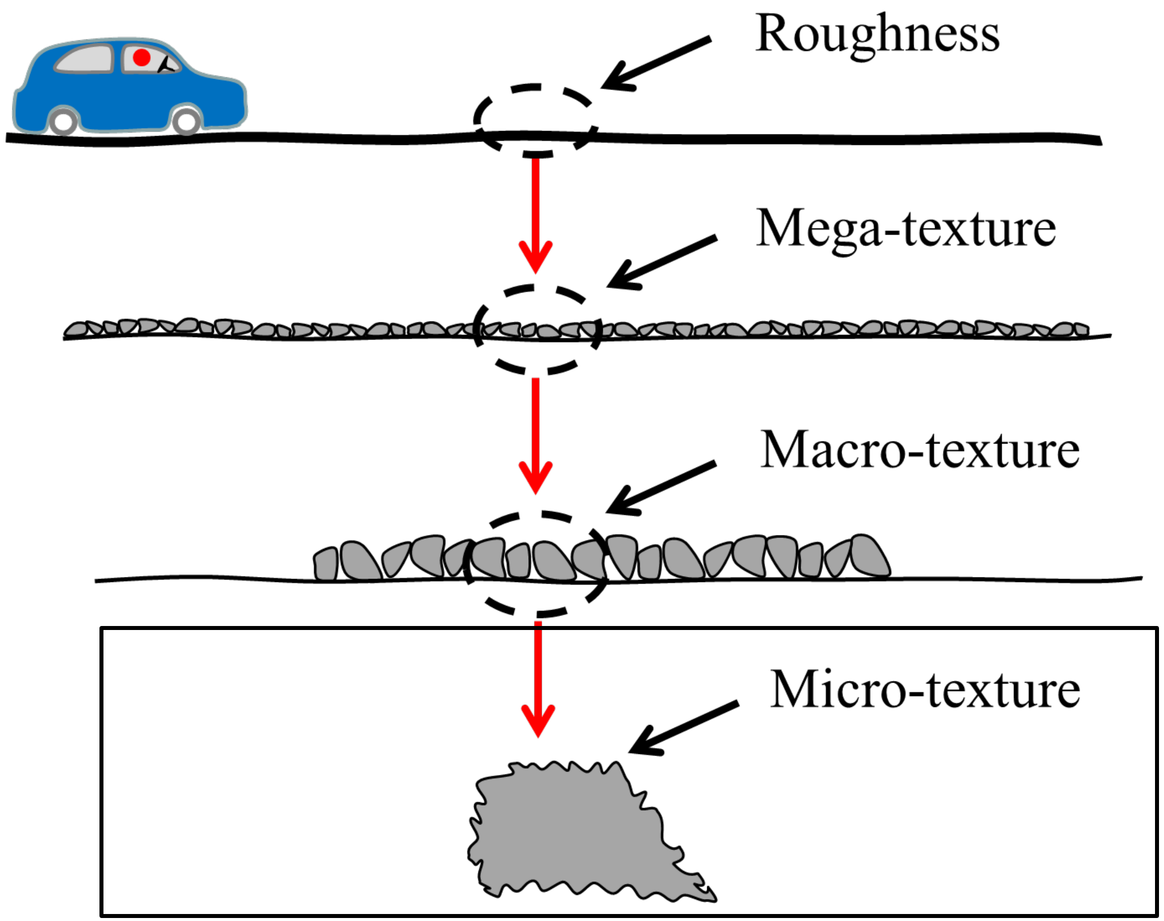


Surface Factors Influencing Skid Resistance



Depends on Aggregate Frictional Resistance

Surface Factors Influencing Skid Resistance



Depends on Aggregate Frictional Resistance

Asphalt mixtures comprise of about 95% aggregates

Advancements in Aggregate Friction Testing

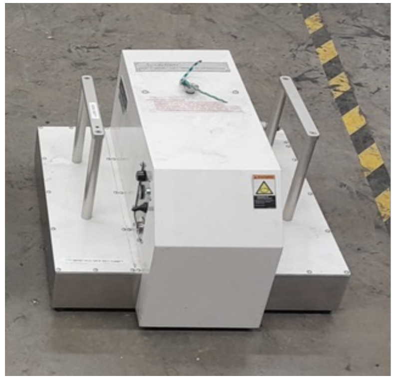
Accelerated aggregate polishing machine along with the British Pendulum Tester (BPT) (20th century)

Issues with BPT:

- Repeatability? depends on experience of person.
- Low test speed (10 km/h)?

Three-wheel Polishing Device (TWPD)

Dynamic Friction Tester (DFT)



Repeatable and test speeds 10 to 90km/h

Advancements in Aggregate Friction Testing

Accelerated aggregate polishing machine along with the Br

(20th century)

Standard Practice for

Sample Preparation and Polishing of Unbound Aggregates for Dynamic Friction Test

AASHTO Designation: PP 103-21 (2022)[1]

AASHTO

Technically Revised: 2021 **Reviewed but Not Updated: 2022**

Technical Section: 1c, Aggregates

1. SCOPE

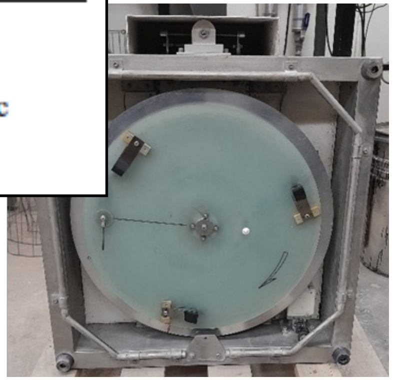
1.1. This method covers the sample preparation and polishing of unbound aggregates for dynamic friction testing using a three-wheel polishing device (TWPD).

Issues with BPT:

- Repeatability? depends on experience of person.
- Low test speed (10 km/h)?

Three-wheel Polishing Device (TWPD)

DFT)



Repeatable and test speeds 10 to 90km/h

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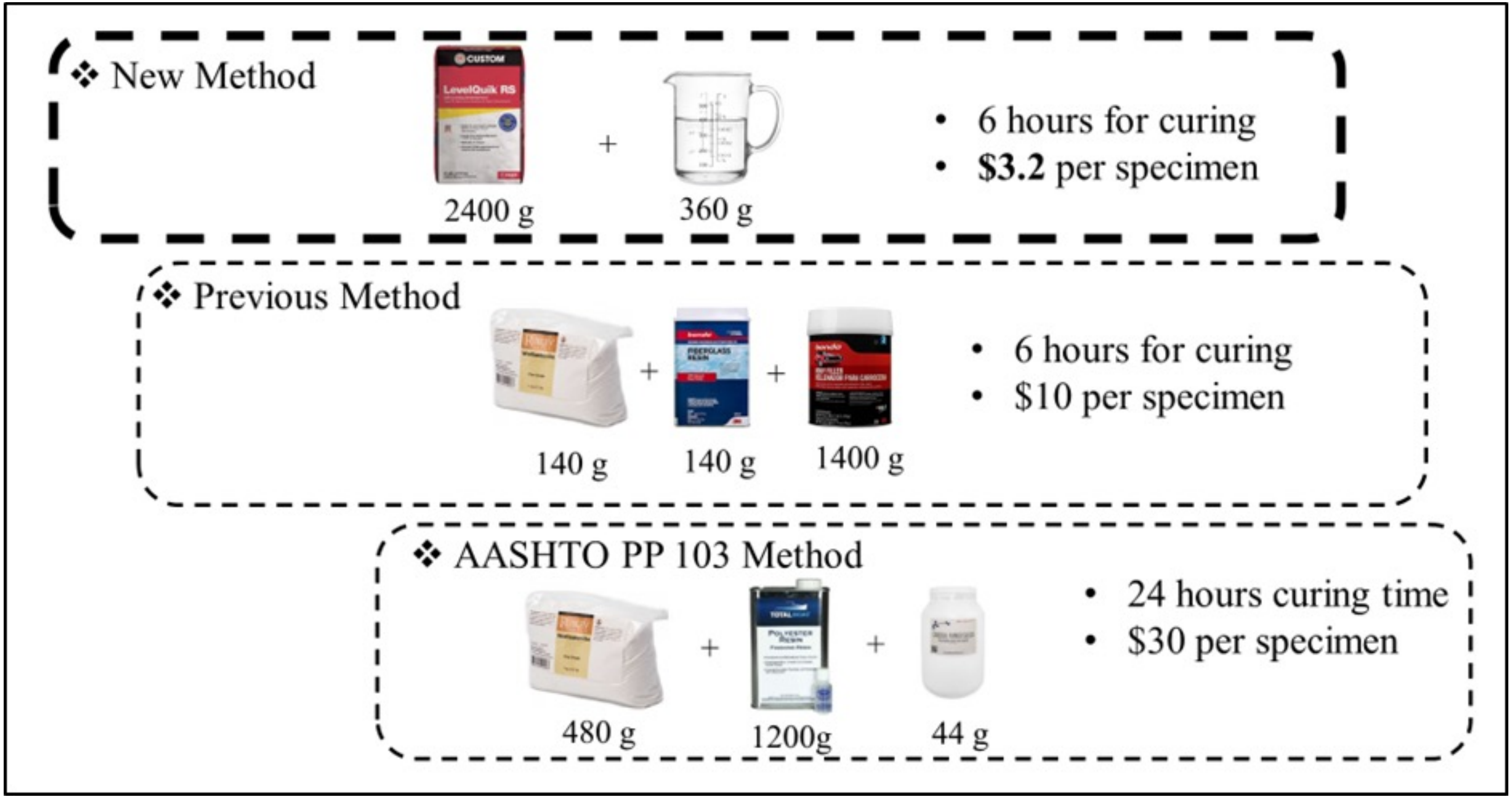
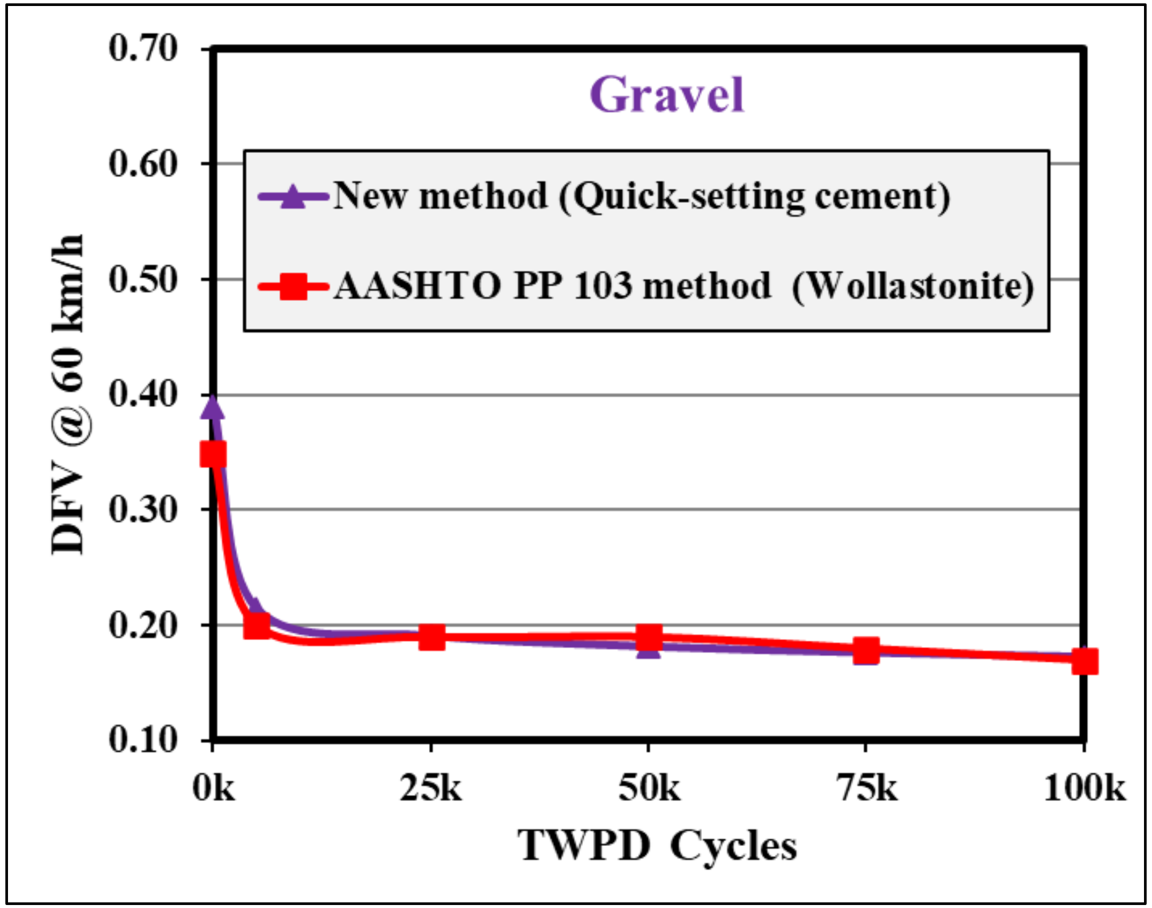
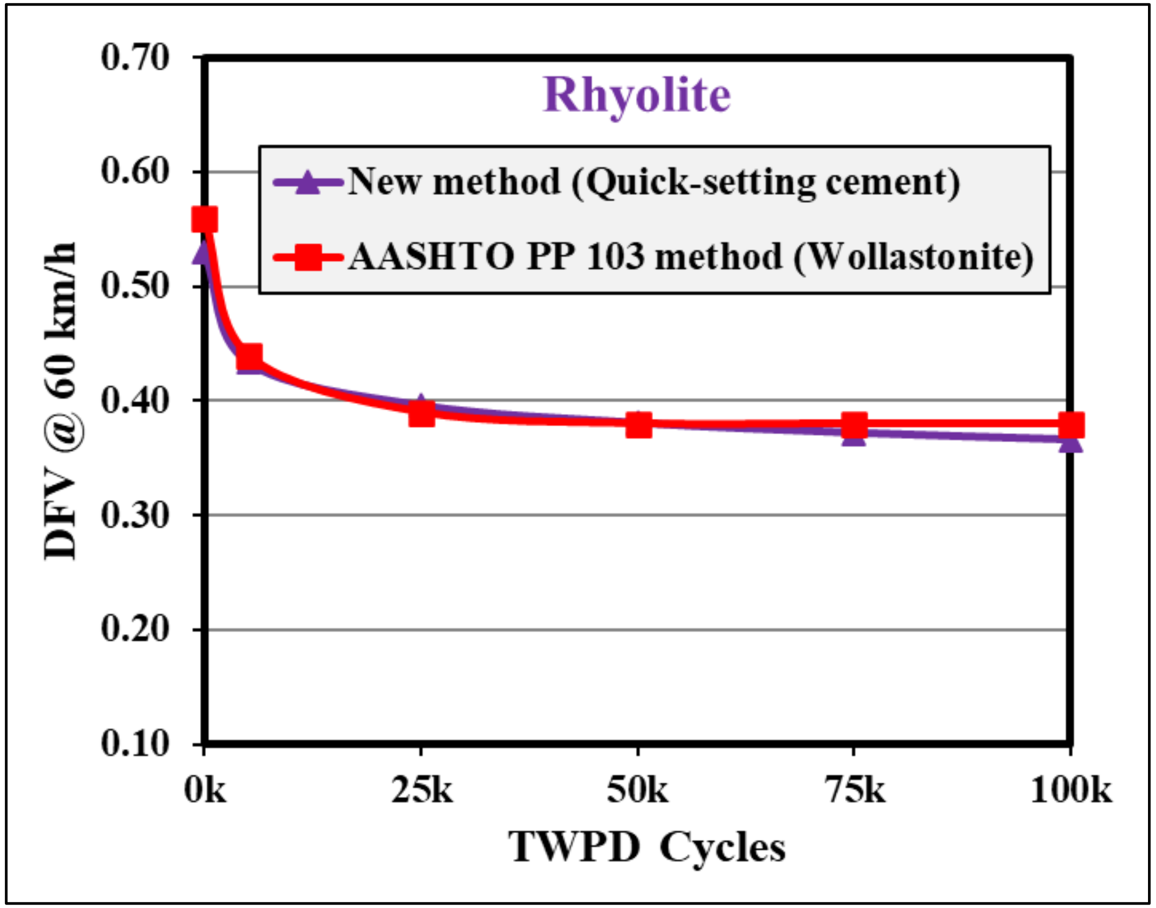
Overview of Specimen Preparation Method

CTIS New Binding Agent



Verification of New Binding Agent Effect





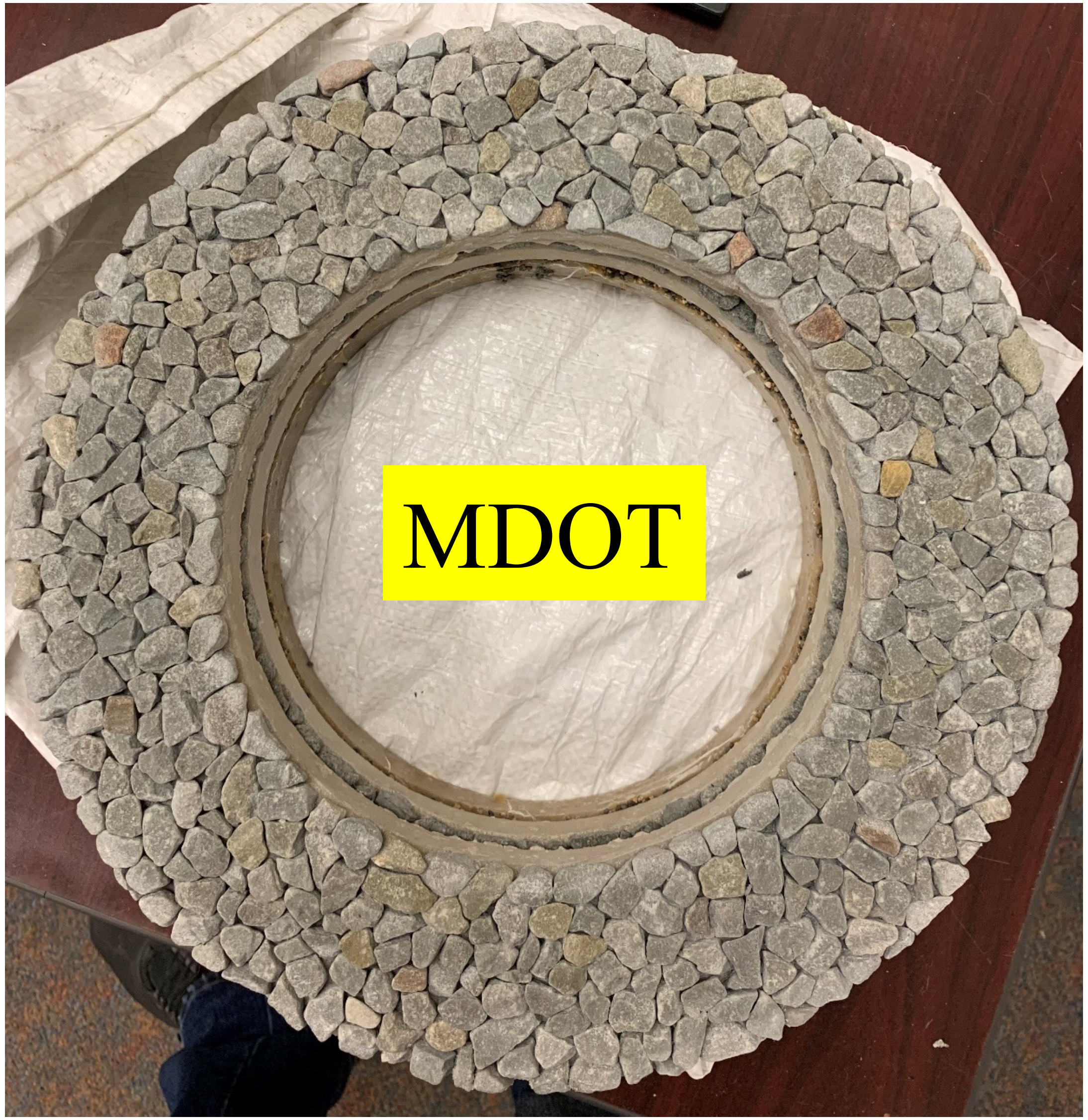
Variability Study with Maryland DOT

Investigate the repeatability/reproducibility of the TWPD-DFT test using the CTIS and MDOT methods

- CTIS sent the MDOT aggregate ring for testing
- MDOT sent the CTIS aggregate ring for testing

Comparing TWPD/DFT Methods		
Description	**CTIS**	**MDOT**
Polishing cycles	0 and 100k	0 and 100k
Tire	Flat-free Grainger tire	Pneumatic Kenda tire
Sample preparation method	Bondo	AASHTO
TWPD Device: Speed	60 rpm	56 rpm
TWPD Device: Weight	150 lb.	150 lb.

Variability Study with Maryland DOT



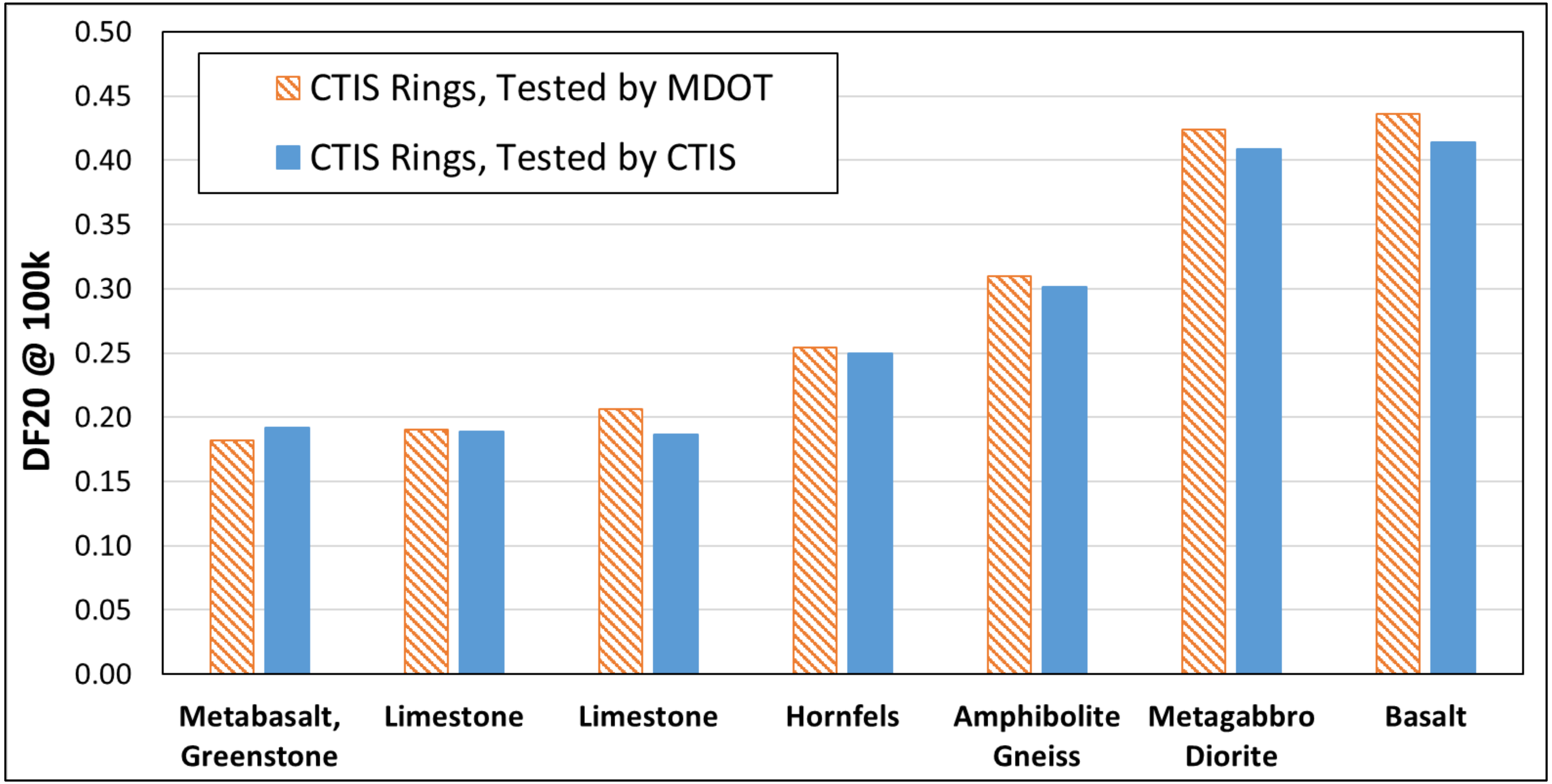
Variability Study with Maryland DOT

Conclusions: Three main possible sources of variability:

1. DFT device
2. Specimen preparation method (tightness): MDOT samples are very tight
3. Tire type: CTIS uses solid tire instead of the MDOT's pneumatic one

Variability Study with Maryland DOT

- **DFT Device**

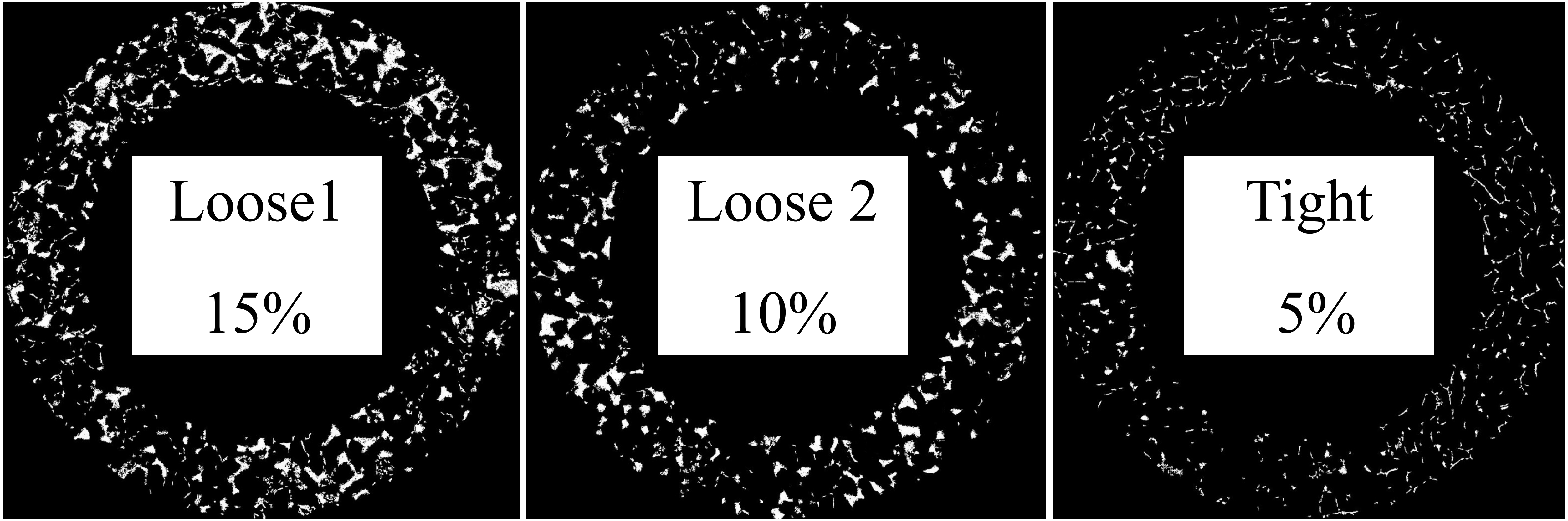


Variability Study with Maryland DOT

- **Tightness**

Variability Study with Maryland DOT

- **Tightness**



Processed Images

Variability Study with Maryland DOT

- **Tightness**

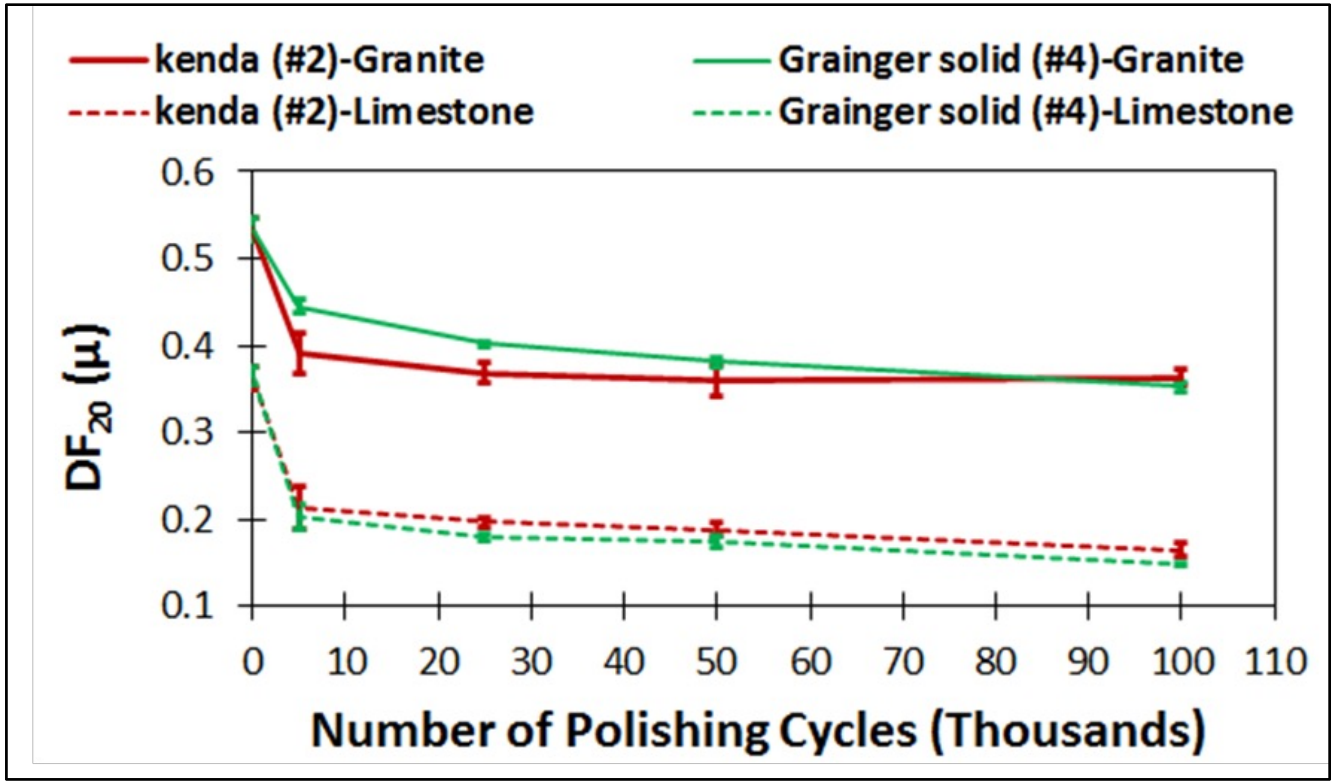
DFT results vs processed Images

Specimen	Estimated voids between the aggregates	DF20 @ 0k	DF20 @ 100k
		Average	Average
Loose1	15%	0.46	0.19
Loose2	10%	0.44	0.19
Tight	5%	0.47	0.18
Average		0.45	0.19
STDEV		0.02	0.01

Variability Study with Maryland DOT

- **Tire Type**

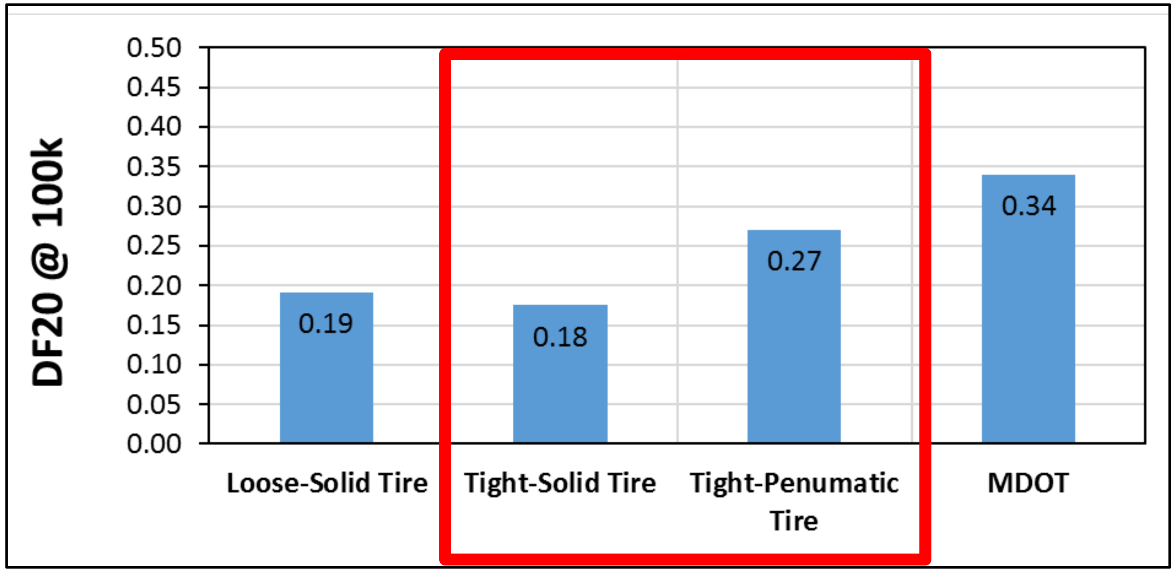
What we did at the beginning of the work



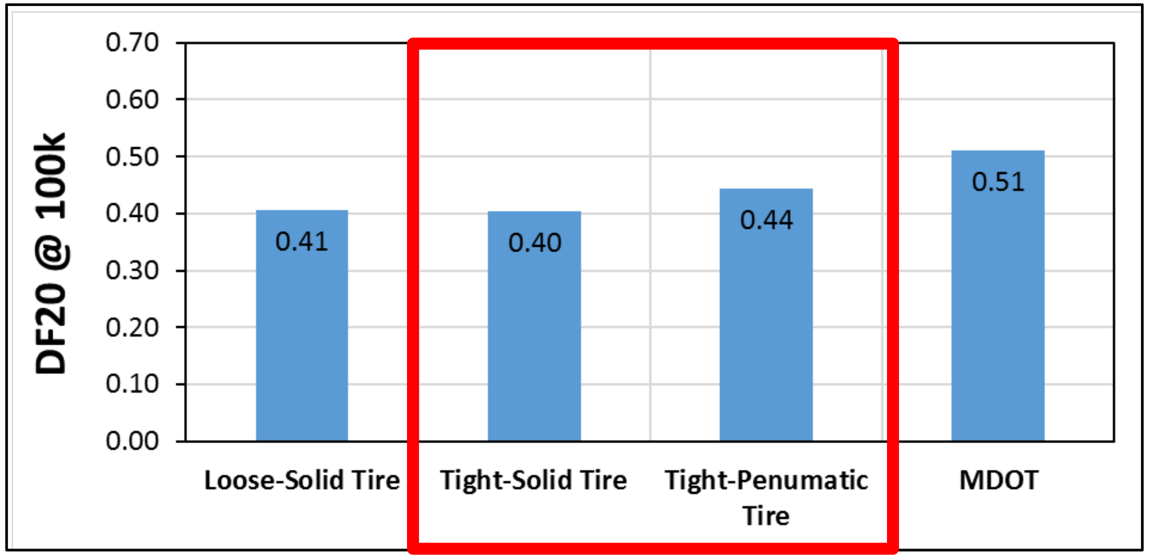
Variability Study with Maryland DOT

▪ Tire Type

- Duplicate specimens were prepared with two aggregate types (Aggregate 1 and Aggregate 2)
- Specimens were prepared very tight like the MDOT specimen's tightness
- First replicate was polished by solid tire and the second one with pneumatic tire



Aggregate 1



Aggregate 2

Variability Study with Maryland DOT

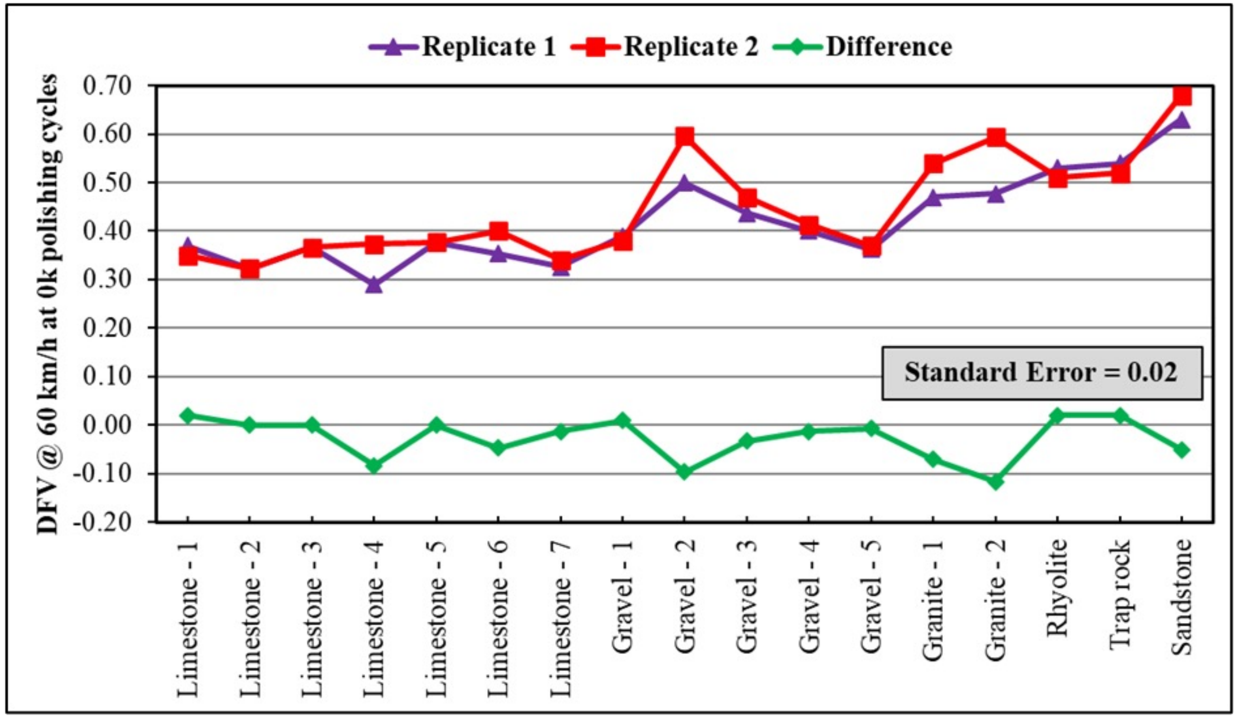
Variability Study with Maryland DOT

Variability Study with Maryland DOT

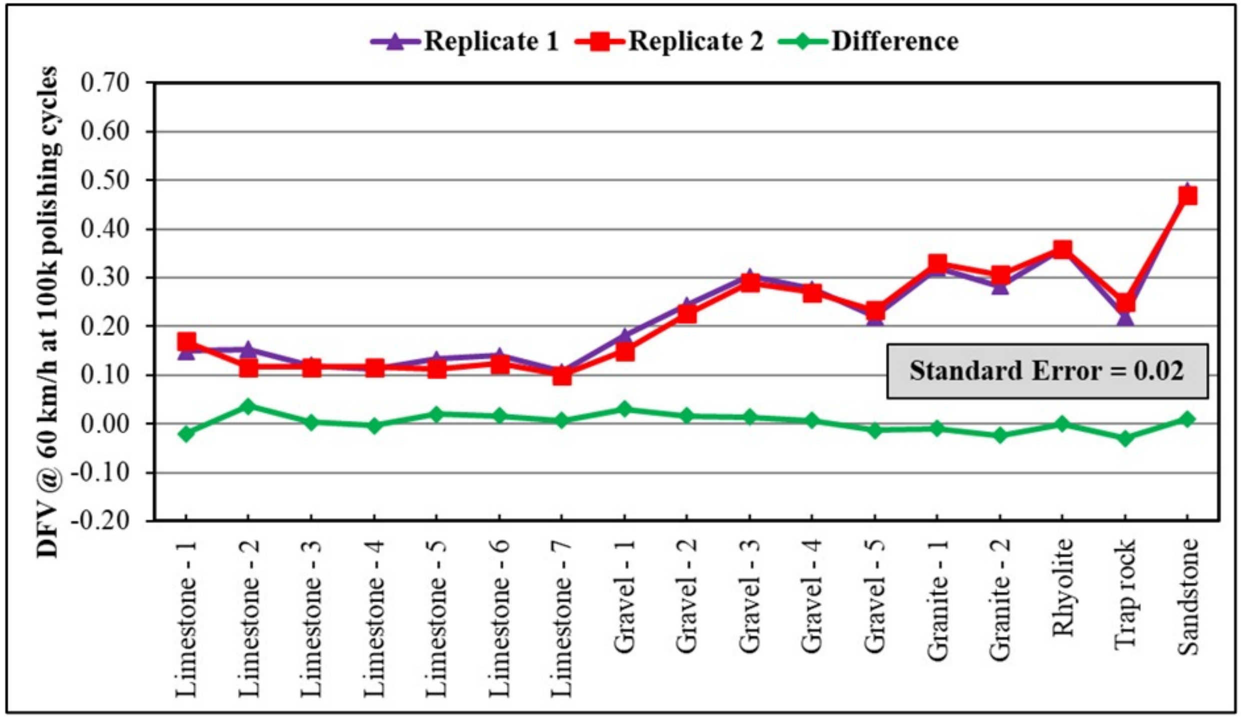
CTIS Lab Variability Study

CTIS Lab Variability Study

- **Specimen Preparation:** Between Replicates



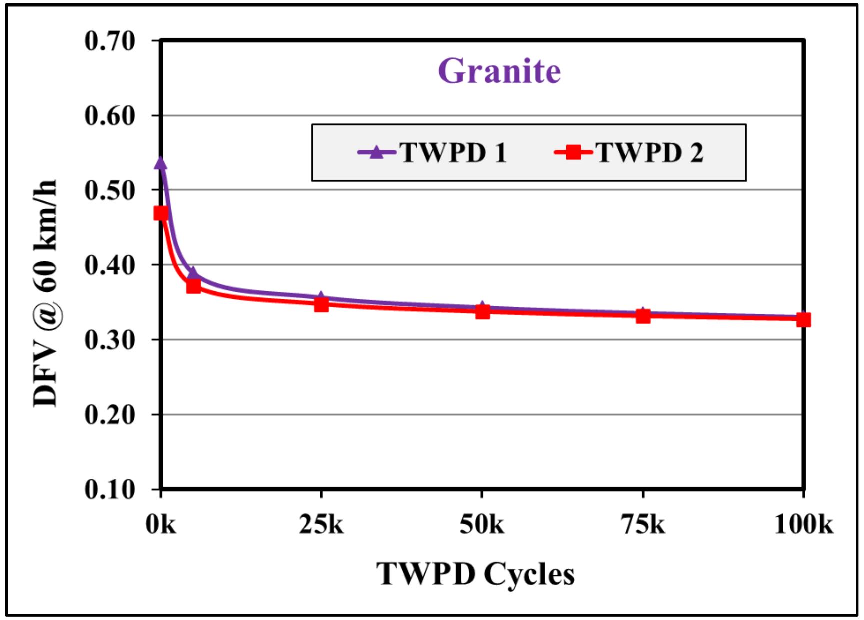
0k Polishing Cycles



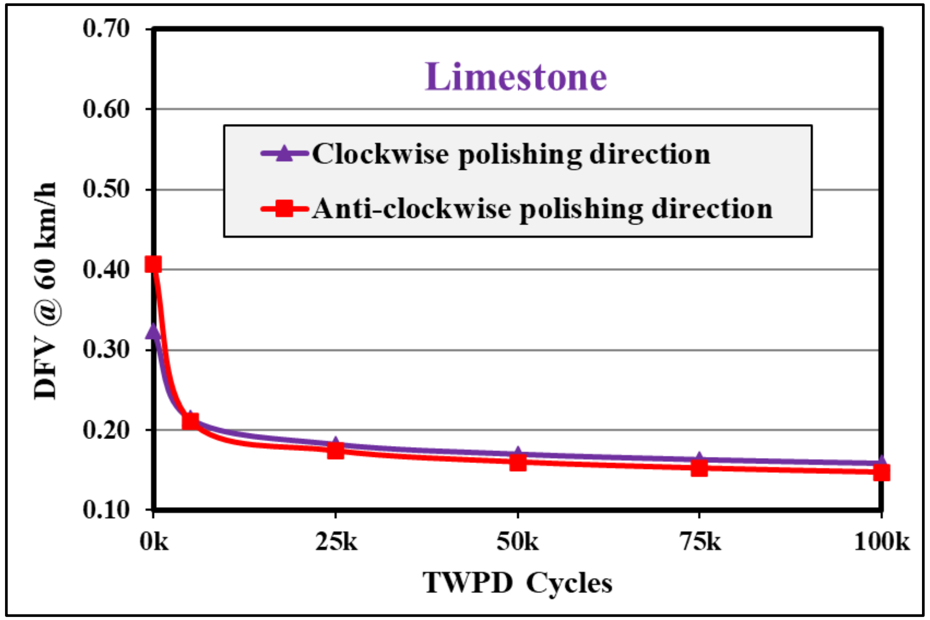
100k Polishing Cycles

CTIS Lab Variability Study

- **TWPD Parameters**



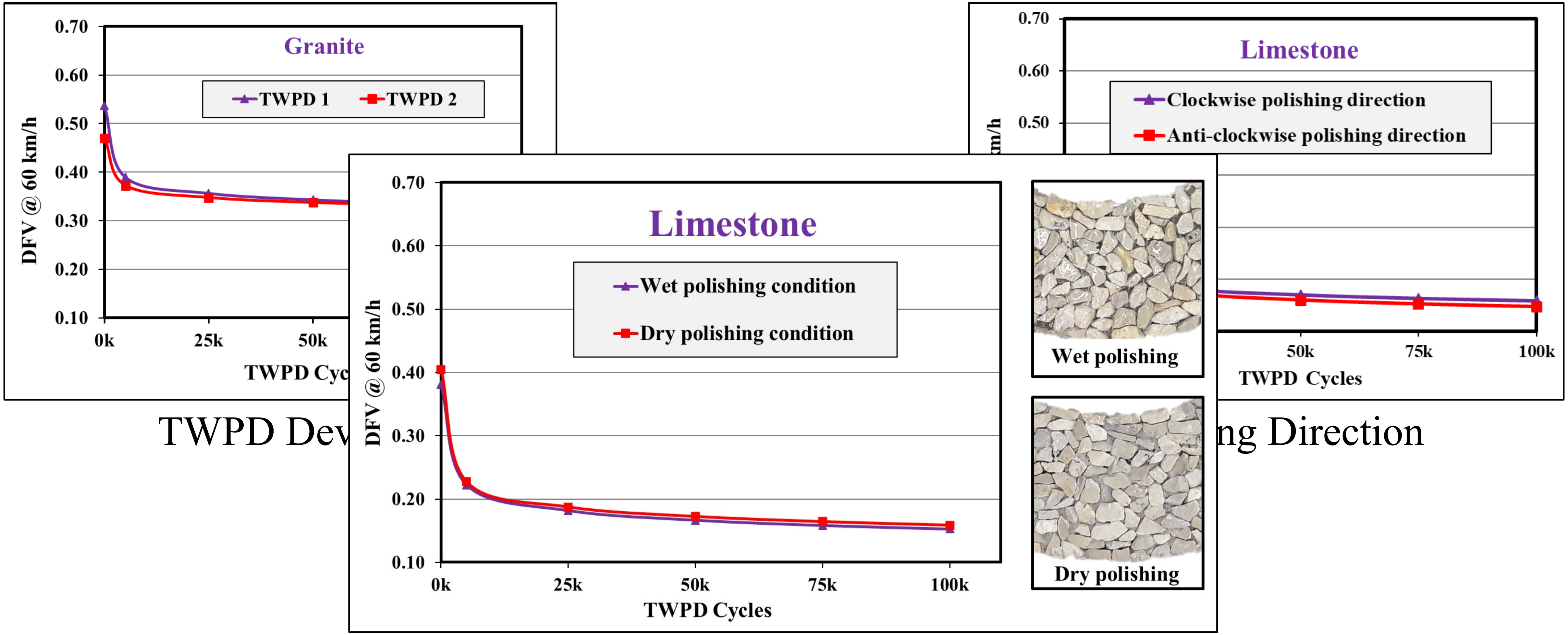
TWPD Device



Polishing Direction

CTIS Lab Variability Study

- ## TWPD Parameters



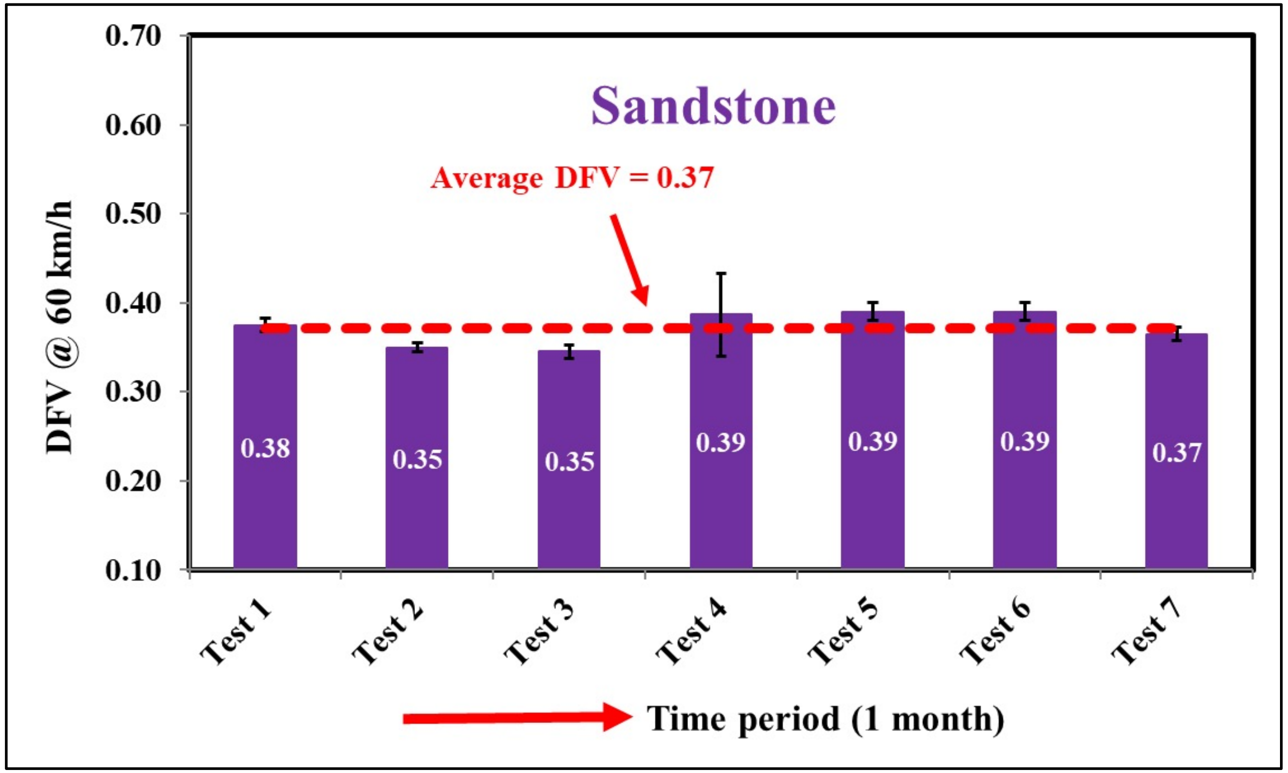
TWPD Dev

ng Direction

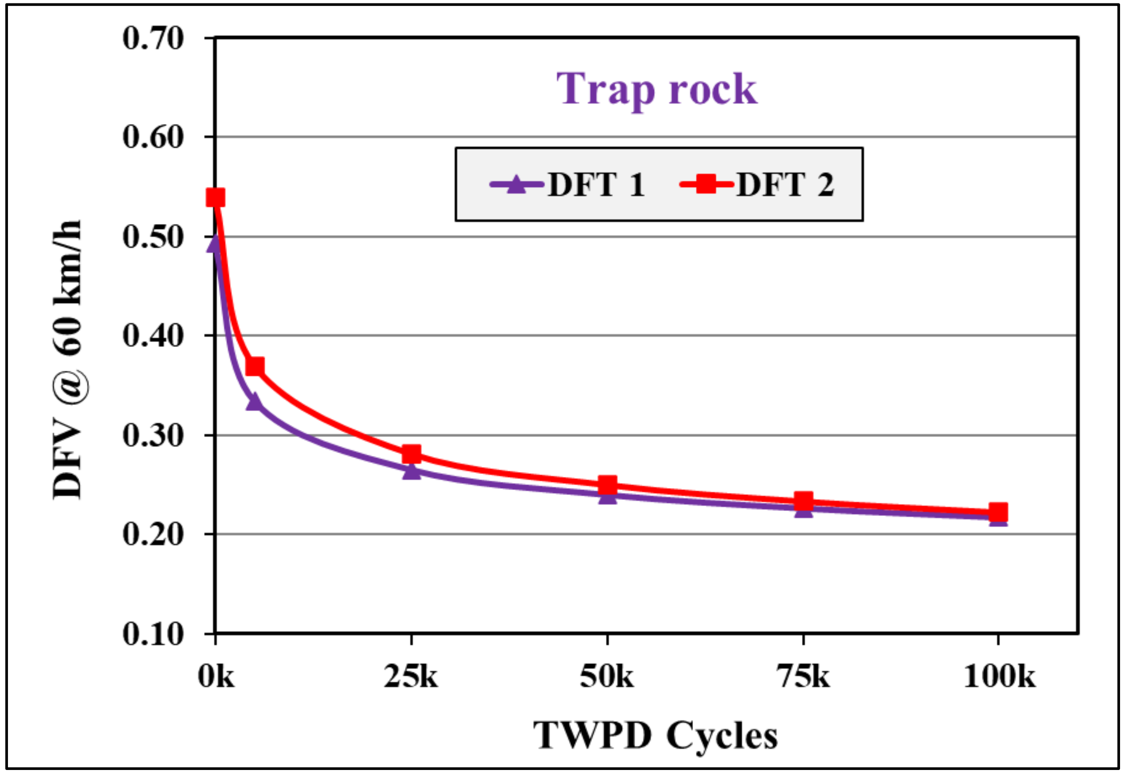
Polishing Condition

CTIS Lab Variability Study

- **DFT Parameters:** Repeatability and Reproducibility



Repeatability



Reproducibility

Variability Study of Aggregate Friction

Major findings:

- Tire pressure variation in Pneumatic tires causes variability in friction results
- Repeated blow outs on Pneumatic tires is a problem
- Solid tires produced consistent friction results (***No more blow outs***)
- CTIS lab variability check showed repeatable results

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The Study Proceeded for Friction Characterization of Texas Aggregates with an objective to correlate TWPD Aggregate Friction with Micro-Deval Aggregate Friction.

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Correlation between TWPD and Micro-Deval ring friction??

What is the correlation???

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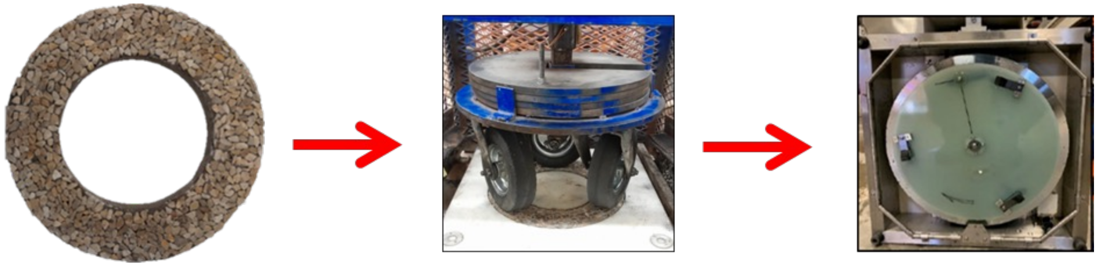
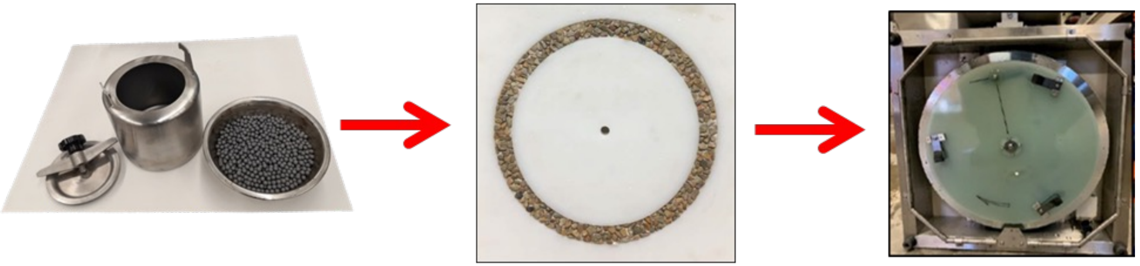
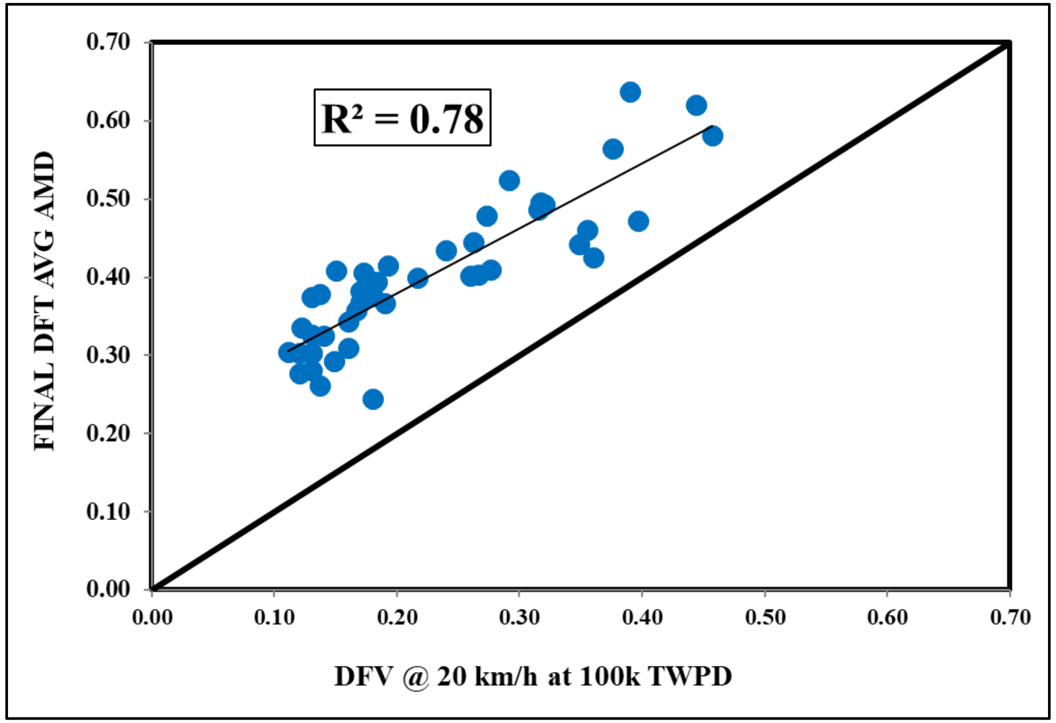




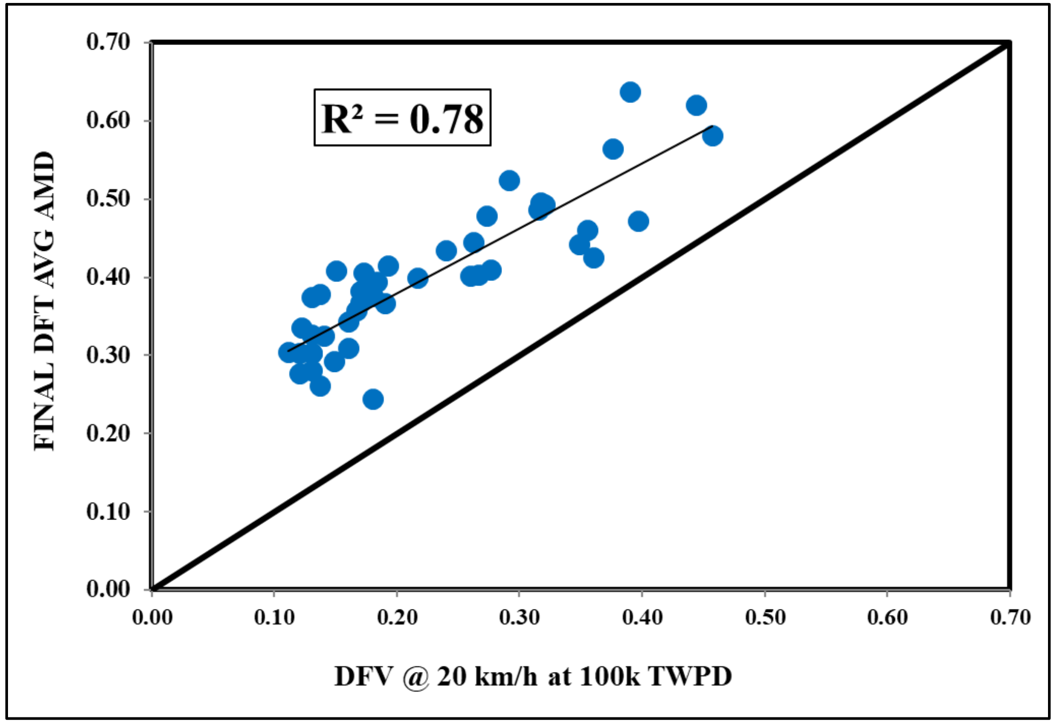
Simulated polishing: Tire / TWPD

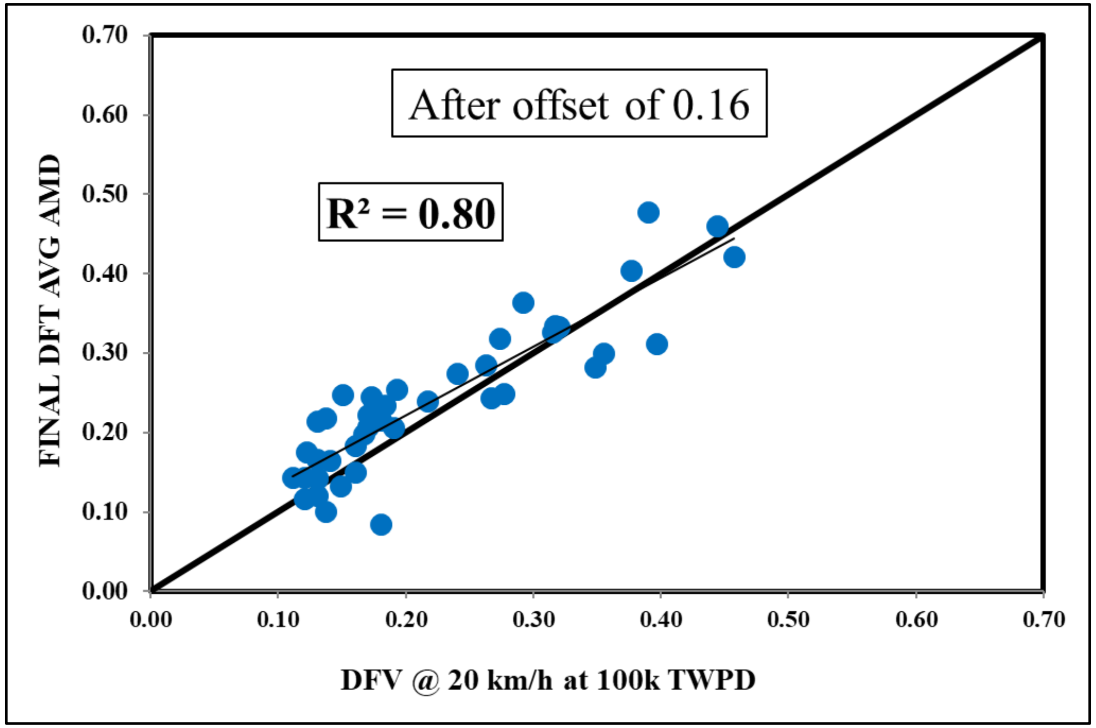
Abrasion action: Steel balls / Cylinder

Correlation between TWPD and Micro-Deval ring friction



Correlation between TWPD and Micro-Deval ring friction





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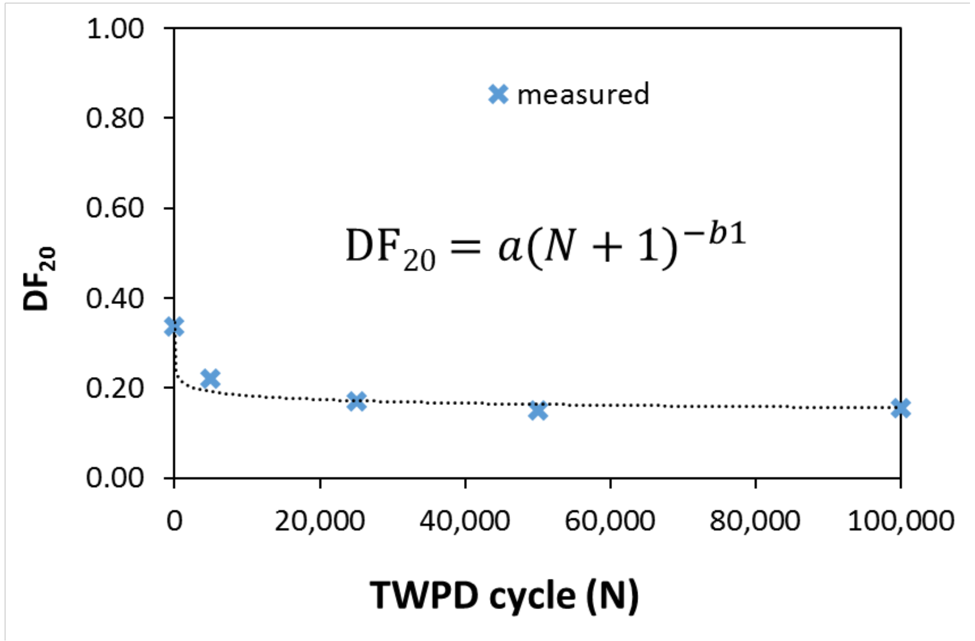
Prediction of DFV at 100k TWPD Cycles

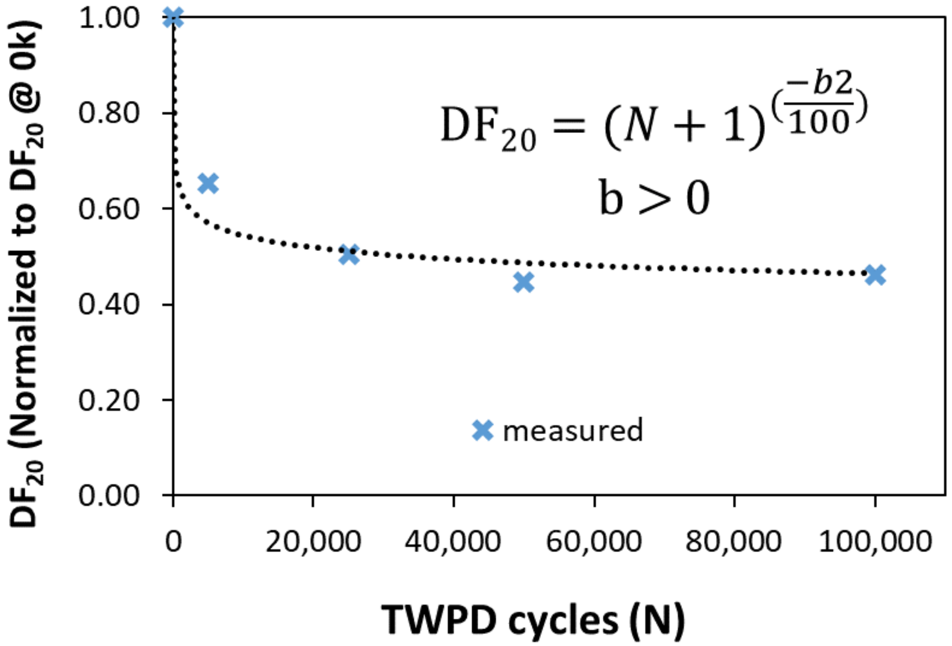
"Power function"

- Final friction life of an aggregate source (DFT at 100k) can be predicted using a power fit function
- DFT measurements made at zero and one or two different polishing cycles can be used to predict the final friction with a reasonably low error



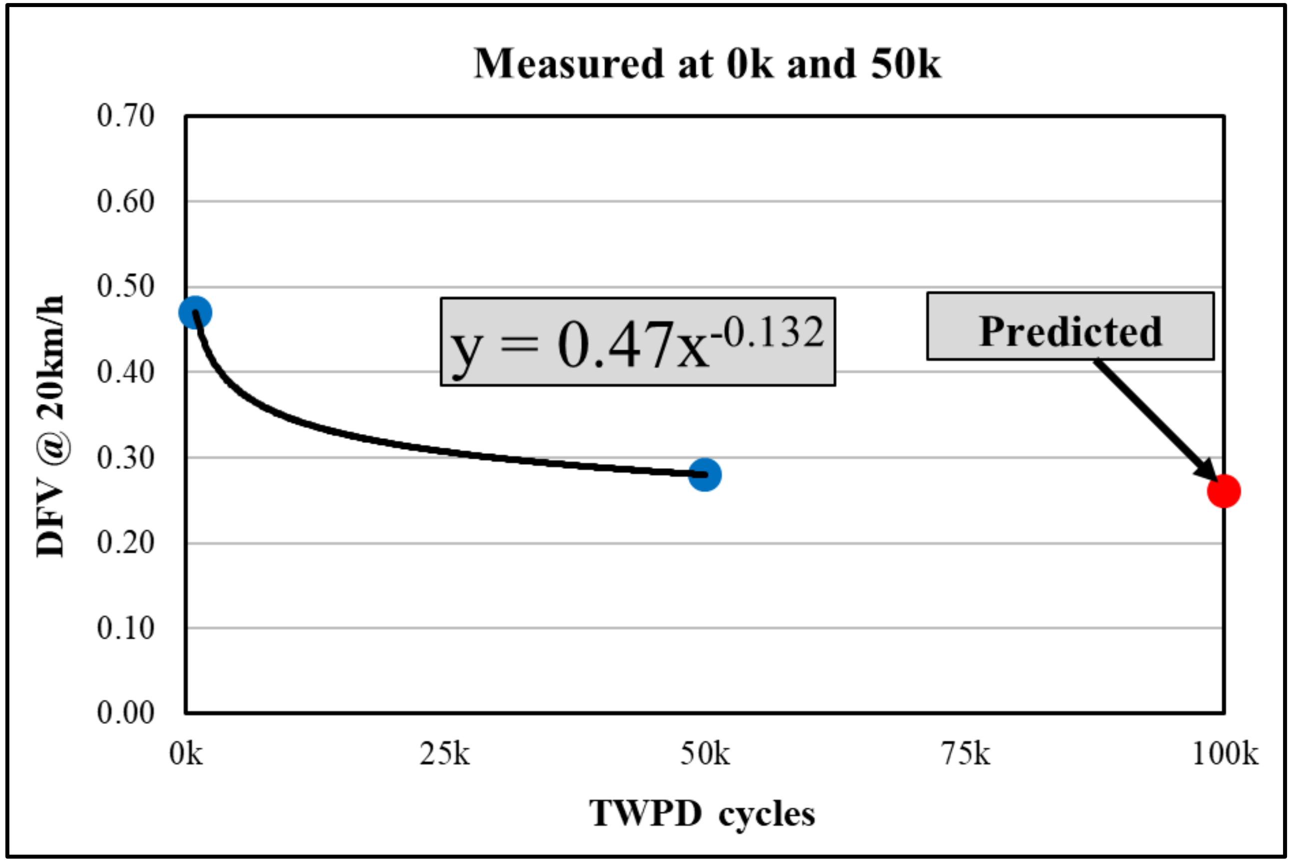
Normalizing the DF20

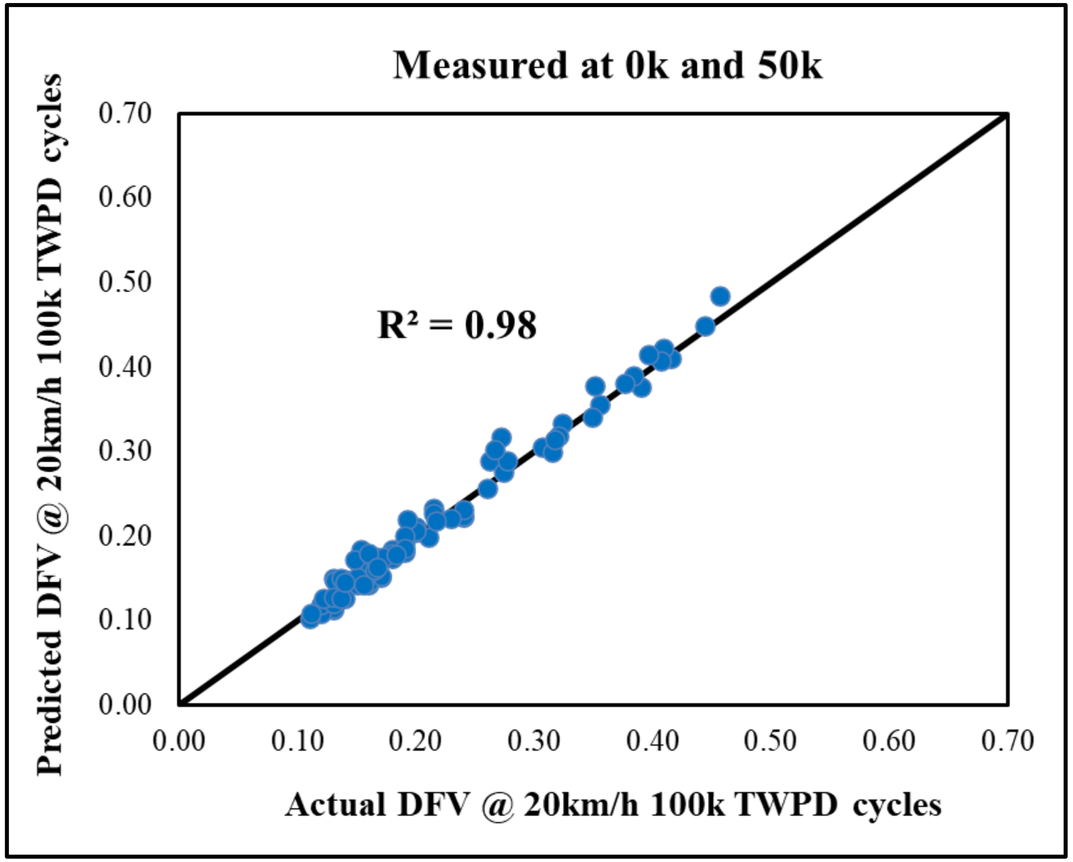
to remove *a*



Prediction of DFV at 100k TWPD Cycles

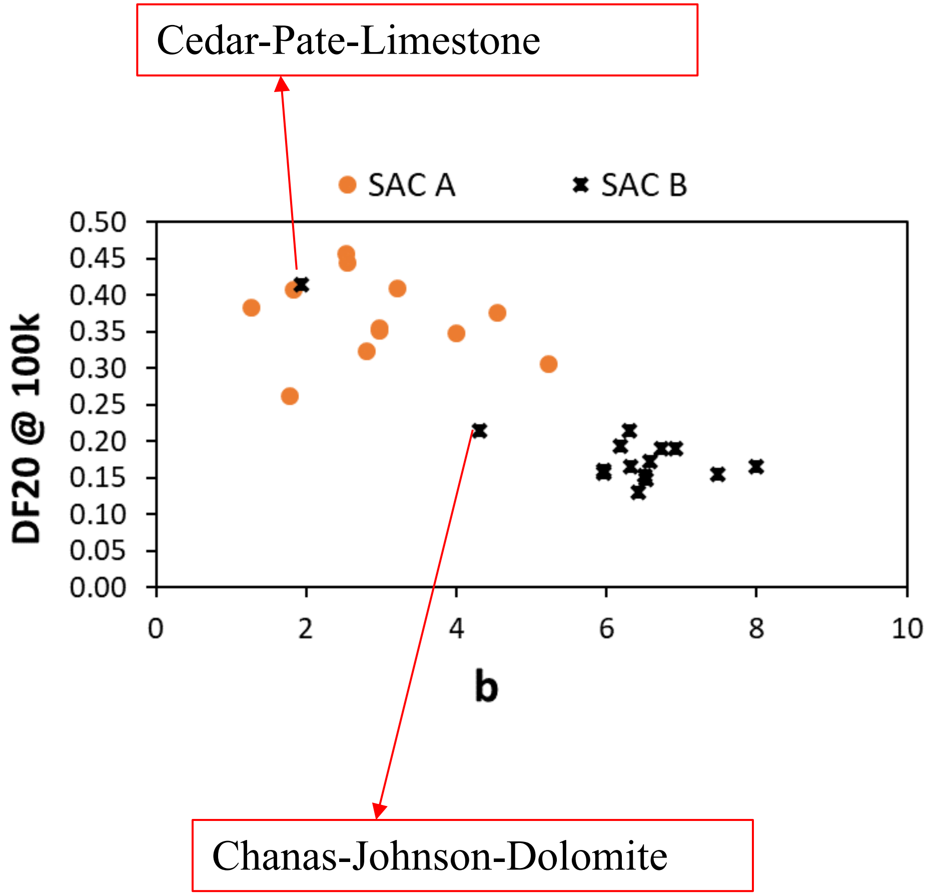
- **Using TWPD 0k and 50k friction values**

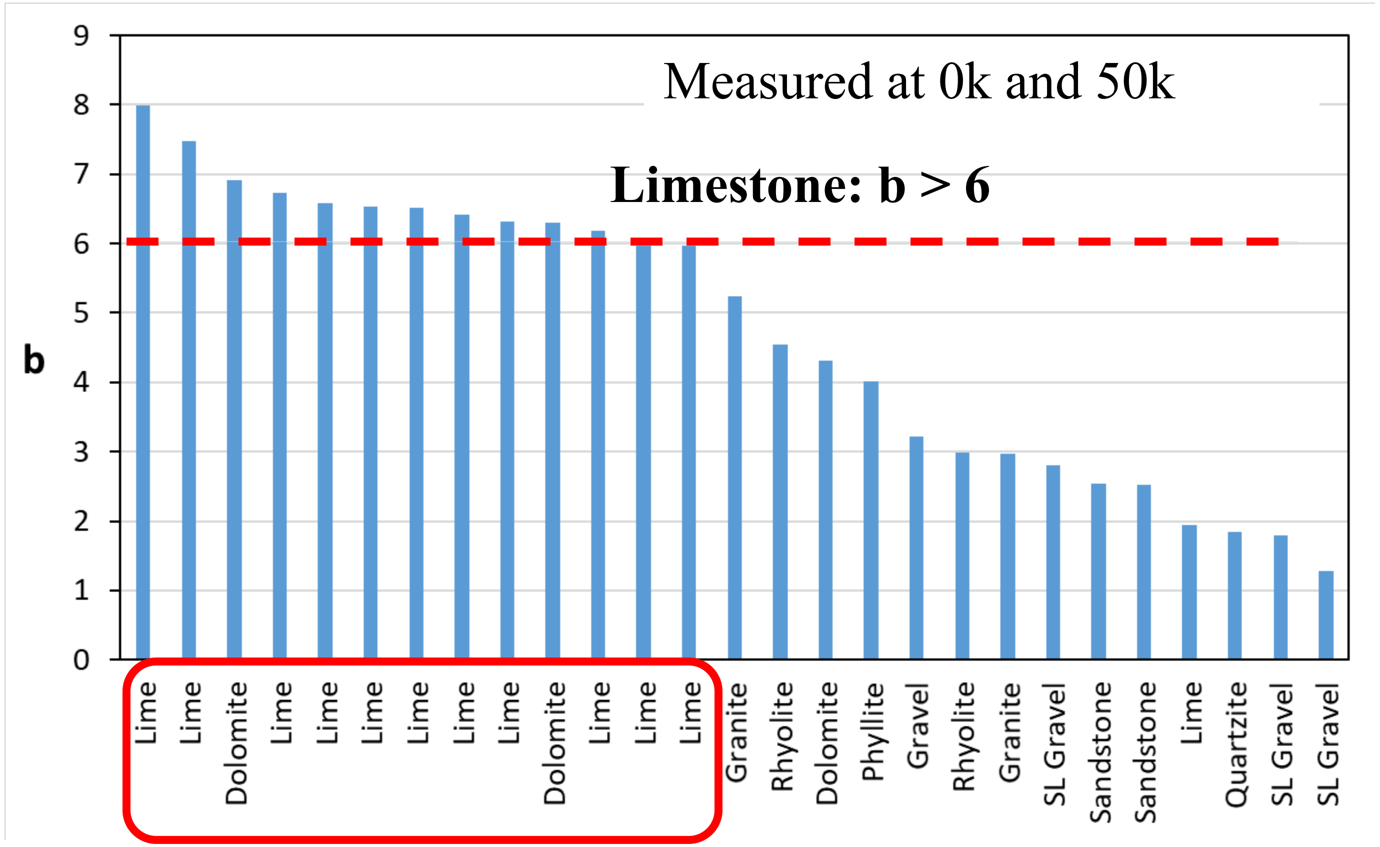




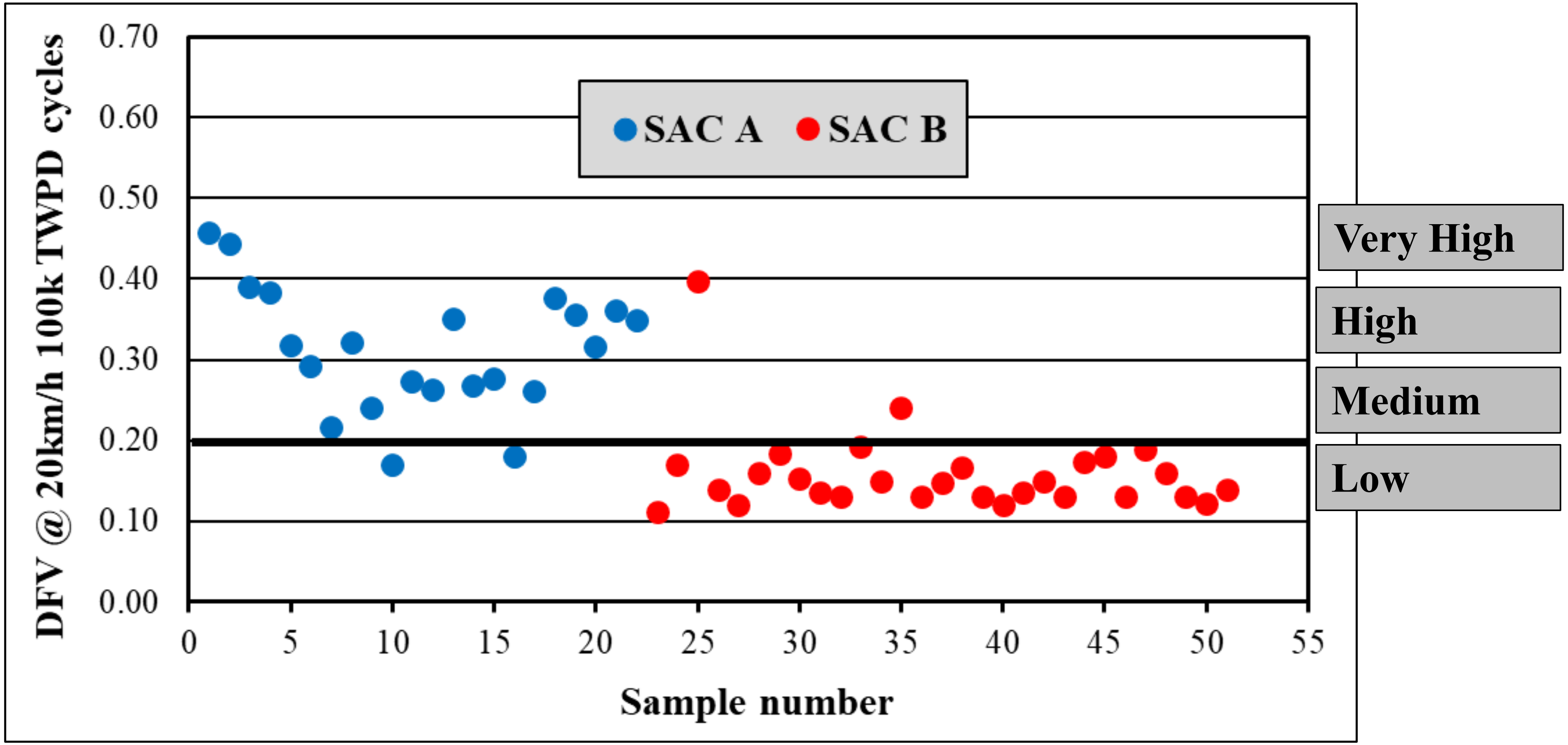
Prediction of DFV at 100k TWPD Cycles

$$DF_{20} = (N+1)^{\left(\frac{-b}{100}\right)}$$





SAC A vs. SAC B aggregate friction



Prediction of DFV at 100k TWPD Cycles

- **Using MDAL, LAAL, and AIR values**

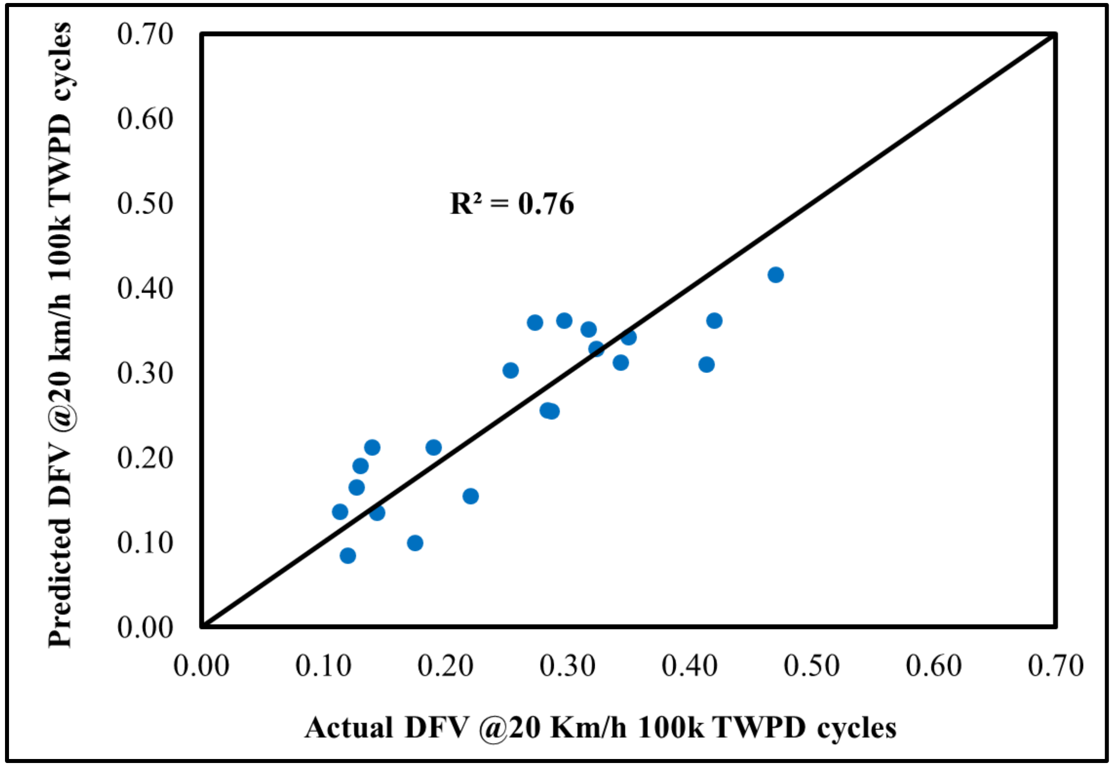
$$DFV_{TWPD} = C_1 + (MDAL \times C_2) + (LAAL \times C_3) + (AIR \times C_4)$$

where, $C_1 = -0.0958$, $C_2 = 0.0065$, $C_3 = 0.0046$, $C_4 = 0.00226$

MDAL = Micro-Deval abrasion loss

LAAL = Los Angeles abrasion loss

AIR = Acid insoluble residue



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Research Article

TRR

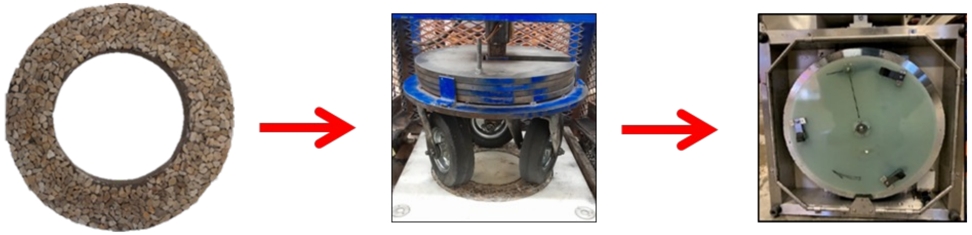
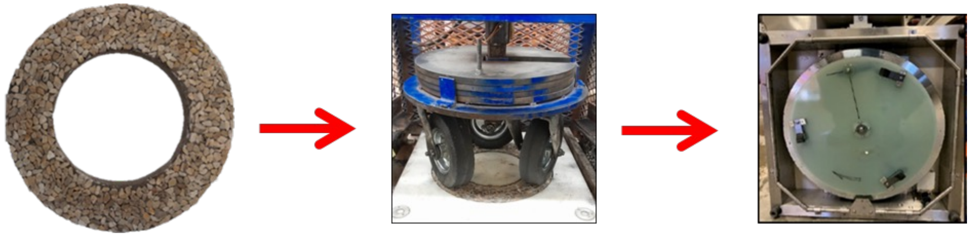
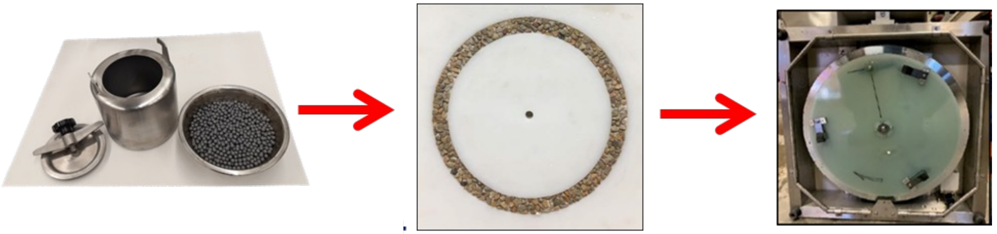
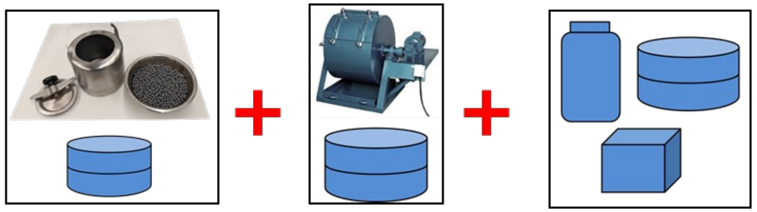
Transportation Research Record
1–11

DOI: 10.1177/03611981241239961
journals.sagepub.com/home/trr
Sage

Alternative Approaches for Rapid Evaluation of Frictional Resistance of Aggregates

G. Sandeep Reddy[1], Miguel A. Montoya[1], Imad N. Abdallah[1], Soheil Nazarian[1], and Richard Izzo[2]

Significance of Prediction Models

1. AASHTO PP 103 method [Standard]		▪ Time 40 hours ▪ Requires TWPD and DFT
2. AASHTO PP 103 method [Accelerated method]		▪ Time 20 hours ▪ Requires TWPD and DFT ▪ **R^2 0.98**
3. Micro-Deval abrasion action		▪ Time 12 hours ▪ Requires only DFT ▪ **R^2 0.78**
4. Micro-Deval, Los Angeles Abrasion, and Acid Insoluble Residue values		▪ Time 5 hours ▪ No need of TWPD and DFT ▪ **R^2 0.76**

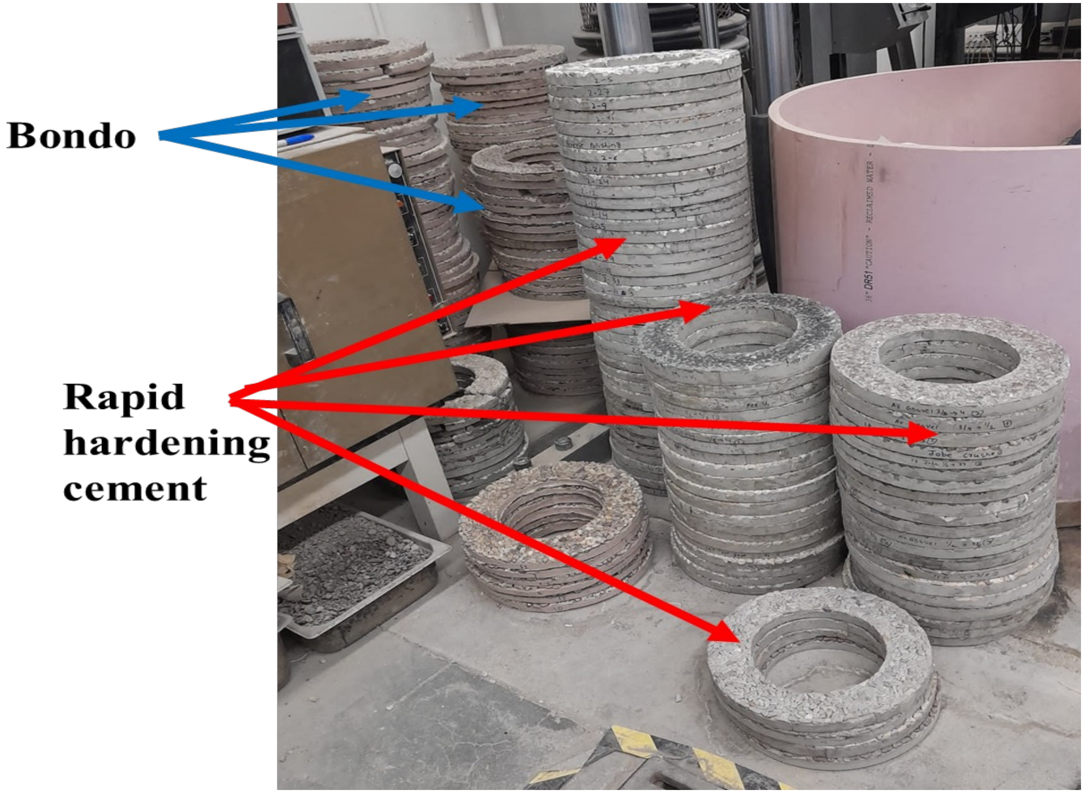
Friction Characterization of Texas Aggregates

- **Work Summary**
  - 150 aggregate rings tested including replicates and repeats (60 sources)
  - Previously tested aggregate friction at 6 TWPD cycles

TWPD DFV @20 km/h					
0k	5k	25k	50k	75k	100k

  - Currently testing at 3 TWPD cycles

TWPD DFV @20 km/h		
0k	50k	100k



Thank you