Fine Aggregates and Their Effect on Friction

Materials & Asphalt Technology Research Summit

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Presentation outline

1. Background of the Study
2. Factors Controlling the Asphalt Mixture Frictional Performance
3. Case Examples for Improving the Mixture Frictional Performance
4. Field Verification of Laboratory Friction
5. Upcoming Field Pilot Test Sections
6. Final Specification

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Goal

- Understand the impact of fine aggregates on mixture frictional performance.
- Provide TxDOT a guideline or procedure to incorporate quality fine aggregates in their AC mixes to improve the skid resistance.
- Specifically, provide guidelines to incorporate skid resistance into the balanced asphalt mixtures.

Rutting

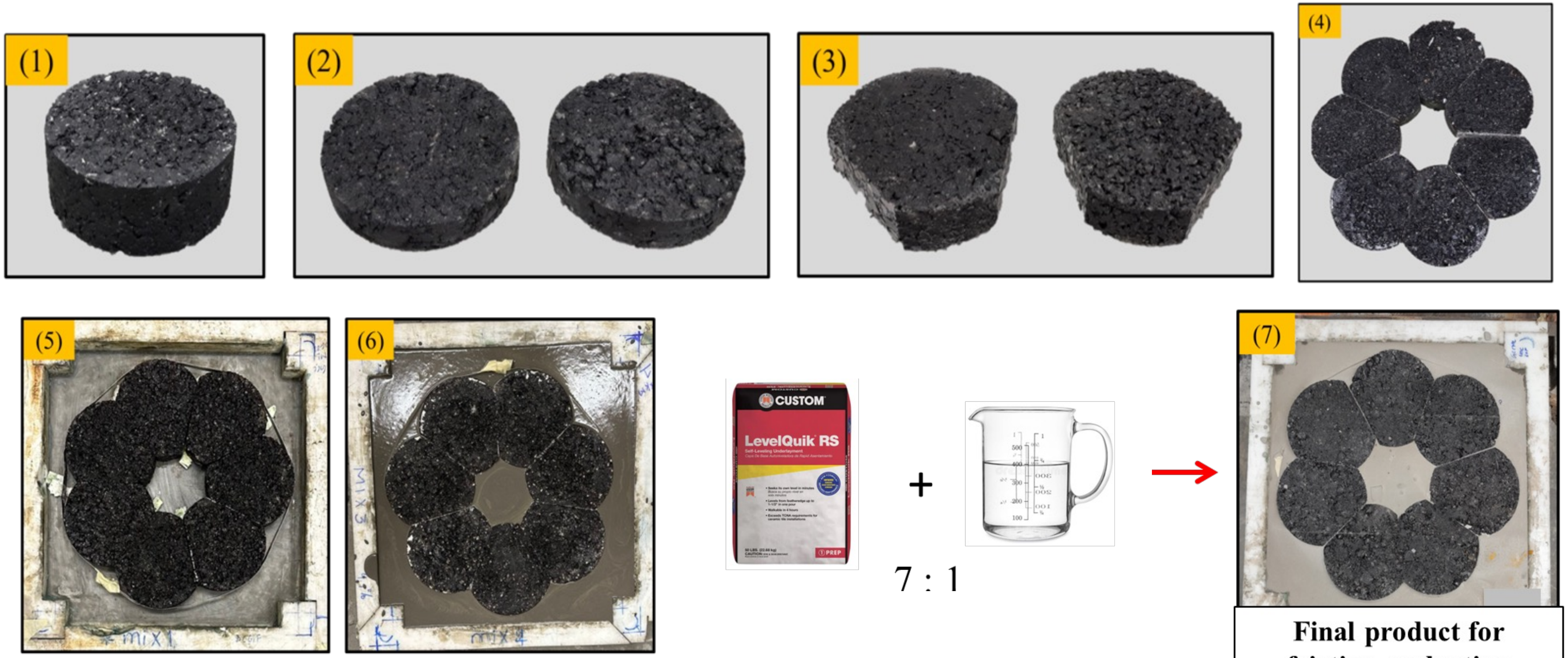
Cracking

Skid Resistance

Methodology for the Laboratory Evaluation of Asphalt Mixture Friction Performance

- ## Sample Preparation

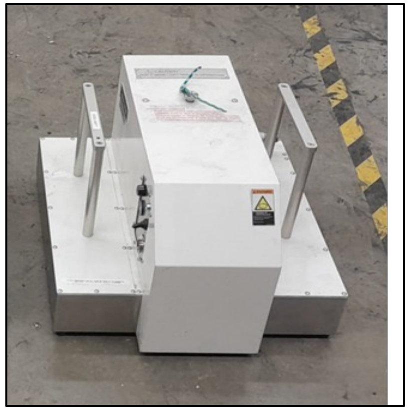
Requires only 4 specimens. (Tex-241-F 62mm height, 7% AV, HWTT/IDT or 80mm height)

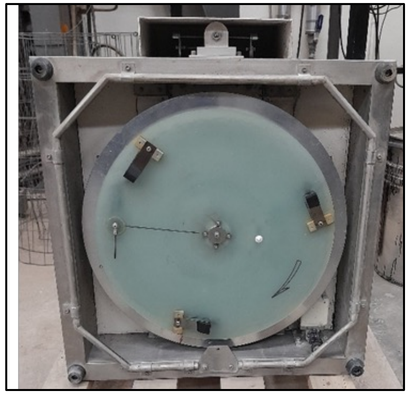


Final product for friction evaluation

Methodology for the Laboratory Evaluation of Asphalt Mixture Friction Performance

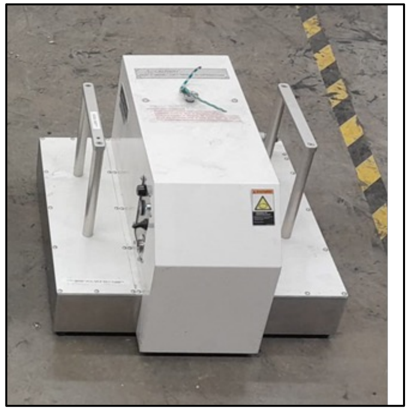
- **Polishing and Friction Testing**

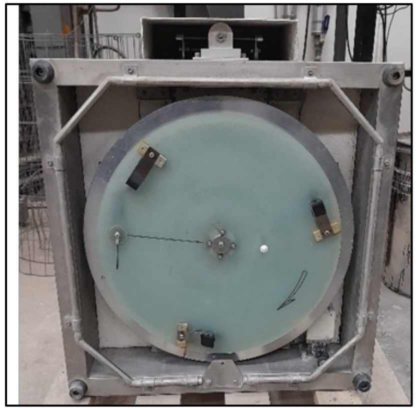


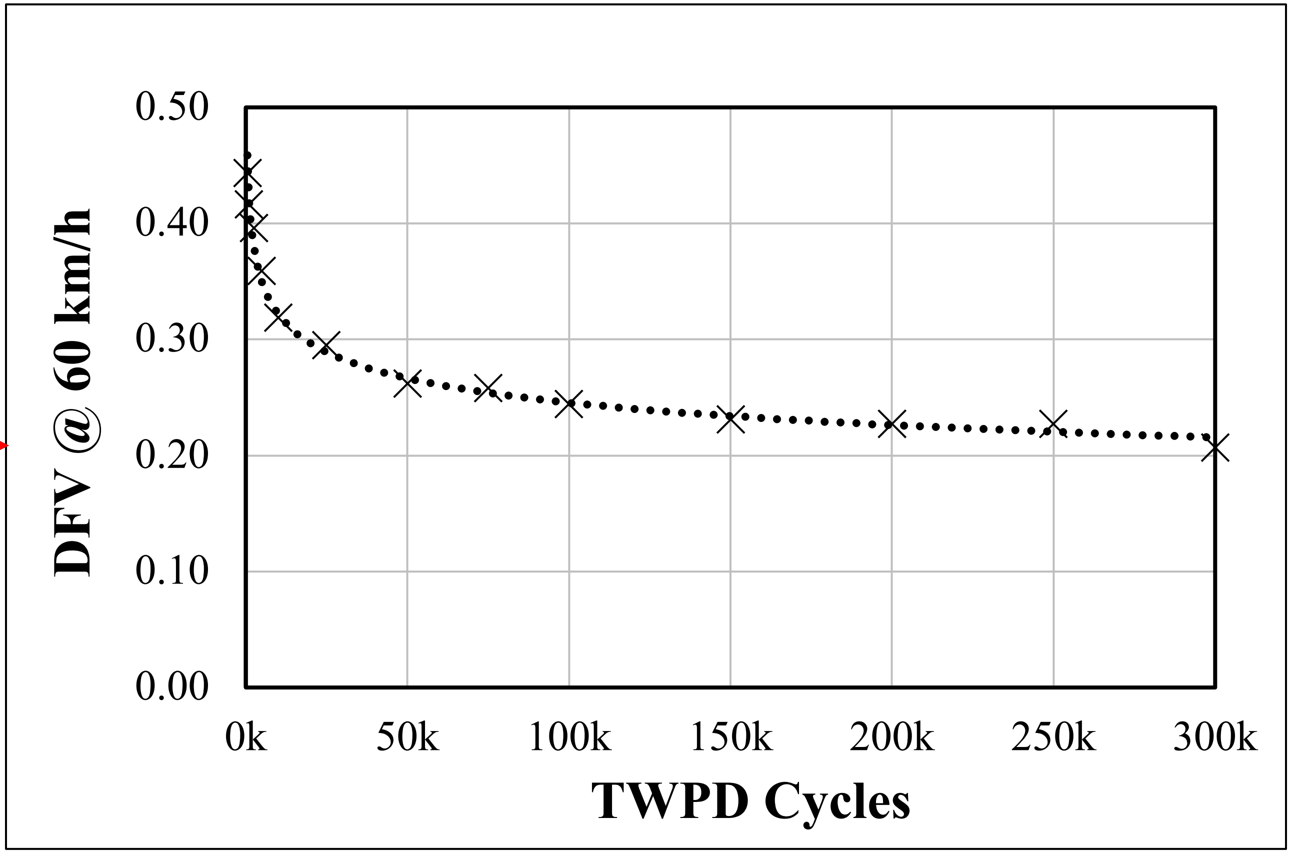


Methodology for the Laboratory Evaluation of Asphalt Mixture Friction Performance

- **Generating the Friction Deterioration Curve**

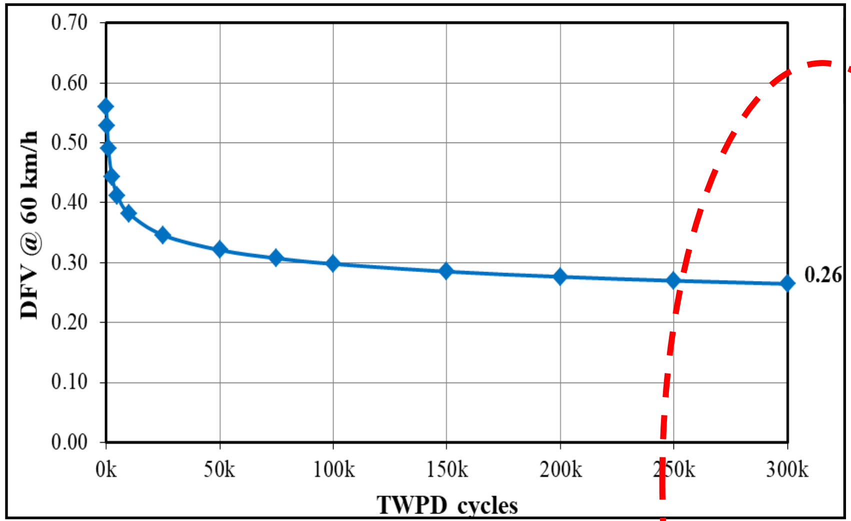


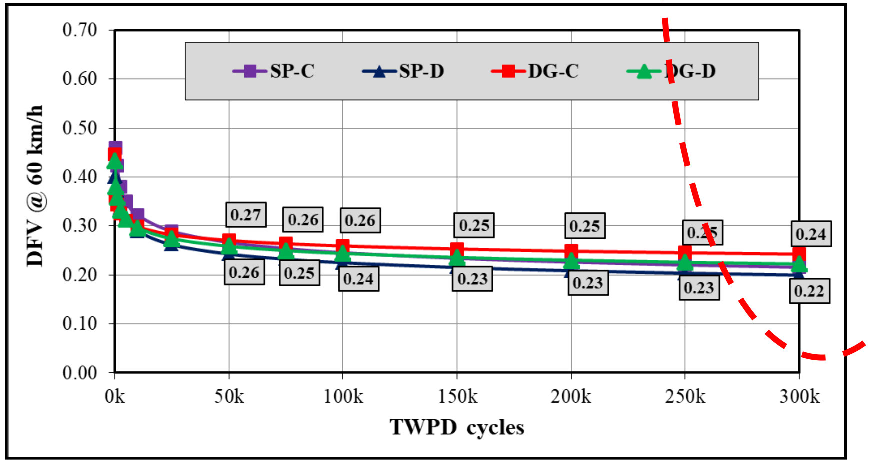


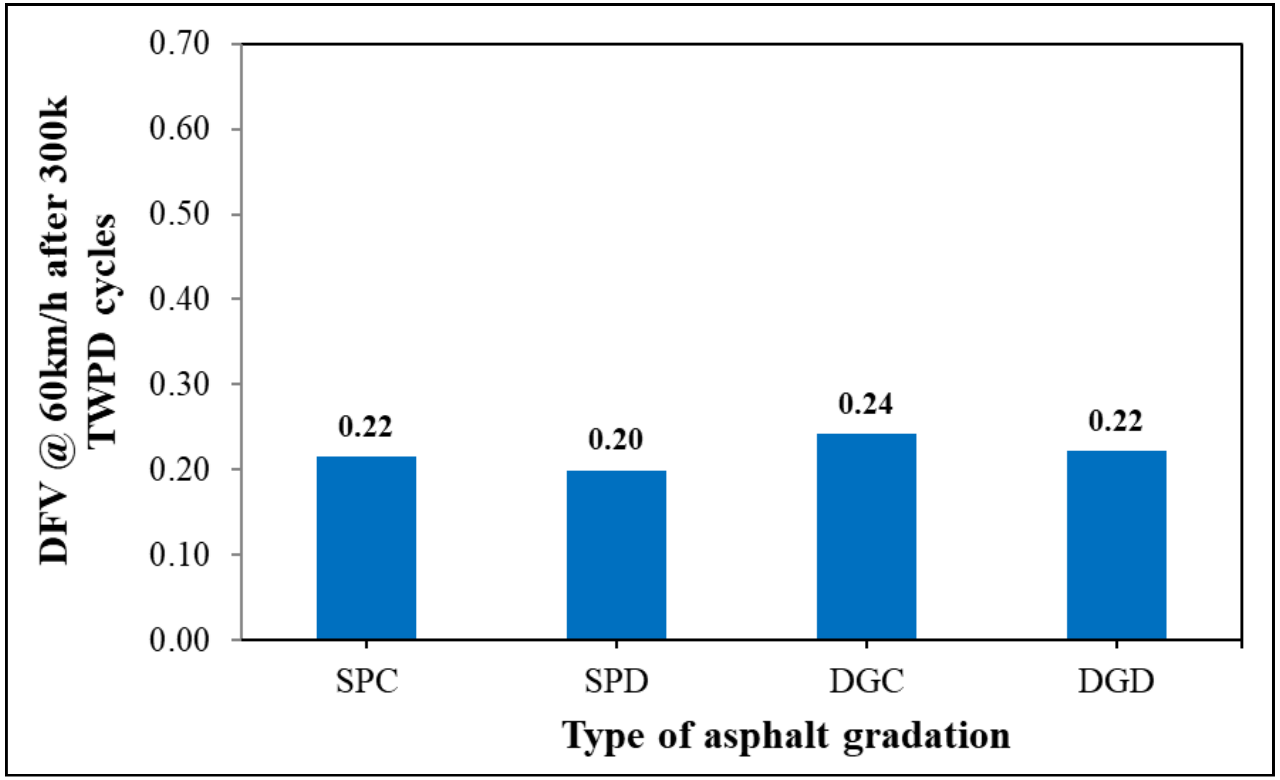


Methodology for the Laboratory Evaluation of Asphalt Mixture Friction Performance

- **Presentation of Terminal Friction Results**







Terminal friction values are important

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Factors Controlling the Asphalt Mixture Frictional Performance

List of Asphalt Mixture Parameters Studied Systematically

- Binder percentage
- Binder grade
- Air voids percentage
- Aggregate gradation
- Asphalt gradation
- Aggregate quality

Factors Controlling the Asphalt Mixture Frictional Performance

- **Modification of typical asphalt mixture into traditional method**

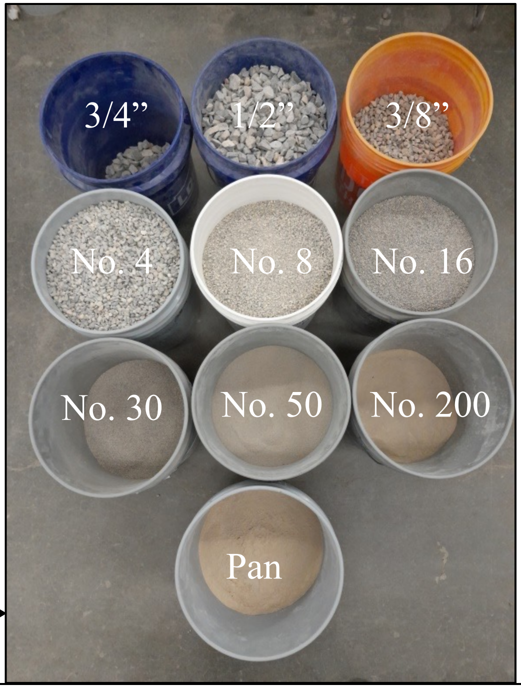
(Different bins and different aggregate types into one aggregate type into different sizes)

		Bin No.1	Bin No.2	Bin No.3	Bin No.4	Bin No.5	Bin No.6	Bin No.7	Bin No.8	Bin No.9	Bin No.10
Individual Bin (%)		Bin No.1 = 10 %	Bin No.2 = 33 %	Bin No.3 = 18 %	Bin No.4 = 5 %	Bin No.5 = 13.7 %			Bin No.8 = 20 %		
Aggregate Source		Limestone_Dolomite	Igneous	Limestone_Dolomite		Limestone_Dolomite			Fractionated RAP		
Aggregate Number		2407201	2407206	2407201		2407201					
Sample ID		McKelligon #67	McKelligon 3/8" Red	Blended Screenings	Mortar Sand	McKelligon 3/8" Limestone			Fine 1/2"		
Sieve Size: Passing	Retained	Aggregate Weight	Aggregate Weight	Aggregate Weight	Aggregate Weight	Aggregate Weight			Fractionated RAP Weight		
-	1"	0.0	0.0	0.0	0.0	0.0			0.0		
1"	3/4"	50.0	0.0	0.0	0.0	0.0			0.0		
3/4"	1/2"	240.0	0.0	0.0	0.0	0.0			0.0		
1/2"	3/8"	85.0	231.0	0.0	0.0	123.3			31.8		
3/8"	No. 4	70.0	924.0	36.0	0.0	417.9			306.9		
No. 4	No. 8	20.0	214.5	261.0	2.5	109.6			243.4		
No. 8	No. 16	10.0	99.0	198.0	5.0	6.9			116.4		
No. 16	No. 30	5.0	49.5	117.0	25.0	6.9			84.7		
No. 30	No. 50	5.0	33.0	72.0	130.0	0.0			74.1		
No. 50	No. 200	10.0	72.6	78.3	86.5	8.9			118.5		
No. 200	Pan	5.0	26.4	137.7	1.0	11.6			82.6		
Totals		500.0	1,650.0	900.0	250.0	685.0			1,058.4		

INDIVIDUAL

Limestone_Dolomite (#67)
Limestone_Dolomite (3/8)
Limestone_Dolomite (Blended screenings)

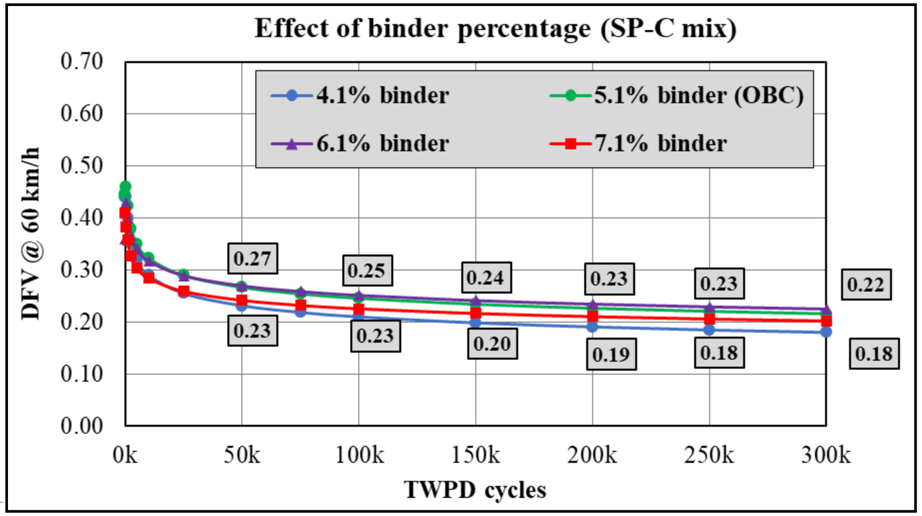
Sieved

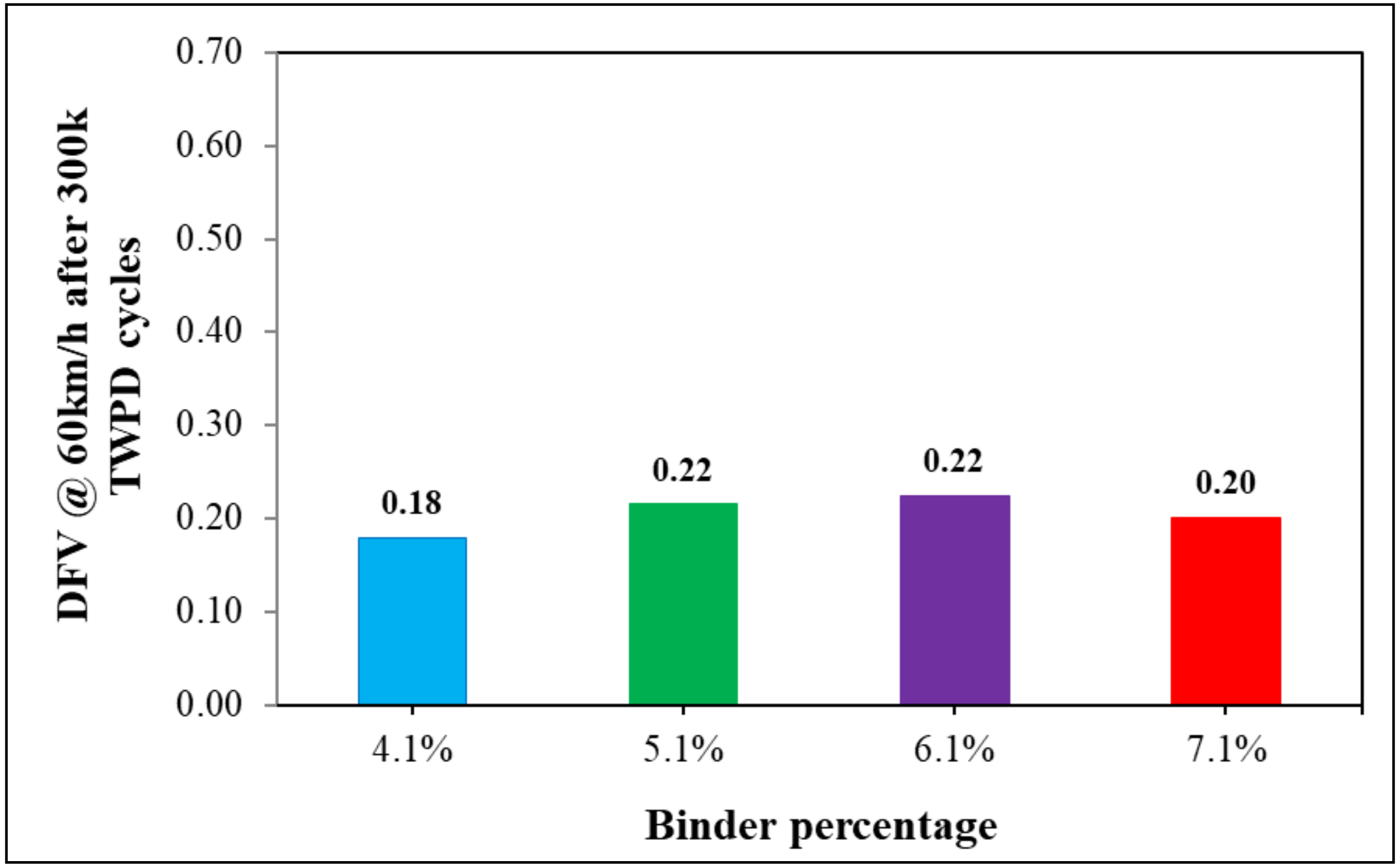


Aggregate separated into different sizes

Effect of Binder percentage

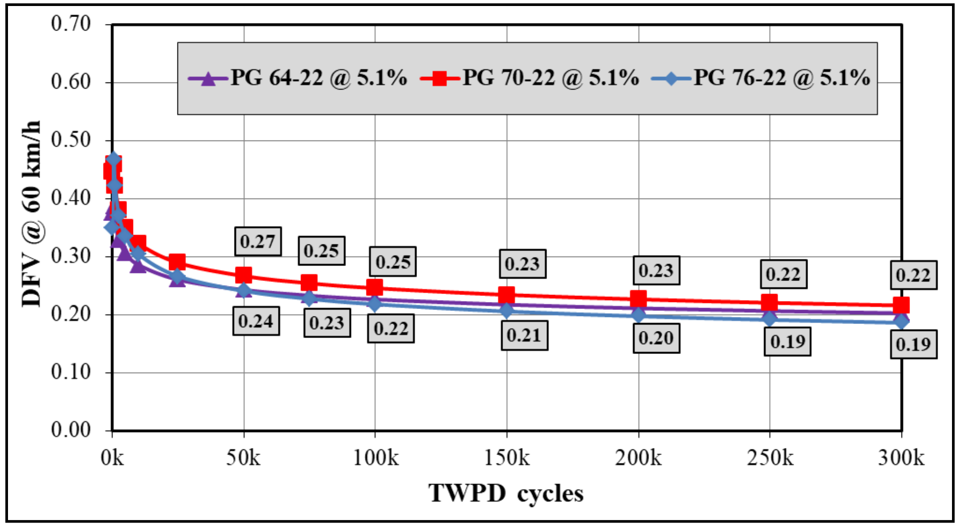
Asphalt mixture (SP-C)
▪ **Binder percentage**
▪ Binder grade
▪ Air voids percentage
▪ Aggregate gradation
▪ Asphalt gradation
▪ Aggregate quality

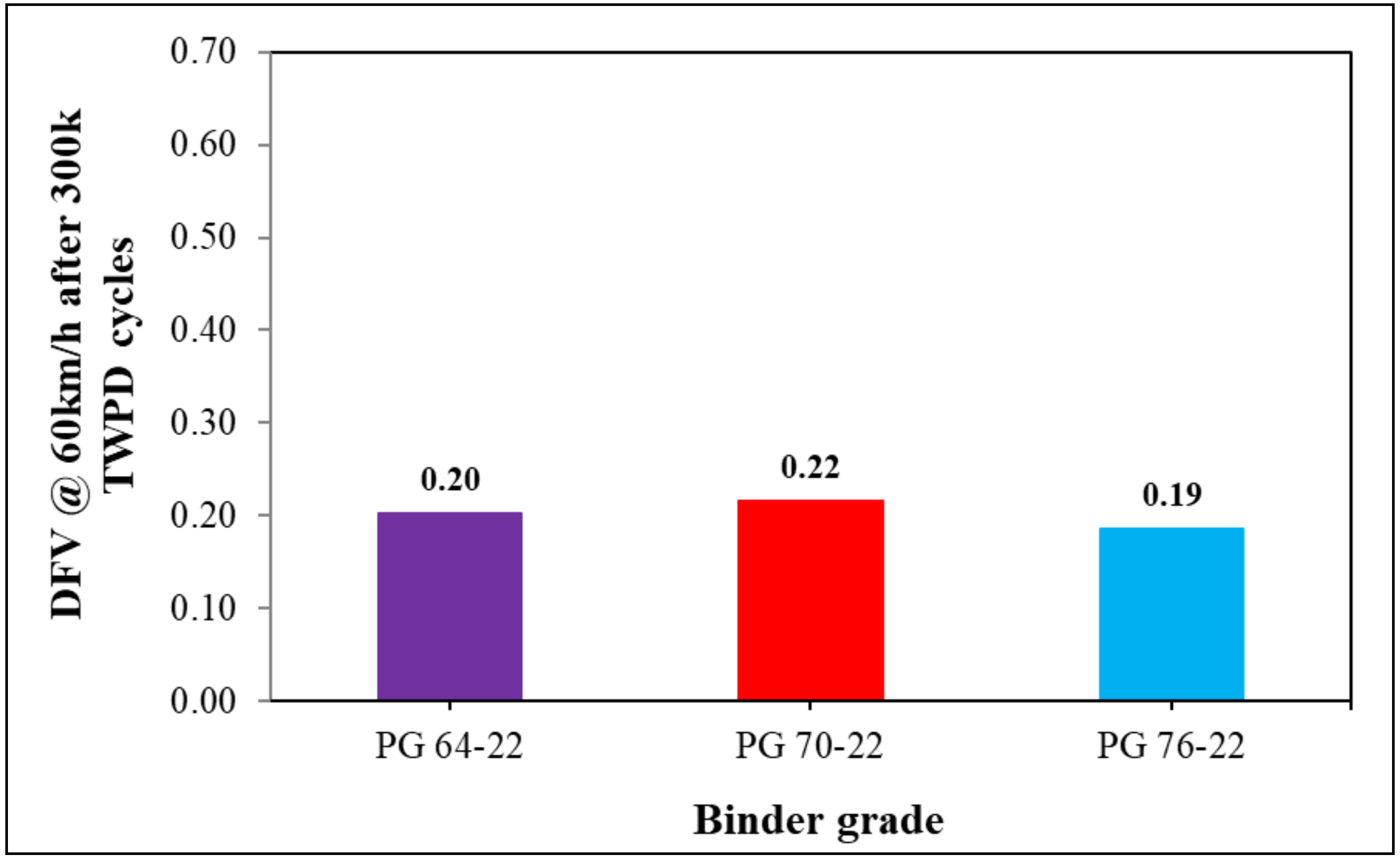




Effect of Binder Grade

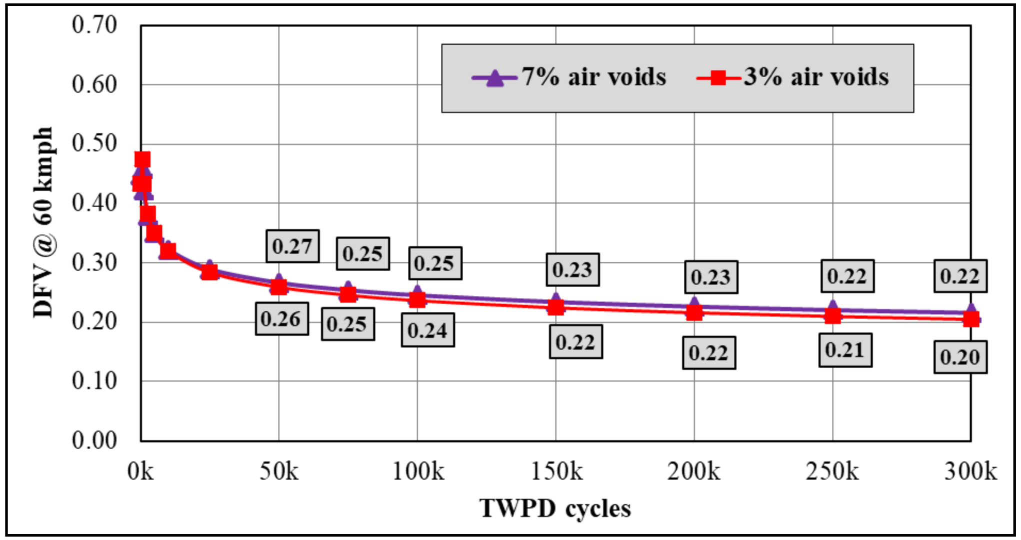
Asphalt mixture (SP-C)
▪ Binder percentage
▪ **Binder grade**
▪ Air voids percentage
▪ Aggregate gradation
▪ Asphalt gradation
▪ Aggregate quality

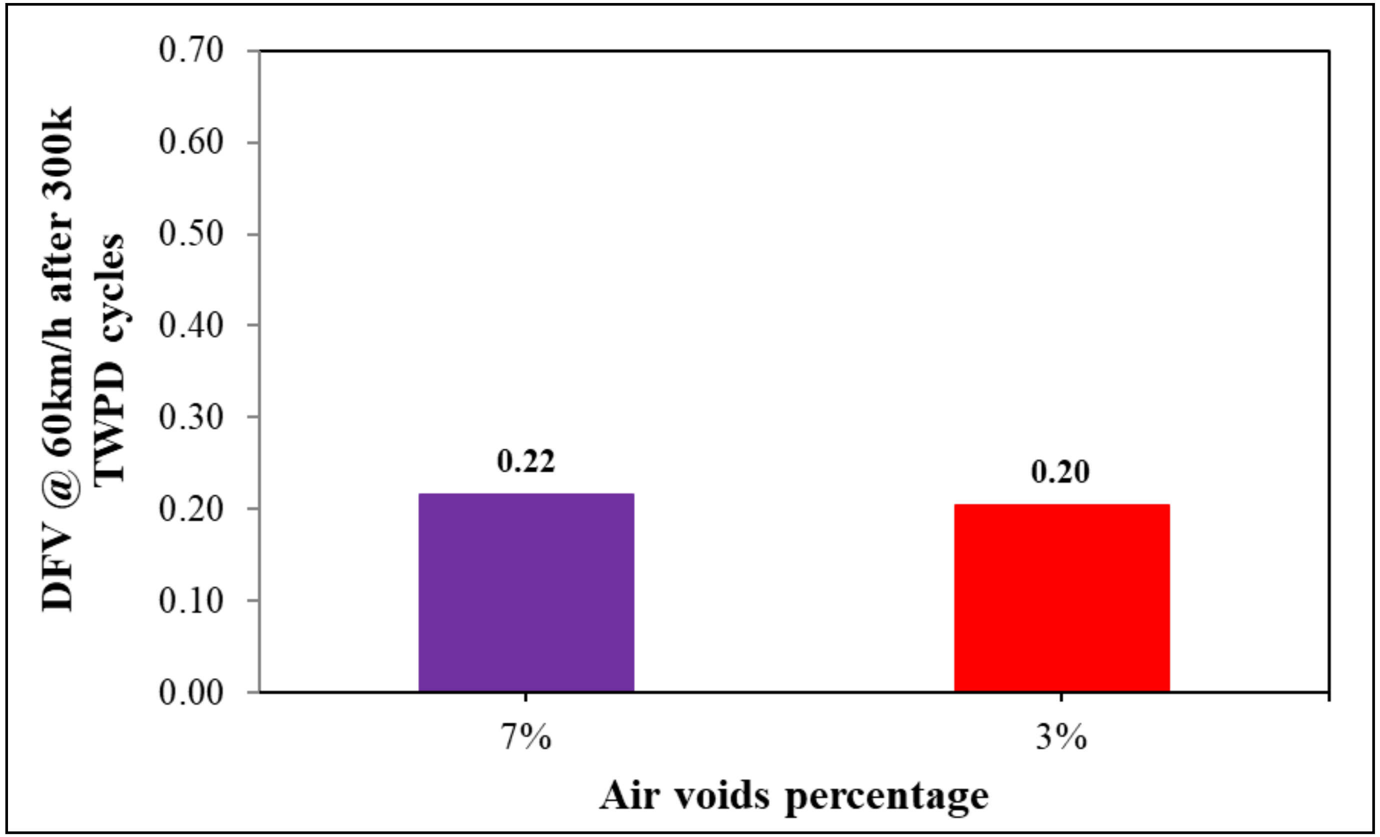




Effect of Air voids Percentage

Asphalt mixture (SP-C)
▪ Binder percentage
▪ Binder grade
▪ **Air voids percentage**
▪ Aggregate gradation
▪ Asphalt gradation
▪ Aggregate quality





Effect of Aggregate Gradation

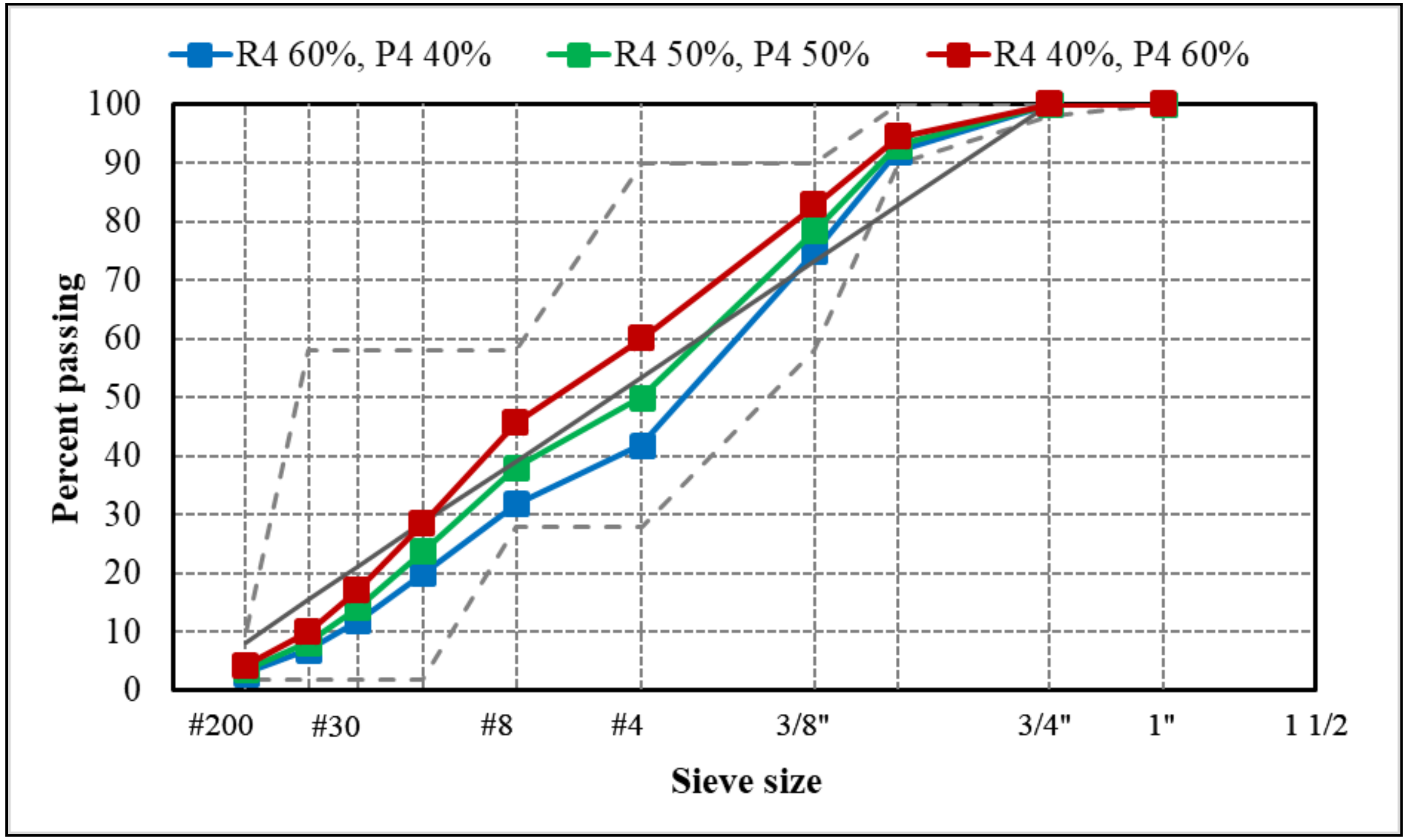
Asphalt mixture (SP-C)
▪ Binder percentage ▪ Binder grade ▪ Air voids percentage ▪ **Aggregate gradation** ▪ Asphalt gradation ▪ Aggregate quality

Sieve size
1"
3/4"
1/2"
3/8"
No. 4
No. 8
No. 16
No. 30
No. 50
No. 200
Pan

R4 **60%**, P4 **40%**

R4 **50%**, P4 **50%**

R4 **40%**, P4 **60%**



R = Retained, P = Passing

Effect of Aggregate Gradation

Asphalt mixture (SP-C)
▪ Binder percentage
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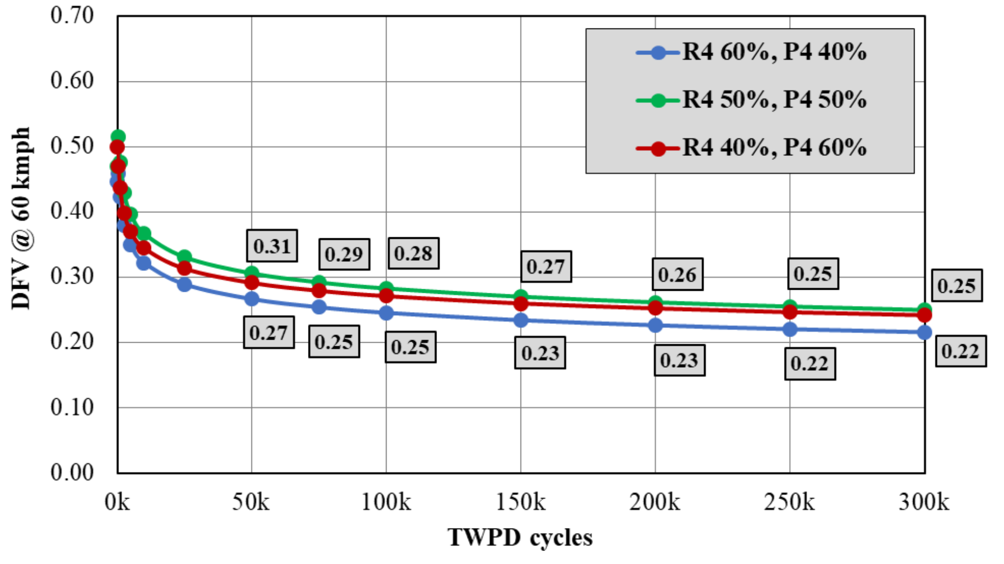
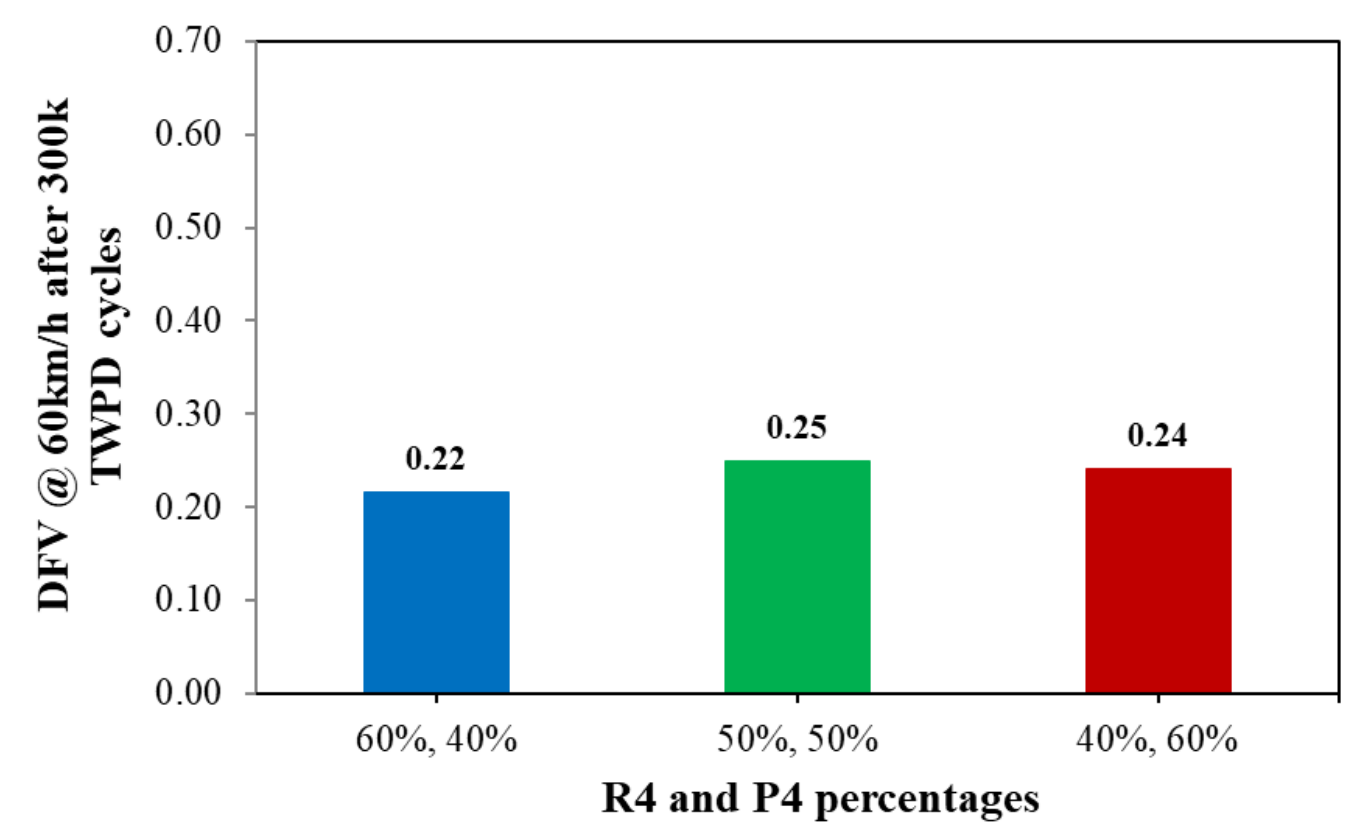
▪ **Aggregate gradation**
▪ Asphalt gradation
▪ Aggregate quality





Effect of Asphalt Gradation

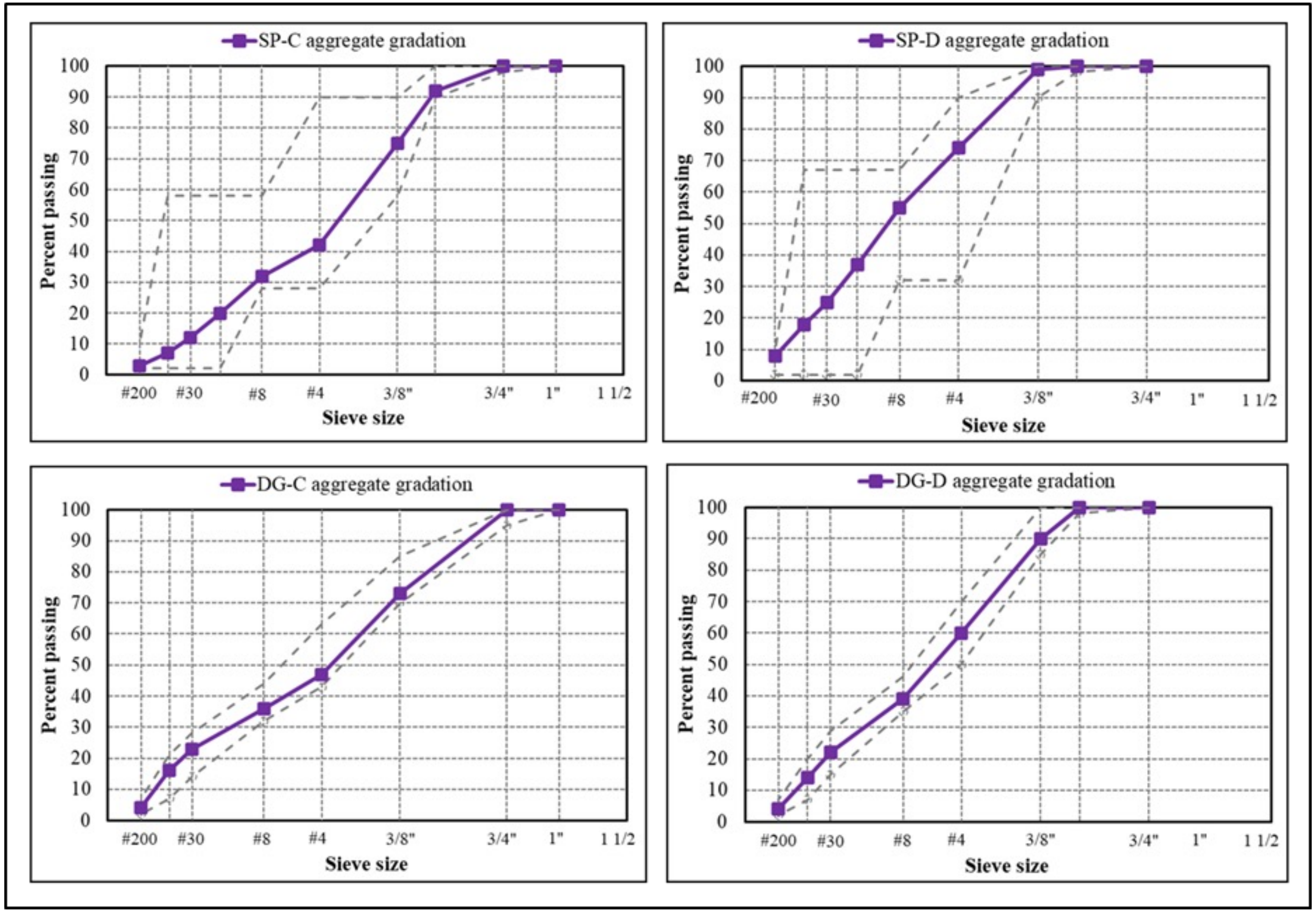
Asphalt mixture (SP-C)
▪ Binder percentage
▪ Binder grade
▪ Air voids percentage
▪ Aggregate gradation
▪ **Asphalt gradation**
▪ Aggregate quality

SP-C (R4 60%, P4 40%, OBC 5.10%)

SP-D (R4 36%, P4 64%, OBC 5.40%)

DG-C (R4 53%, P4 47%, OBC 5.00%)

DG-D (R4 40%, P4 60%, OBC 5.95%)



R = Retained, P = Passing

Effect of Asphalt Gradation

Asphalt mixture (SP-C)
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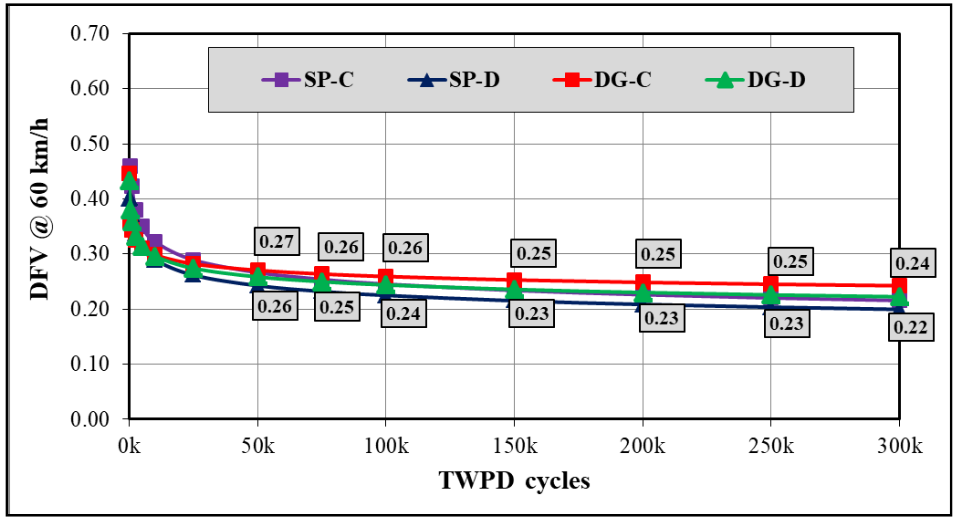
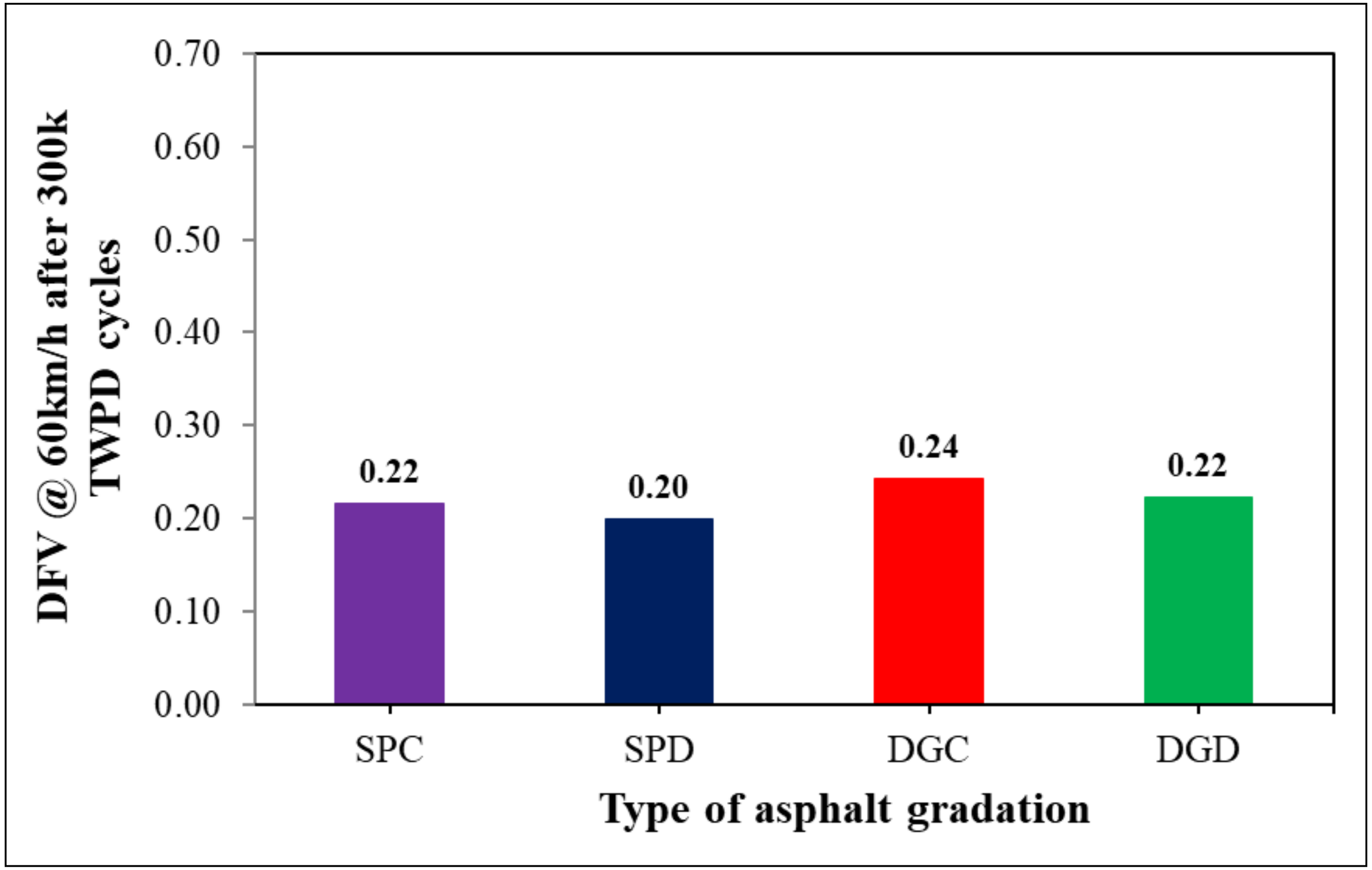




Effect of Aggregate Quality

Asphalt mixture (SP-C)
▪ Binder percentage
▪ Binder grade
▪ Air voids percentage
▪ Aggregate gradation
▪ Asphalt gradation
▪ **Aggregate quality**

Effect of Aggregate Quality

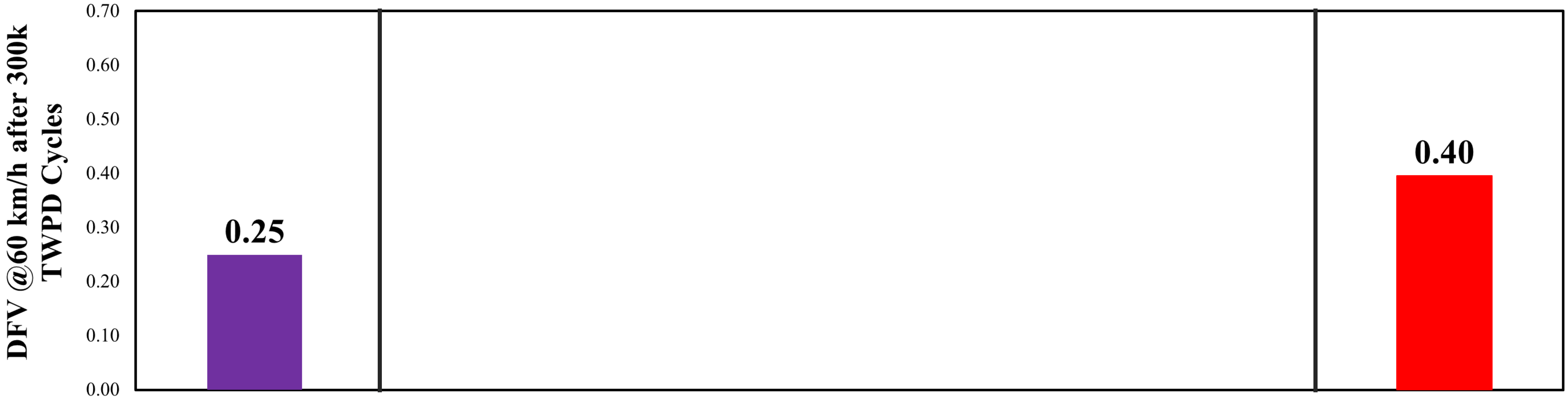
Sieve sizes (Passing – Retained)	**Aggregate type in asphalt mixture**					
P 3/4" – R No. 4 (Coarse)						
P No. 4 – R No. 30 (Coarse-fine)						
P No. 30 – Pan (Fines)						

Effect of Aggregate Quality

Sieve sizes (Passing – Retained)	Aggregate type in asphalt mixture					
	Mix 1					**Mix 6**
P 3/4" – R No. 4 (Coarse)	Limestone_ Dolomite (100%)					Sandstone (100%)
P No. 4 – R No. 30 (Coarse-fine)						
P No. 30 – Pan (Fines)						

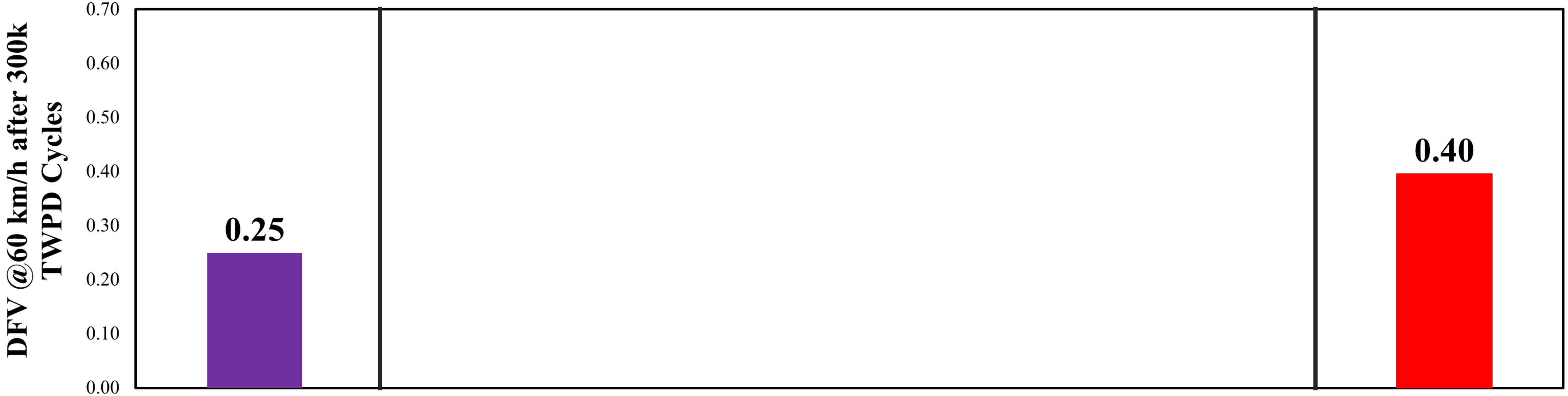
Effect of Aggregate Quality

Sieve sizes (Passing – Retained)	Aggregate type in asphalt mixture				
	Mix 1				**Mix 6**
P 3/4" – R No. 4 (Coarse)	Limestone_ Dolomite (100%)				Sandstone (100%)
P No. 4 – R No. 30 (Coarse-fine)					
P No. 30 – Pan (Fines)					



Effect of Aggregate Quality

Sieve sizes (Passing – Retained)	Aggregate type in asphalt mixture					
	Mix 1	**Mix 2**			**Mix 5**	**Mix 6**
P 3/4” – R No. 4 (Coarse)	Limestone_ Dolomite (100%)	Sandstone (50%)			Limestone_ Dolomite (50%)	Sandstone (100%)
P No. 4 – R No. 30 (Coarse-fine)		Limestone_ Dolomite (50%)			Sandstone (50%)	
P No. 30 – Pan (Fines)						



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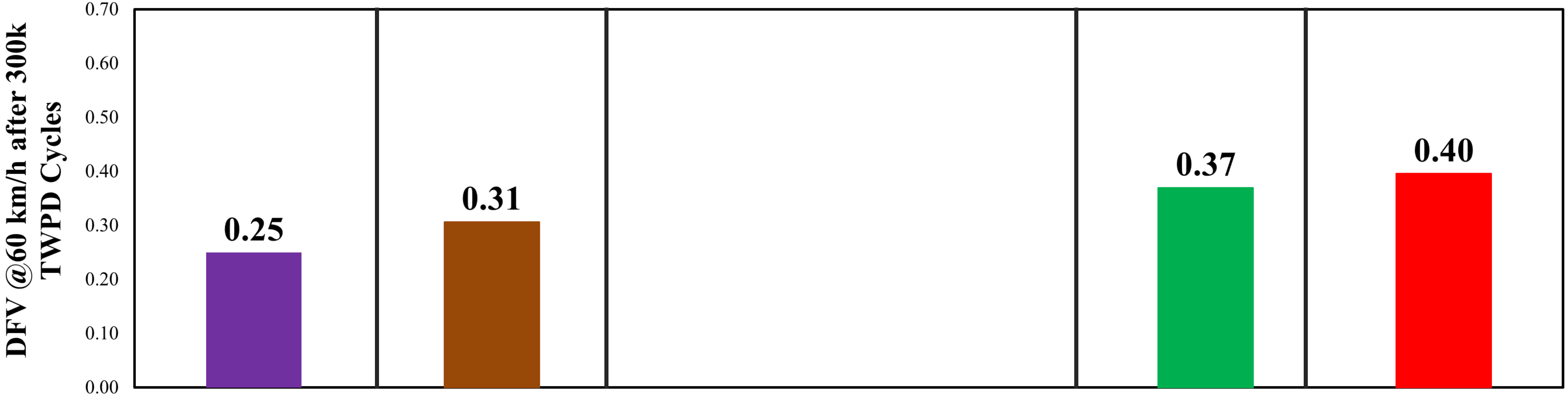
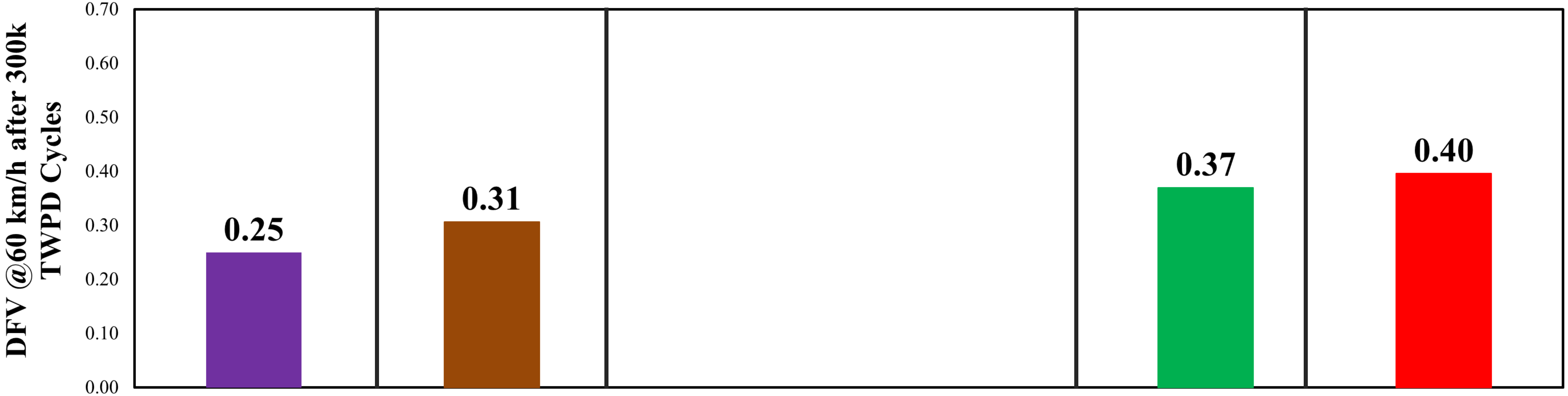
Sieve sizes (Passing – Retained)	Aggregate type in asphalt mixture					
	Mix 1	**Mix 2**			**Mix 5**	**Mix 6**
P 3/4” – R No. 4 (Coarse)	Limestone_ Dolomite (100%)	Sandstone (50%)			Limestone_ Dolomite (50%)	Sandstone (100%)
P No. 4 – R No. 30 (Coarse-fine)		Limestone_ Dolomite (50%)			Sandstone (50%)	
P No. 30 – Pan (Fines)						



Effect of Aggregate Quality

Sieve sizes (Passing – Retained)	Aggregate type in asphalt mixture					
	Mix 1	**Mix 2**	**Mix 3**	**Mix 4**	**Mix 5**	**Mix 6**
P 3/4” – R No. 4 (Coarse)	Limestone_ Dolomite (100%)	Sandstone (50%)	Limestone_ Dolomite (50%)	Limestone_ Dolomite (50%)	Limestone_ Dolomite (50%)	Sandstone (100%)
P No. 4 – R No. 30 (Coarse-fine)		Limestone_ Dolomite (50%)	Limestone_ Dolomite (36%)	Sandstone (36%)	Sandstone (50%)	
P No. 30 – Pan (Fines)			Sandstone (14%)	Limestone_ Dolomite (14%)		



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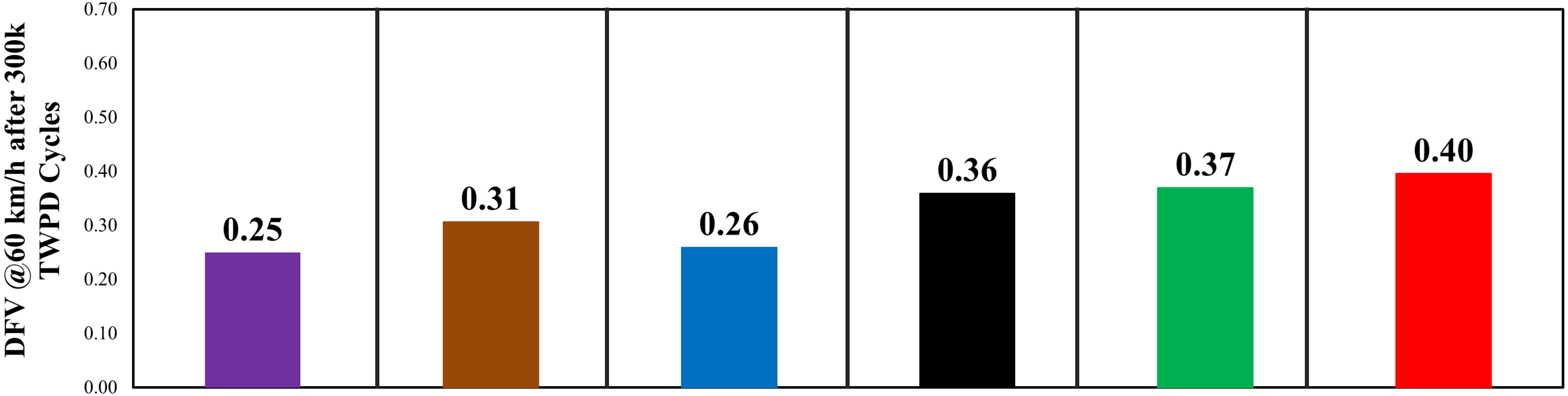
Sieve sizes (Passing – Retained)	Aggregate type in asphalt mixture					
	Mix 1	**Mix 2**	**Mix 3**	**Mix 4**	**Mix 5**	**Mix 6**
P 3/4" – R No. 4 (Coarse)	Limestone_ Dolomite (100%)	Sandstone (50%)	Limestone_ Dolomite (50%)	Limestone_ Dolomite (50%)	Limestone_ Dolomite (50%)	Sandstone (100%)
P No. 4 – R No. 30 (Coarse-fine)		Limestone_ Dolomite (50%)	Limestone_ Dolomite (36%)	Sandstone (36%)	Sandstone (50%)	
P No. 30 – Pan (Fines)			Sandstone (14%)	Limestone_ Dolomite (14%)		

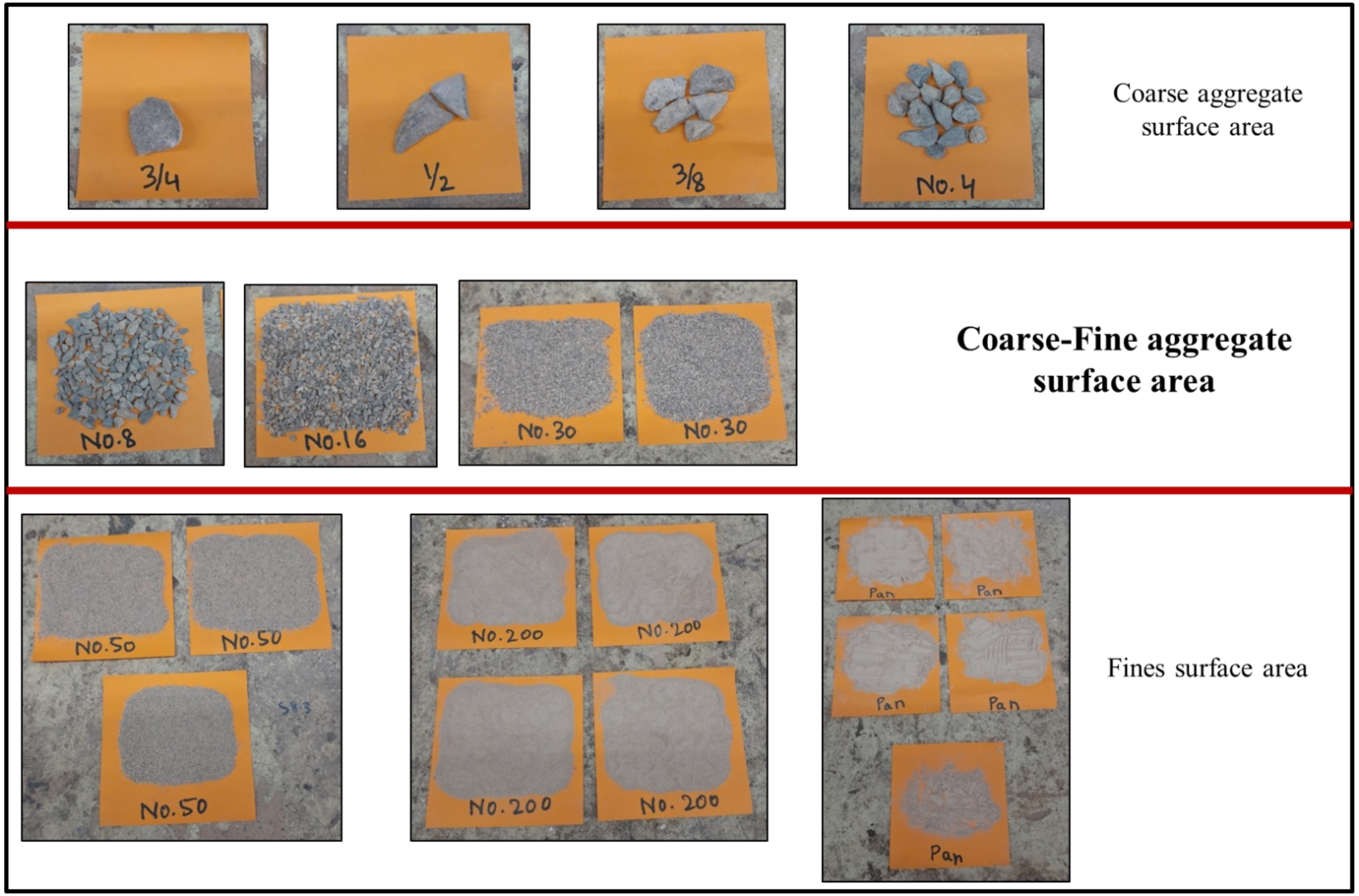


Factors Controlling the Asphalt Mixture Frictional Performance

Asphalt mixture

- Binder percentage
- Binder grade
- Air voids percentage
- Aggregate gradation
- Asphalt gradation
- **Aggregate quality**

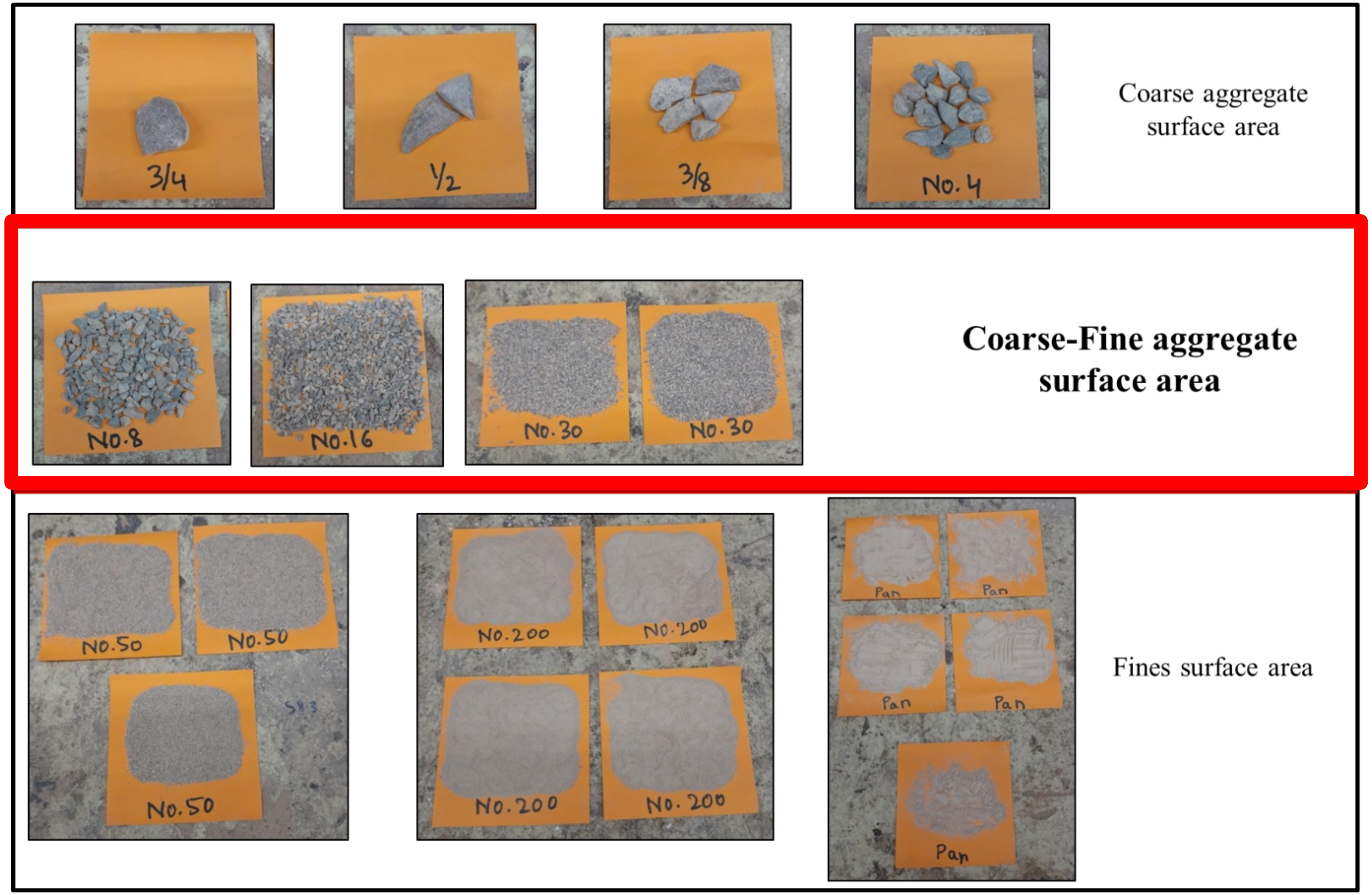
❖ ***Surface area illustration of 10 grams of aggregate of each size***



Factors Controlling the Asphalt Mixture Frictional Performance

Asphalt mixture
▪ Binder percentage ▪ Binder grade ▪ Air voids percentage ▪ Aggregate gradation ▪ Asphalt gradation ▪ **Aggregate quality**

❖ *Surface area illustration of 10 grams of aggregate of each size*



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Case example 1: Bin based approach (Mixture from El Paso District (SP-C))

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			Bin No.1	Bin No.2	Bin No.3	Bin No.4	Bin No.5	Bin No.6	Bin No.7	Bin No.8	Bin No.9	Bin No.10
Individual Bin (%):			Bin No.1 = 14 %	Bin No.2 = 40 %	Bin No.3 = 26 %	Bin No.4 = 10 %				Bin No.8 = 10 %		
Aggregate Source:			Igneous	Igneous	Igneous					Fractionated RAP		
Aggregate Number:			2407101	2407101	2407101							
Sample ID:			3/4 Red	Red-3/8	Red Screenings	Section 10 Mortar Sand				Fine 1/2"		
	Sieve Size: Passing	Sieve Size: Retained	Hydrated Lime Weight	Aggregate Weight	Aggregate Weight	Aggregate Weight				Fractionated RAP Weight		
INDIVIDUAL	-	1"	0.0	0.0	0.0	0.0				0.0		
	1"	3/4"	13.2	0.0	0.0	0.0				0.0		
	3/4"	1/2"	46.2	0.0	0.0	0.0				0.0		
	1/2"	3/8"	24.9	9.8	0.0	0.1				2.1		
	3/8"	No. 4	45.1	272.1	16.6	0.2				34.4		
	No. 4	No. 8	5.7	99.3	83.6	0.3				24.0		
	No. 8	No. 16	1.6	6.6	59.0	1.0				13.3		
	No. 16	No. 30	0.4	2.1	35.5	12.9				13.5		
	No. 30	No. 50	0.4	1.3	31.2	41.3				9.6		
	No. 50	No. 200	0.8	4.8	27.7	43.2				8.5		
	No. 200	Pan	1.5	4.1	6.4	1.0				1.2		
	Totals		140.0	400.0	260.0	100.0				106.6		

Case example 1: Bin based approach (Mixture from El Paso District (SP-C))

40% Sandstone

			Bin No.1	Bin No.2	Bin No.3	Bin No.4	Bin No.5	Bin No.6	Bin No.7	Bin No.8	Bin No.9	Bin No.10
	Individual Bin (%):		Bin No.1 = 14 %	Bin No.2 = 40 %	Bin No.3 = 26 %	Bin No.4 = 10 %				Bin No.8 = 10 %		
	Aggregate Source:		Igneous	Igneous	Igneous					Fractionated RAP		
	Aggregate Number:		2407101	2407101	2407101							
	Sample ID:		3/4 Red	Red-3/8	Red Screenings	Section 10 Mortar Sand				Fine 1/2"		
	Sieve Size:		Hydrated Lime Weight	Aggregate Weight	Aggregate Weight	Aggregate Weight				Fractionated RAP Weight		
	Passing	Retained										
INDIVIDUAL	-	1"	0.0	0.0	0.0	0.0				0.0		
	1"	3/4"	13.2	0.0	0.0	0.0				0.0		
	3/4"	1/2"	46.2	0.0	0.0	0.0				0.0		
	1/2"	3/8"	24.9	9.8	0.0	0.1				2.1		
	3/8"	No. 4	45.1	272.1	16.6	0.2				34.4		
	No. 4	No. 8	5.7	99.3	83.6	0.3				24.0		
	No. 8	No. 16	1.6	6.6	59.0	1.0				13.3		
	No. 16	No. 30	0.4	2.1	35.5	12.9				13.5		
	No. 30	No. 50	0.4	1.3	31.2	41.3				9.6		
	No. 50	No. 200	0.8	4.8	27.7	43.2				8.5		
	No. 200	Pan	1.5	4.1	6.4	1.0				1.2		
	Totals		140.0	400.0	260.0	100.0				106.6		

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		Bin No.1	Bin No.2	Bin No.3	Bin No.4	Bin No.5	Bin No.6	Bin No.7	Bin No.8	Bin No.9	Bin No.10
Individual Bin (%):		Bin No.1 = 14 %	Bin No.2 = 40 %	Bin							
Aggregate Source:		Igneous	Igneous								
Aggregate Number:		2407101	2407101								
Sample ID:		3/4 Red	Red-3/8	Re							
Sieve Size:		Hydrated Lime Weight	Aggregate Weight	A							
Passing	Retained										
-	1"	0.0	0.0								
1"	3/4"	13.2	0.0								
3/4"	1/2"	46.2	0.0								
1/2"	3/8"	24.9	9.8								
3/8"	No. 4	45.1	272.1								
No. 4	No. 8	5.7	99.3								
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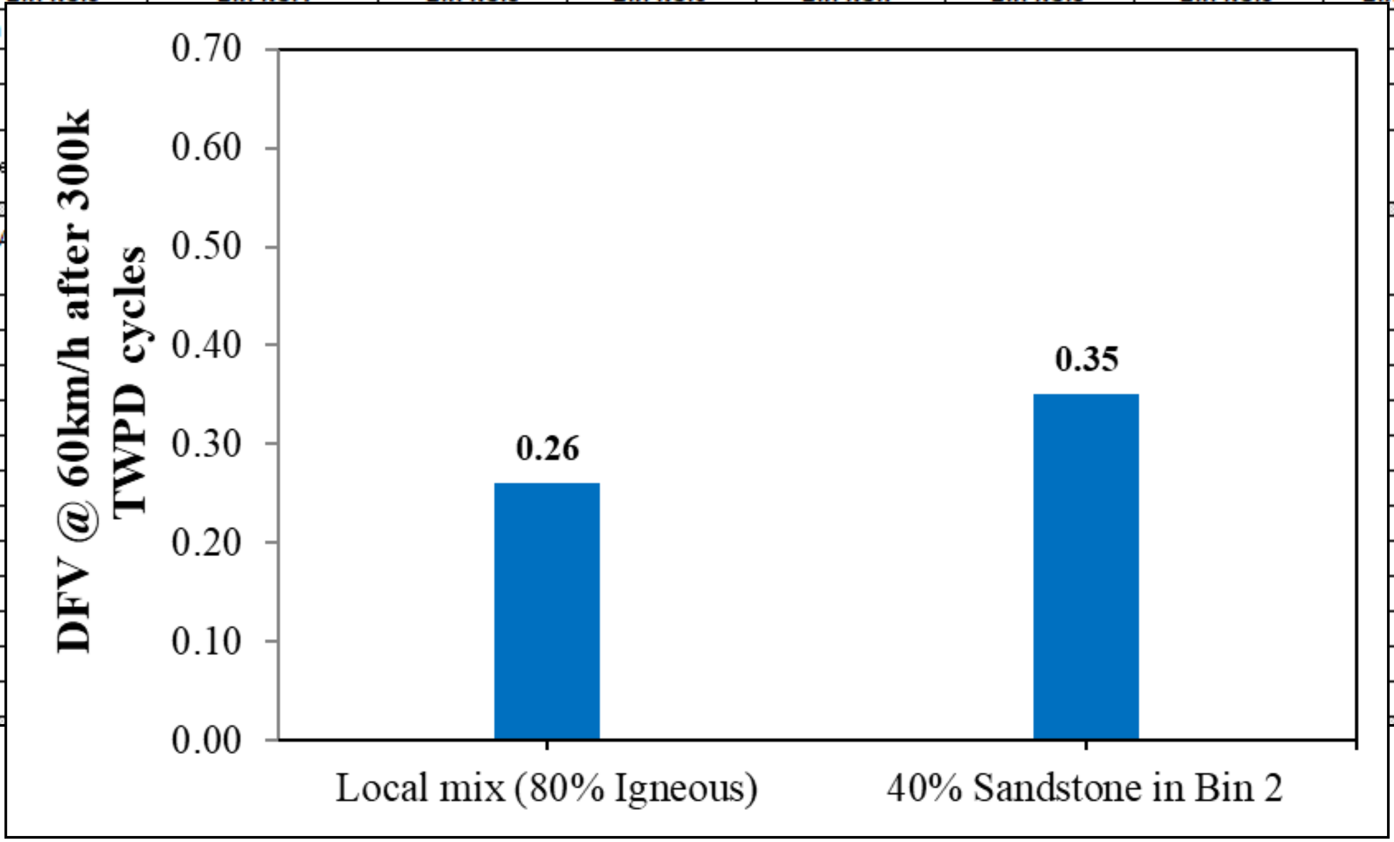
No. 16	No. 30	0.4	2.1								
No. 30	No. 50	0.4	1.3								
No. 50	No. 200	0.8	4.8								
No. 200	Pan	1.5	4.1								
Totals		140.0	400.0								

INDIVIDUAL



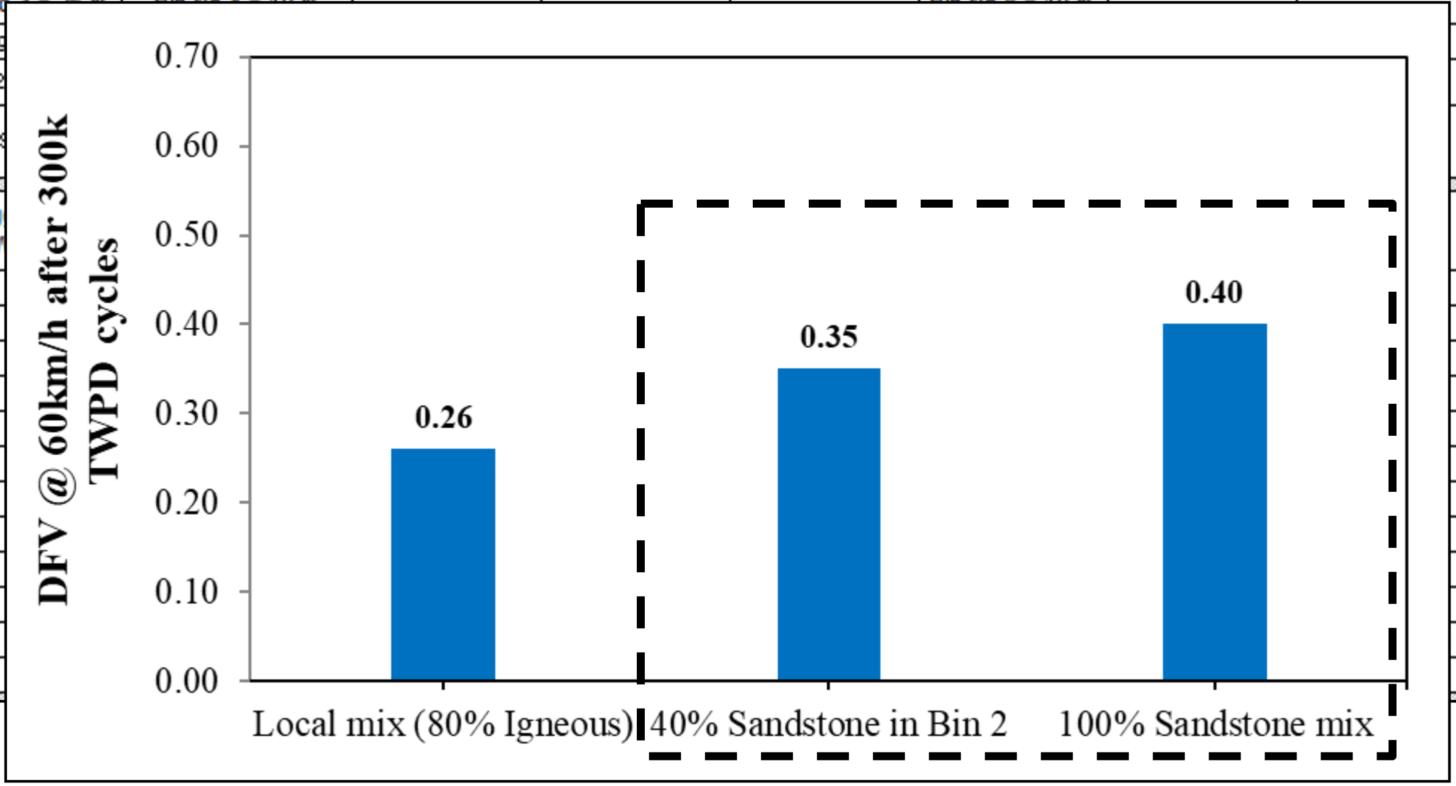
Case example 1: Bin based approach (Mixture from El Paso District (SP-C))

40% Sandstone

	Bin No.1	Bin No.2	Bin No.3	Bin No.4	Bin No.5	Bin No.6	Bin No.7	Bin No.8	Bin No.9	Bin No.10
Individual Bin (%):	Bin No.1 = 14 %	Bin No.2 = 40 %								
Aggregate Source:	Igneous	Igneous								
Aggregate Number:	2407101	2407101								
Sample ID:	3/4 Red	Red-3/8								

Sieve Size: Passing	Sieve Size: Retained	Hydrated Lime Weight	Aggregate Weight
-	1"	0.0	0.0
1"	3/4"	13.2	0.0
3/4"	1/2"	46.2	0.0
1/2"	3/8"	24.9	9.8
3/8"	No. 4	45.1	272.1
No. 4	No. 8	5.7	99.3
No. 8	No. 16	1.6	6.6
No. 16	No. 30	0.4	2.1
No. 30	No. 50	0.4	1.3
No. 50	No. 200	0.8	4.8
No. 200	Pan	1.5	4.1
Totals		140.0	400.0

INDIVIDUAL



Presentation outline

1. Background of the Study
2. Factors Controlling the Asphalt Mixture Frictional Performance
3. Case Examples for Improving the Mixture Frictional Performance
4. **Field Verification of Laboratory Friction**
5. Upcoming Field Pilot Test Sections
6. Final Specification

Field Verification of Laboratory Friction

- **Approach:** Collect field cores, polish in the lab and compare with lab friction deterioration curve

Cores extraction on wheel path and in between wheel paths

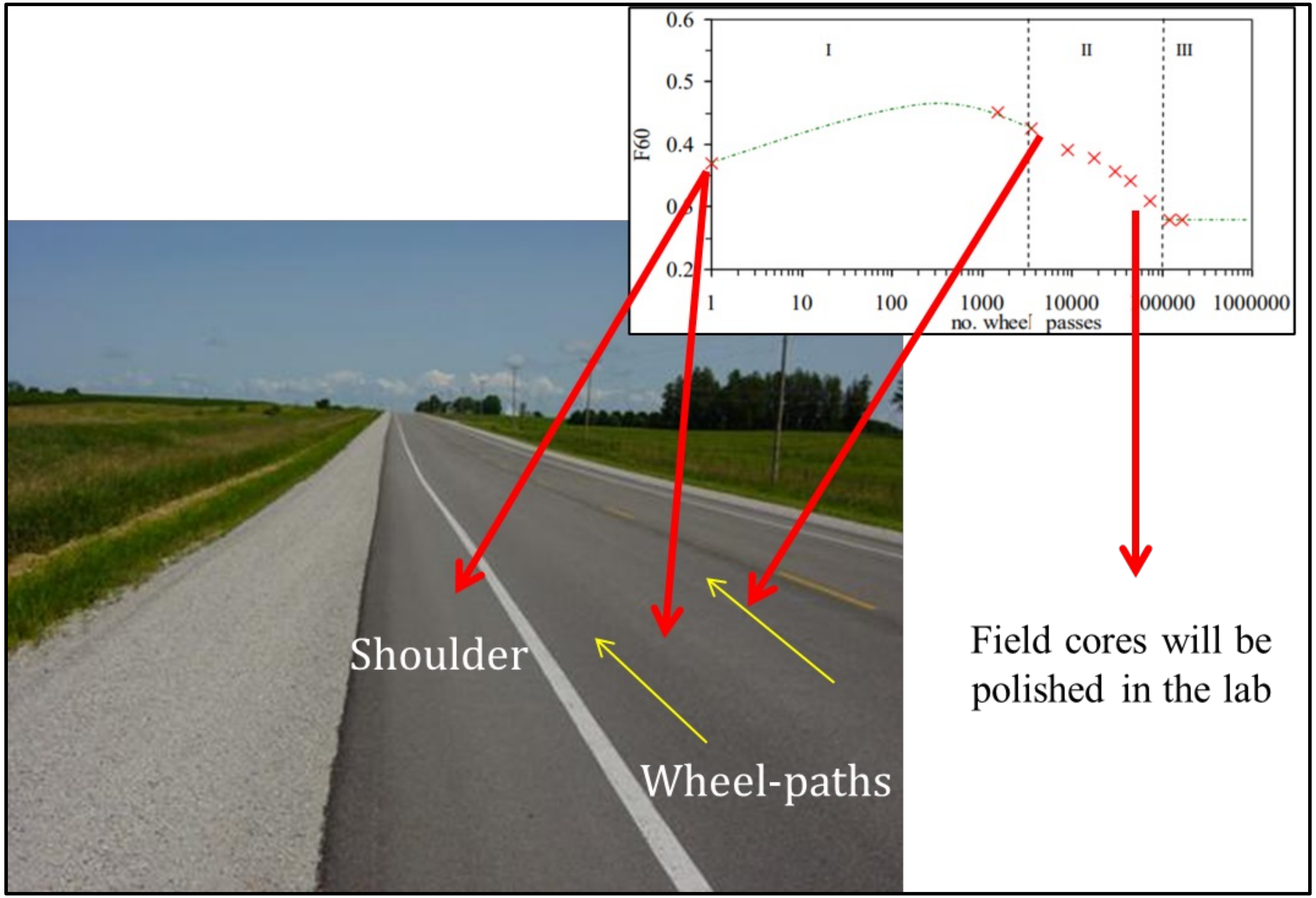
On Wheel Path Cores

In between Wheel Path Cores

Field Verification of Laboratory Friction

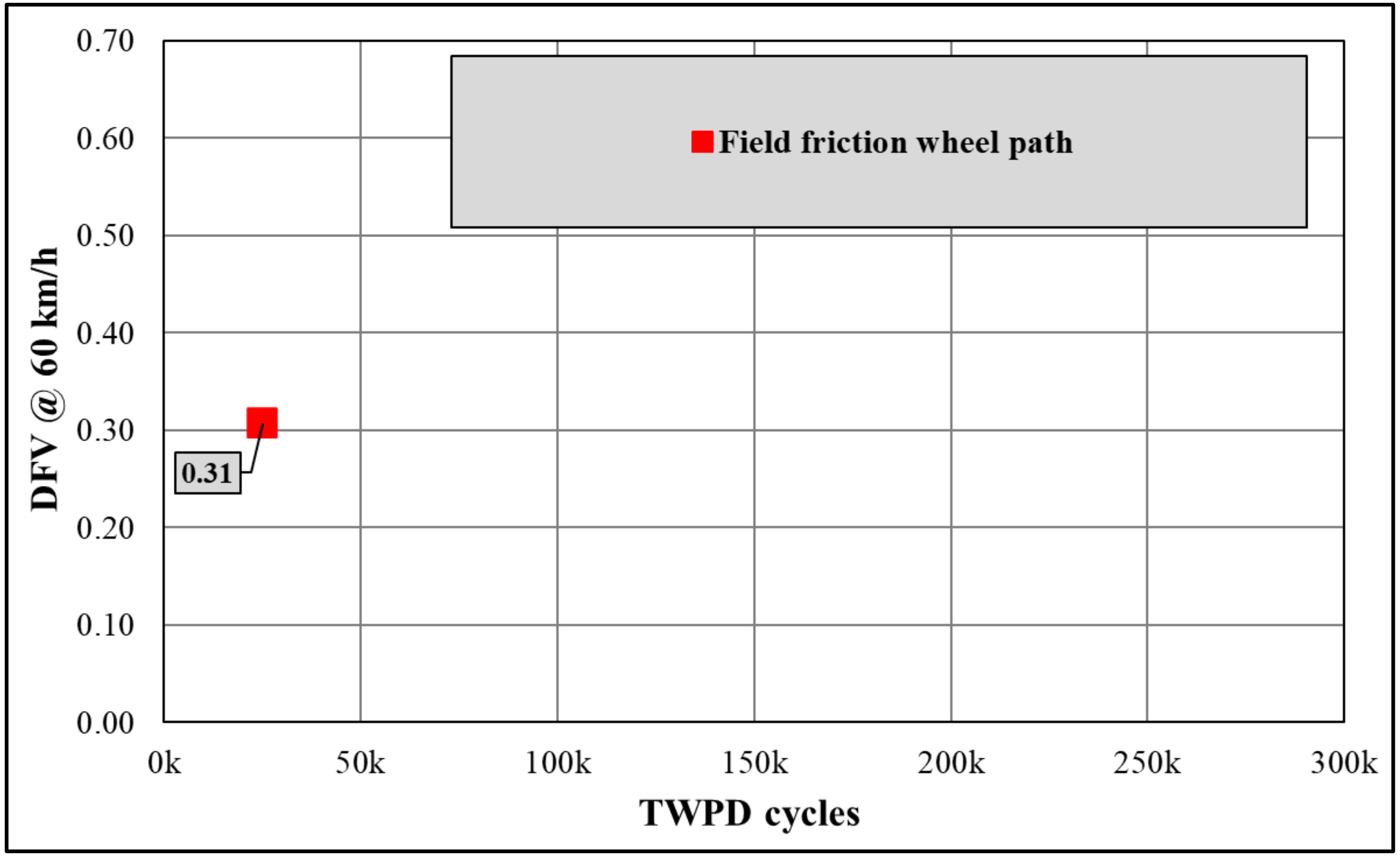
Targeted Sections

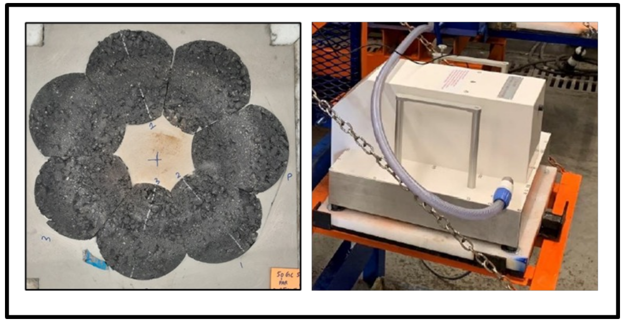
S. No.	Name of the project
1	YKM SH71
2	SAT SL337
3	ATL US59
4	CHS US70
5	PAR SH37

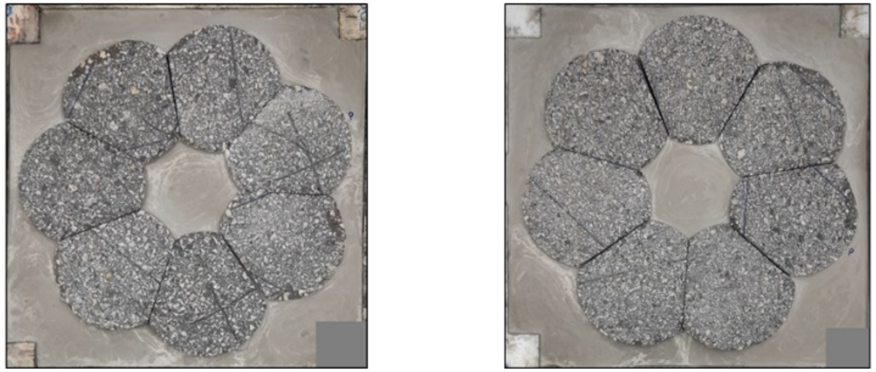


Field Verification of Laboratory Friction

- **YKM SH71**







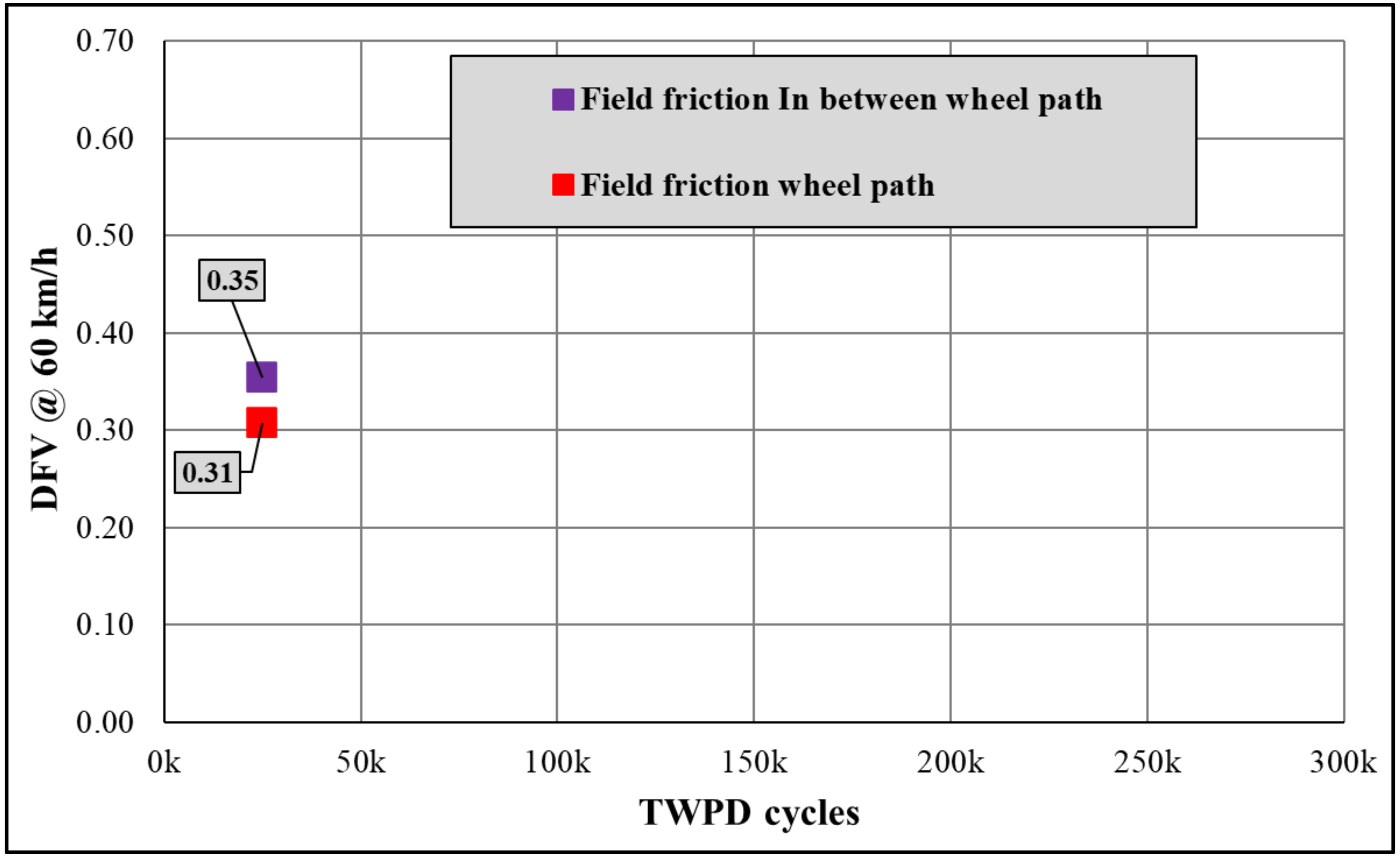
On Wheel Path Cores

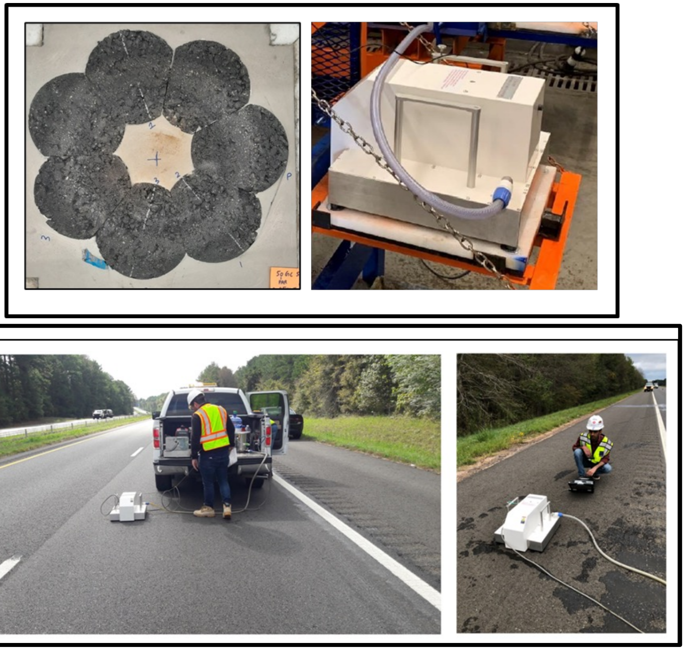
In between Wheel Path Cores

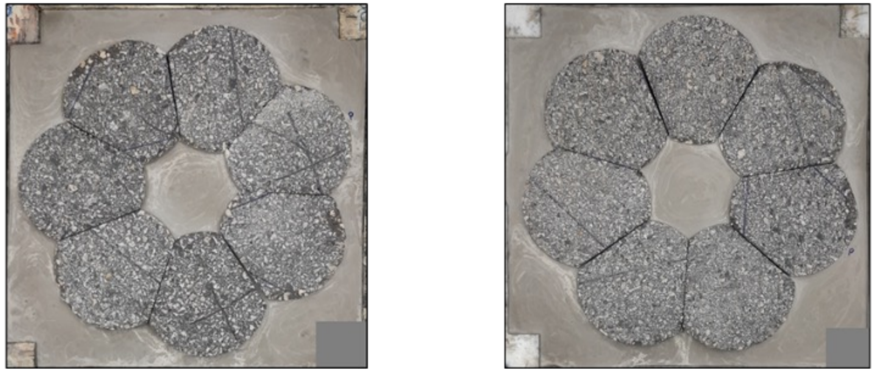
YKM SH71 Section 4 Asphalt Rings

Field Verification of Laboratory Friction

- **YKM SH71**







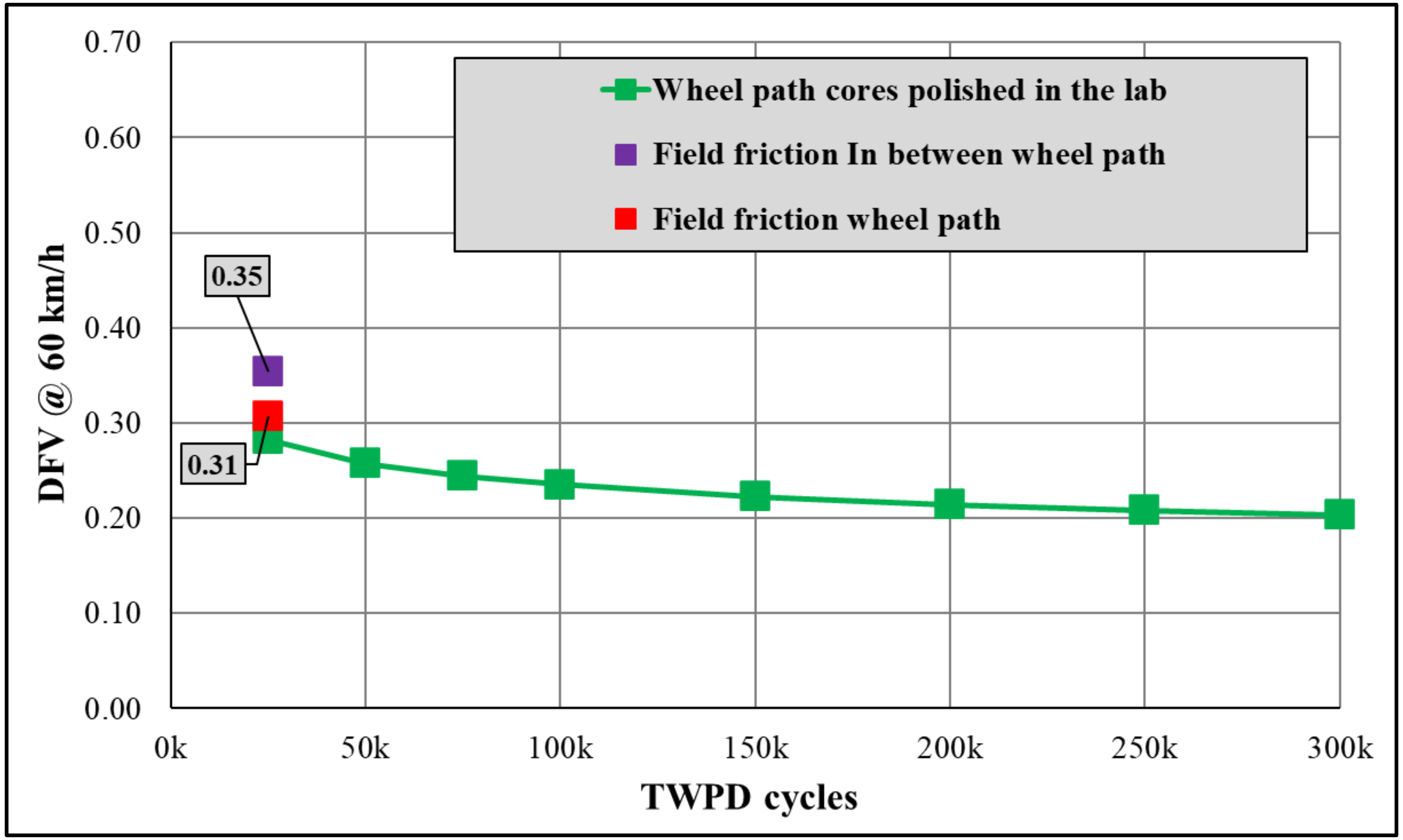
On Wheel Path Cores

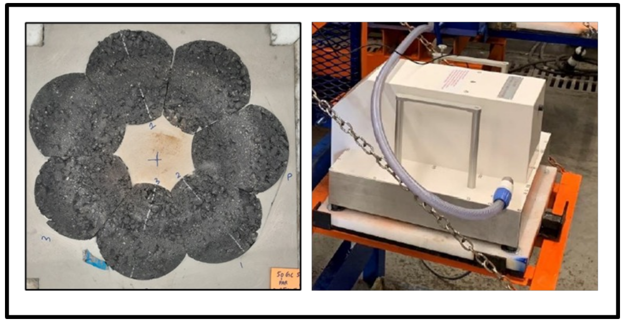
In between Wheel Path Cores

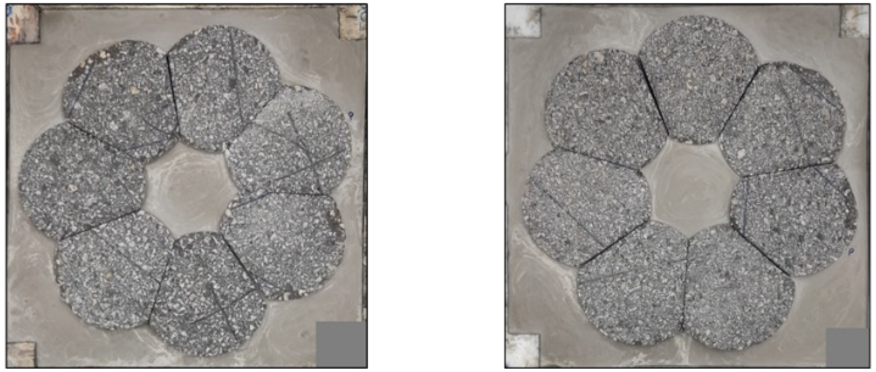
YKM SH71 Section 4 Asphalt Rings

Field Verification of Laboratory Friction

- **YKM SH71**







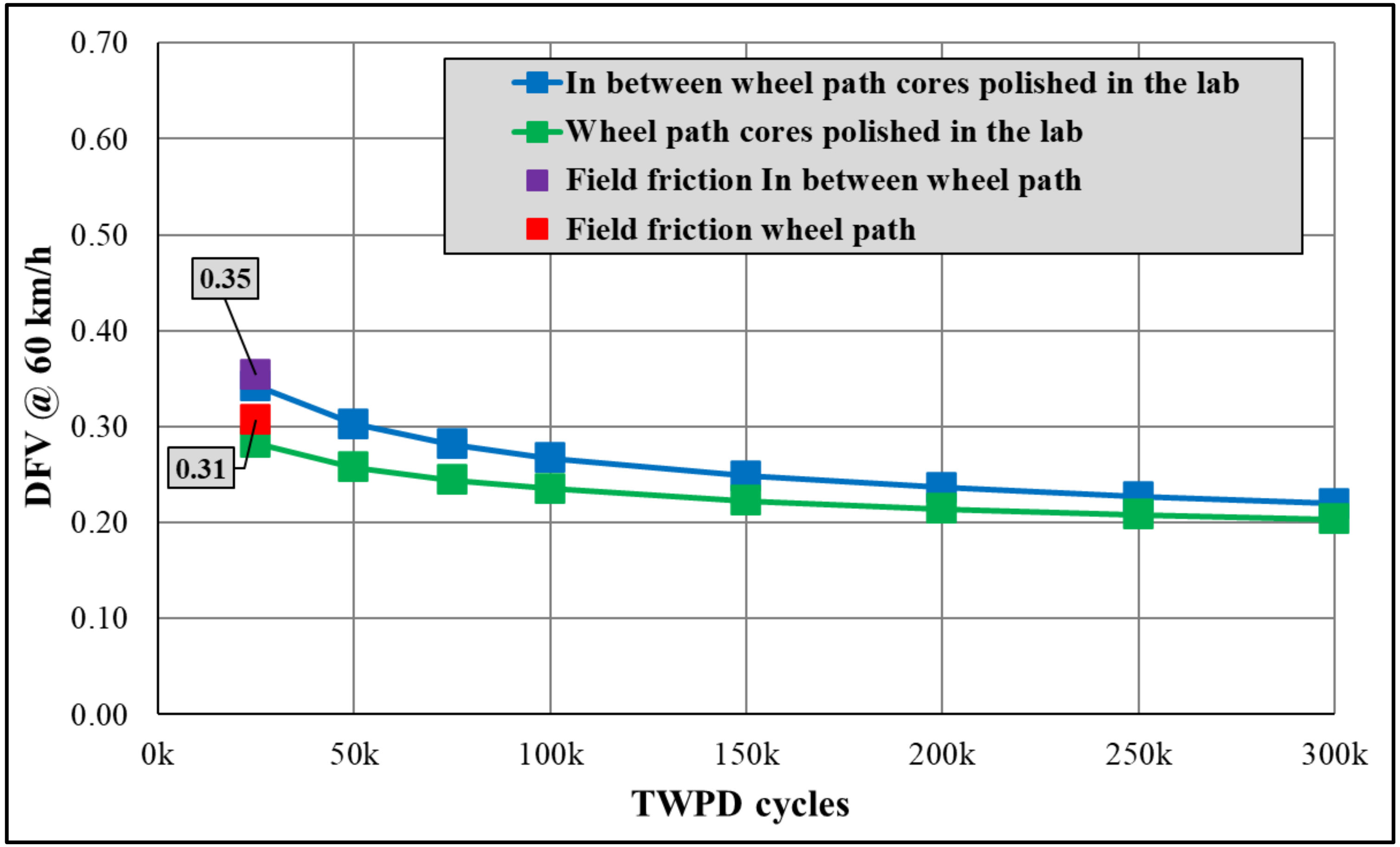
On Wheel Path Cores

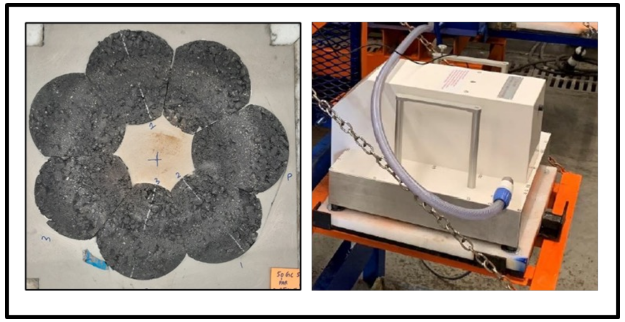
In between Wheel Path Cores

YKM SH71 Section 4 Asphalt Rings

Field Verification of Laboratory Friction

- **YKM SH71**





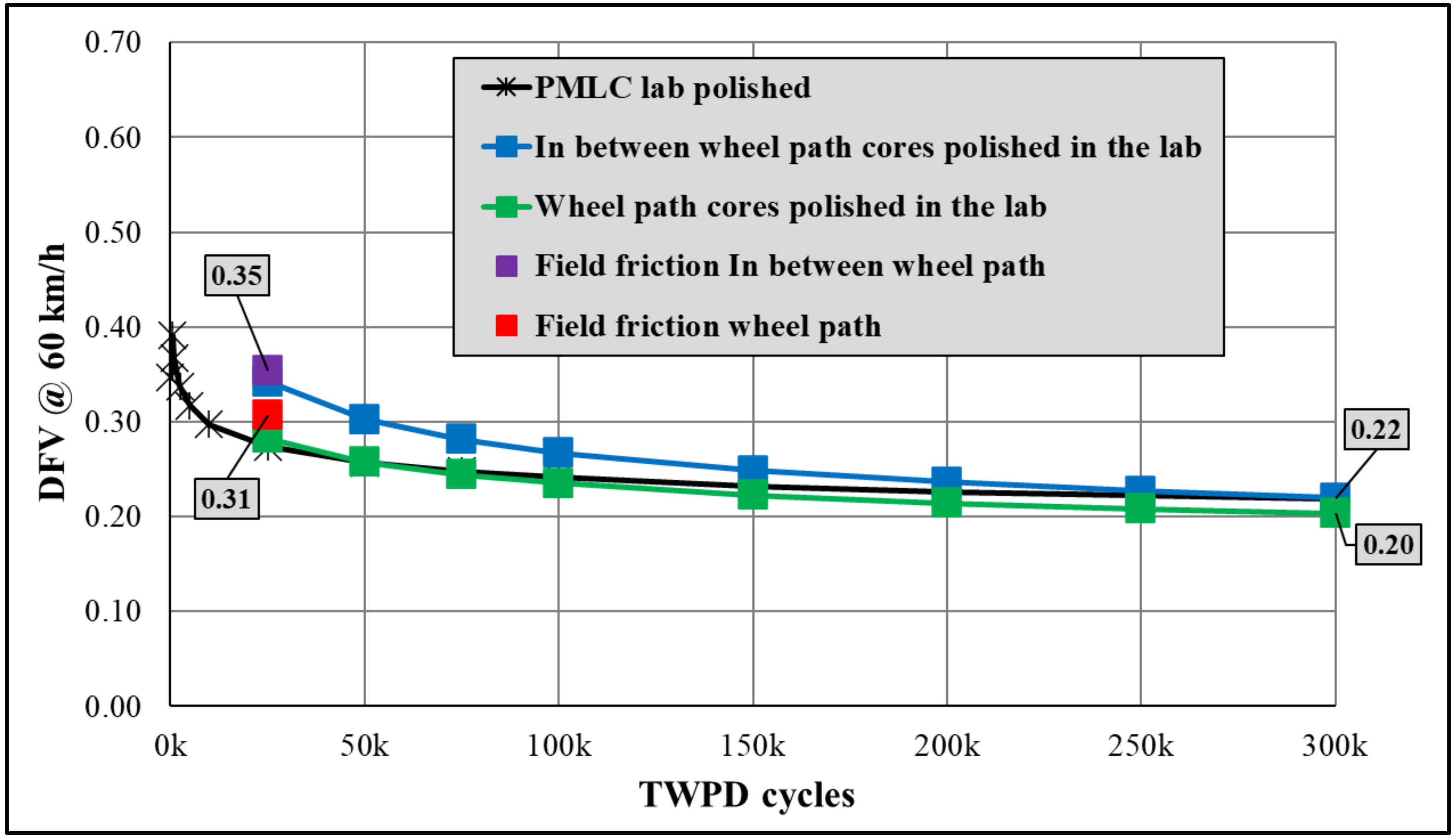
On Wheel Path Cores

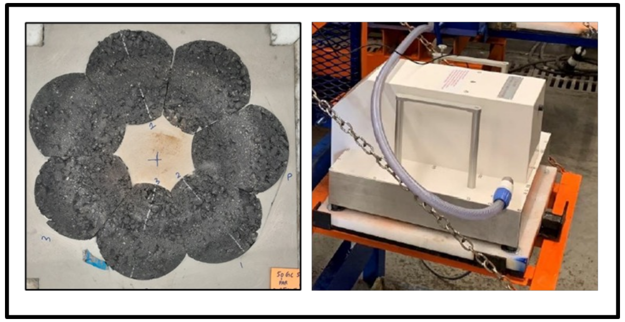
In between Wheel Path Cores

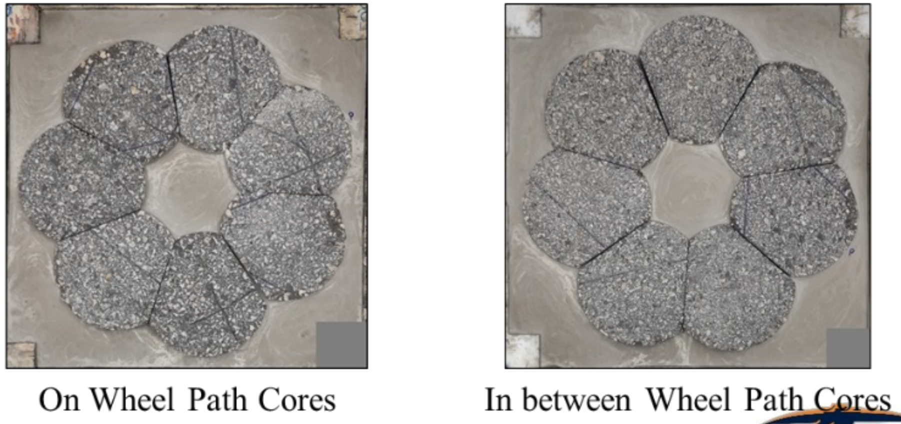
YKM SH71 Section 4 Asphalt Rings

Field Verification of Laboratory Friction

- **YKM SH71**



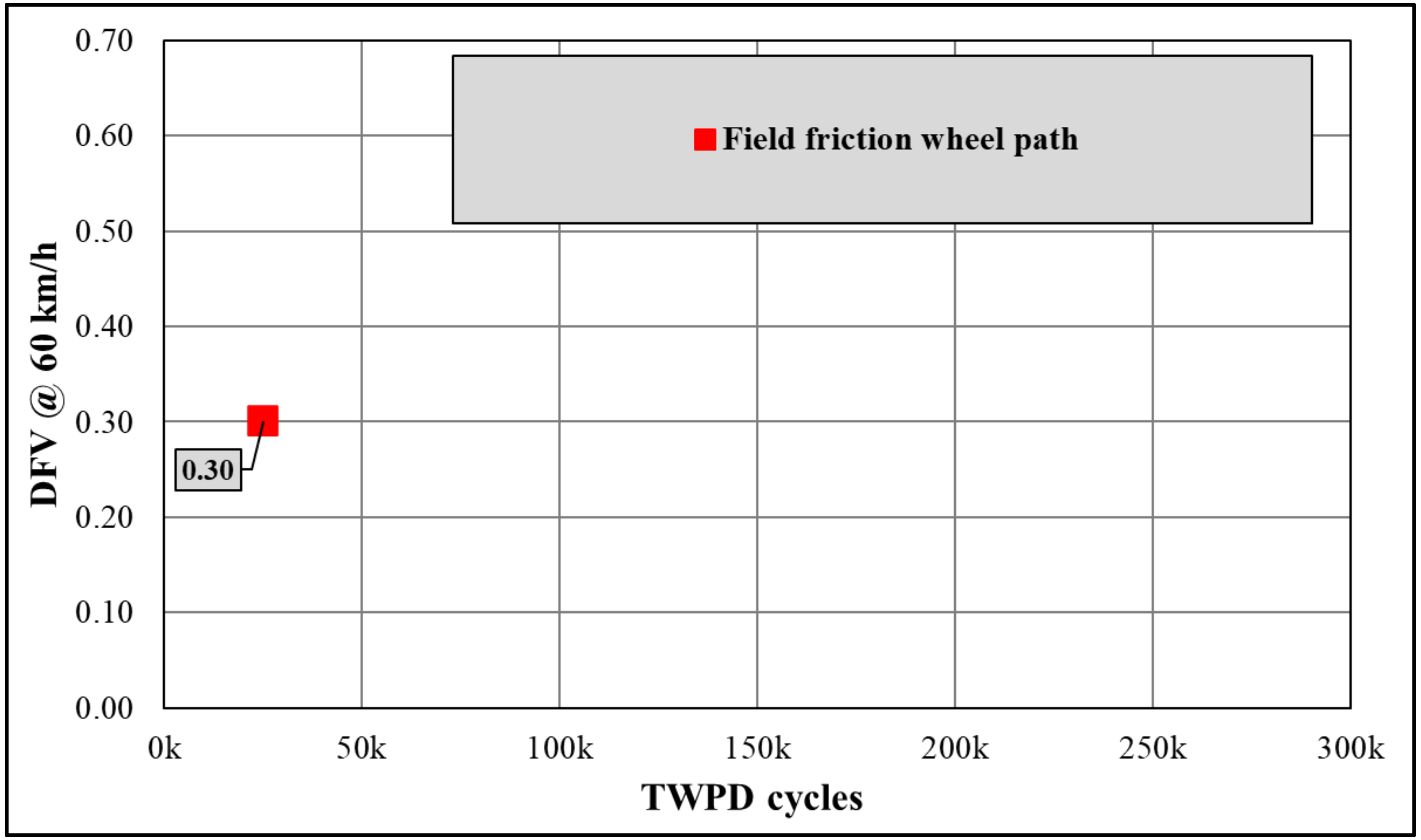


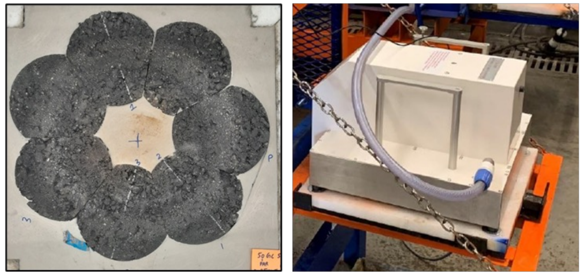


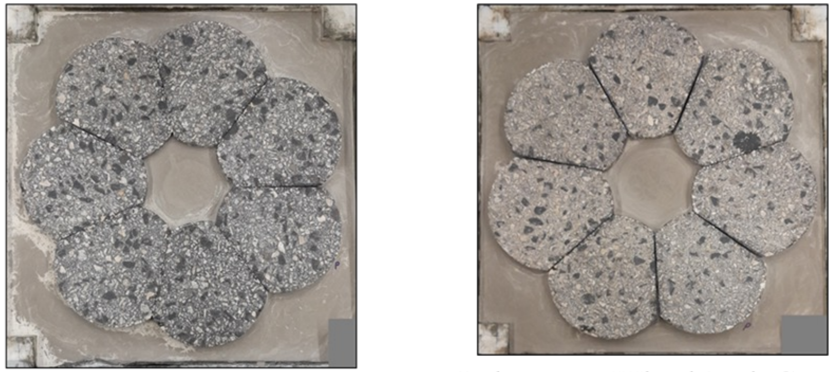
YKM SH71 Section 4 Asphalt Rings

Field Verification of Laboratory Friction

- **SAT SL337**







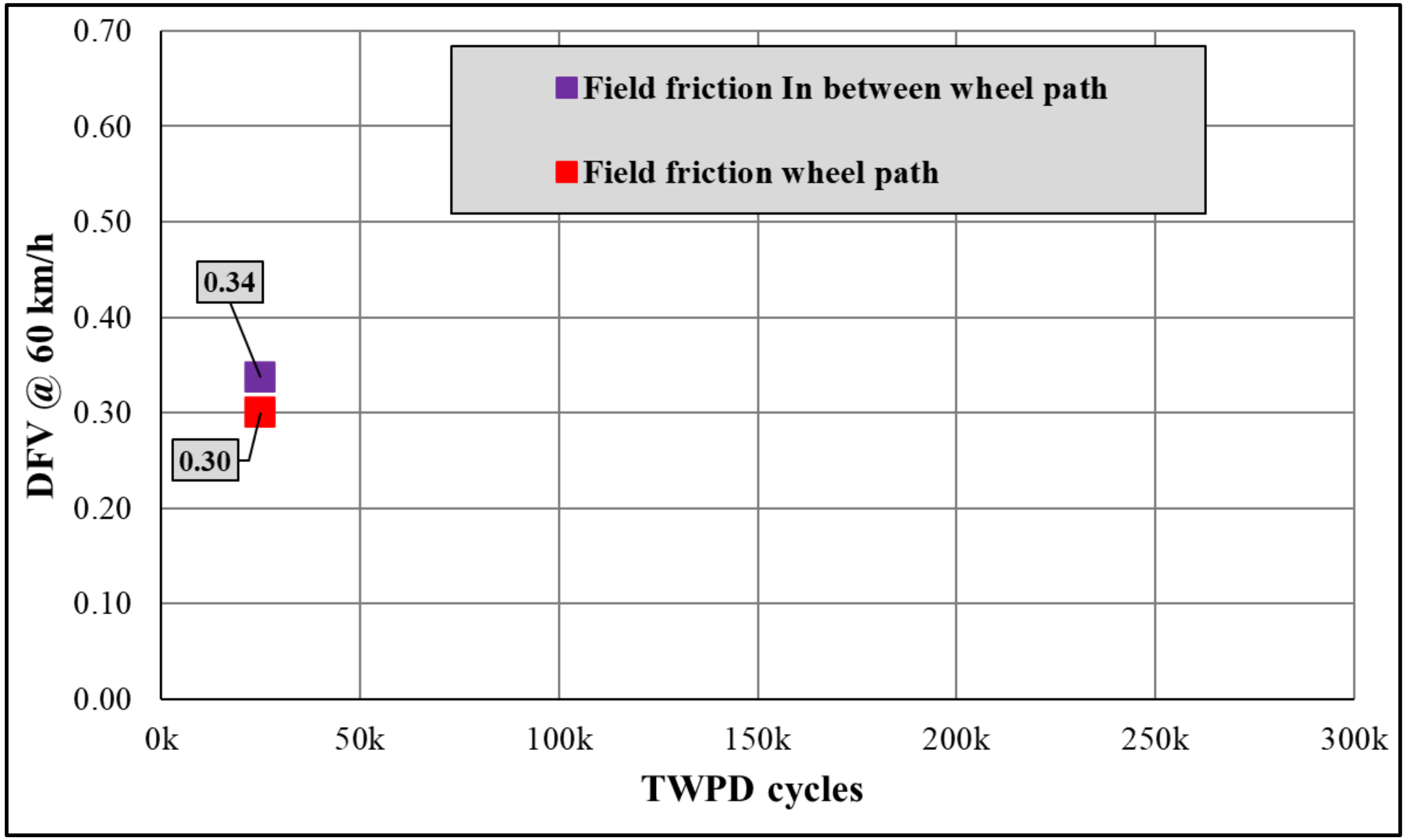
On Wheel Path Cores

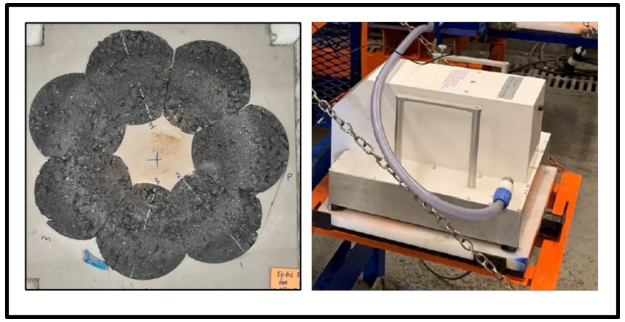
In between Wheel Path Cores

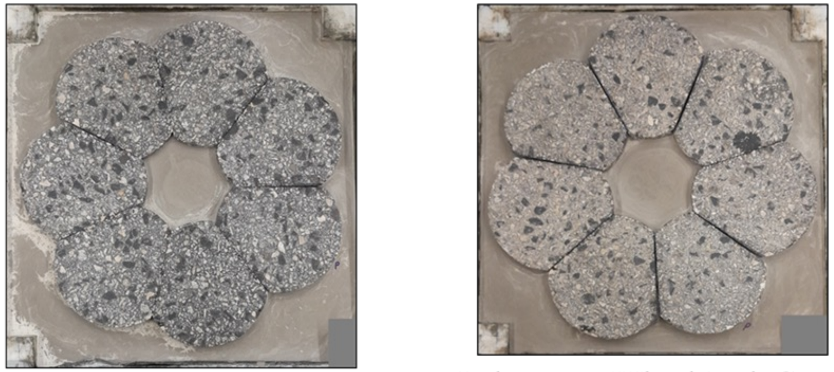
SAT SL337 Section 2 Asphalt Rings

Field Verification of Laboratory Friction

- **SAT SL337**







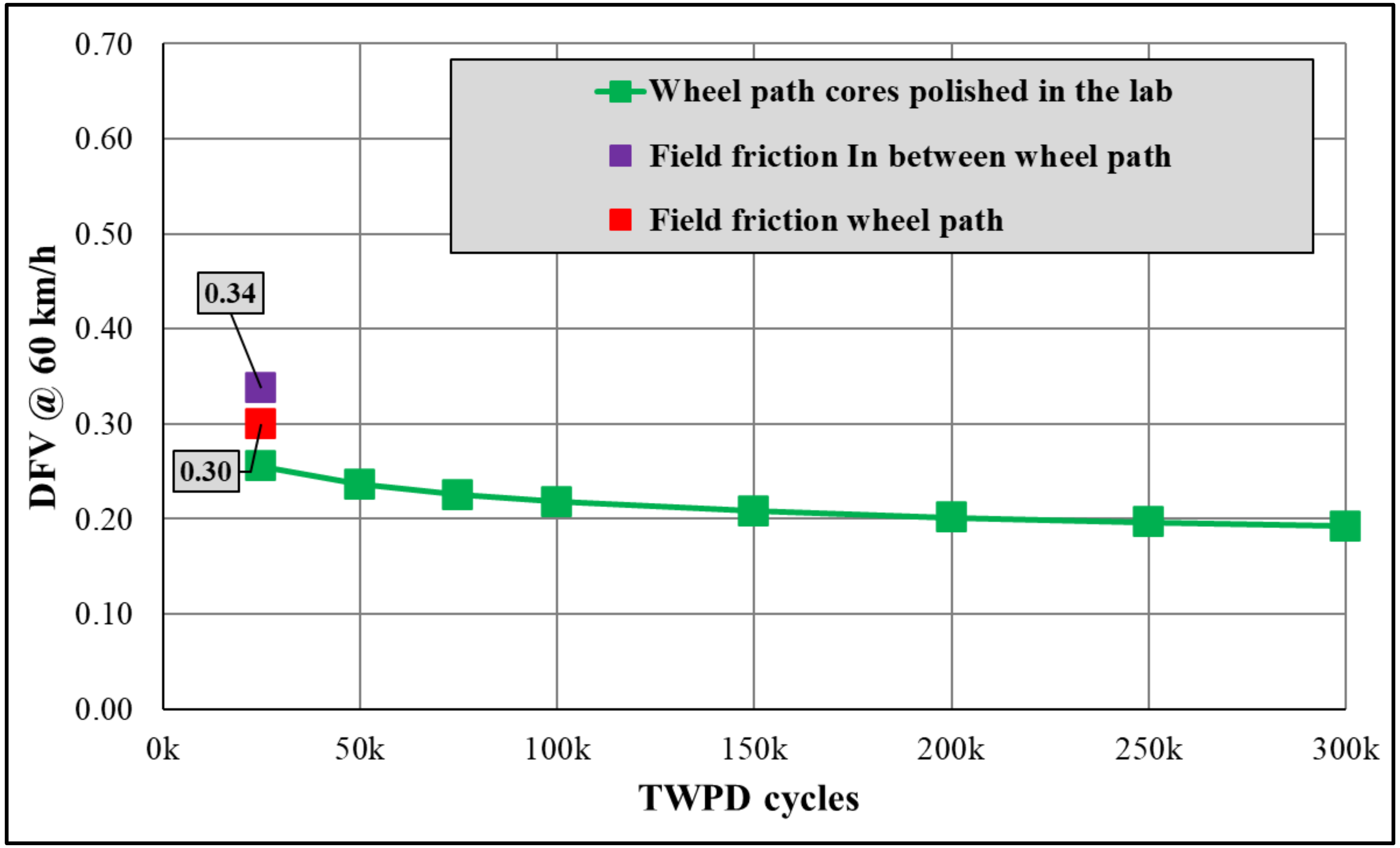
On Wheel Path Cores

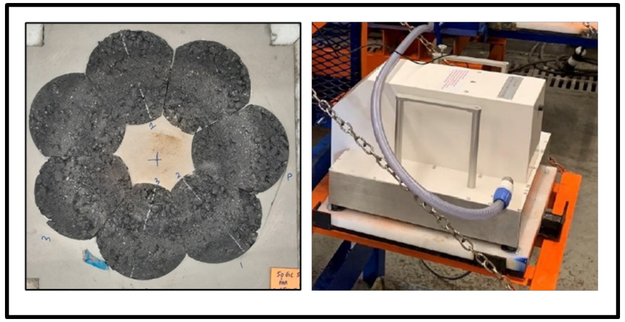
In between Wheel Path Cores

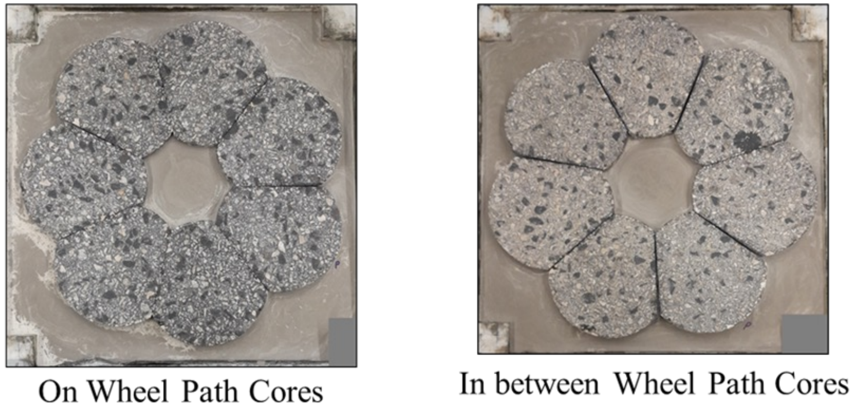
SAT SL337 Section 2 Asphalt Rings

Field Verification of Laboratory Friction

- **SAT SL337**







SAT SL337 Section 2 Asphalt Rings

Field Verification of Laboratory Friction

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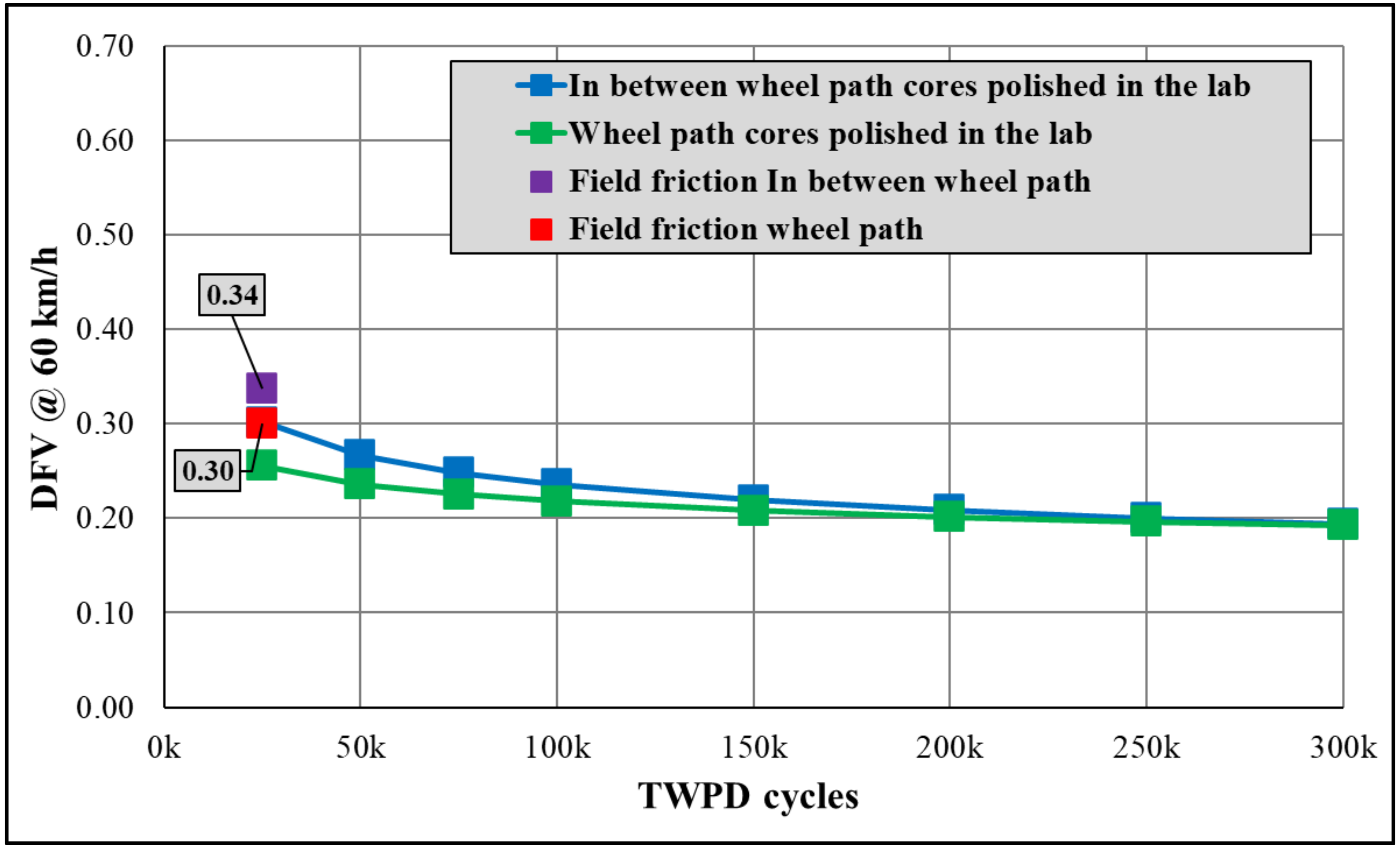

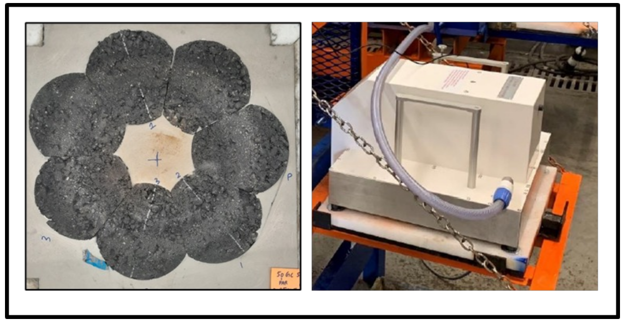

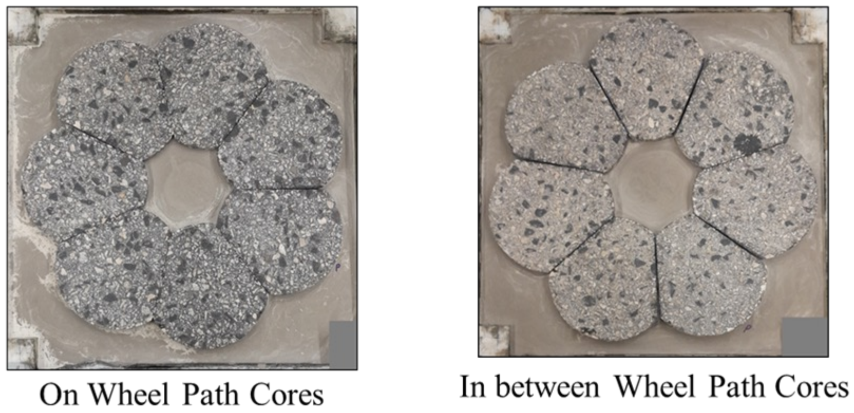

SAT SL337 Section 2 Asphalt Rings

Field Verification of Laboratory Friction

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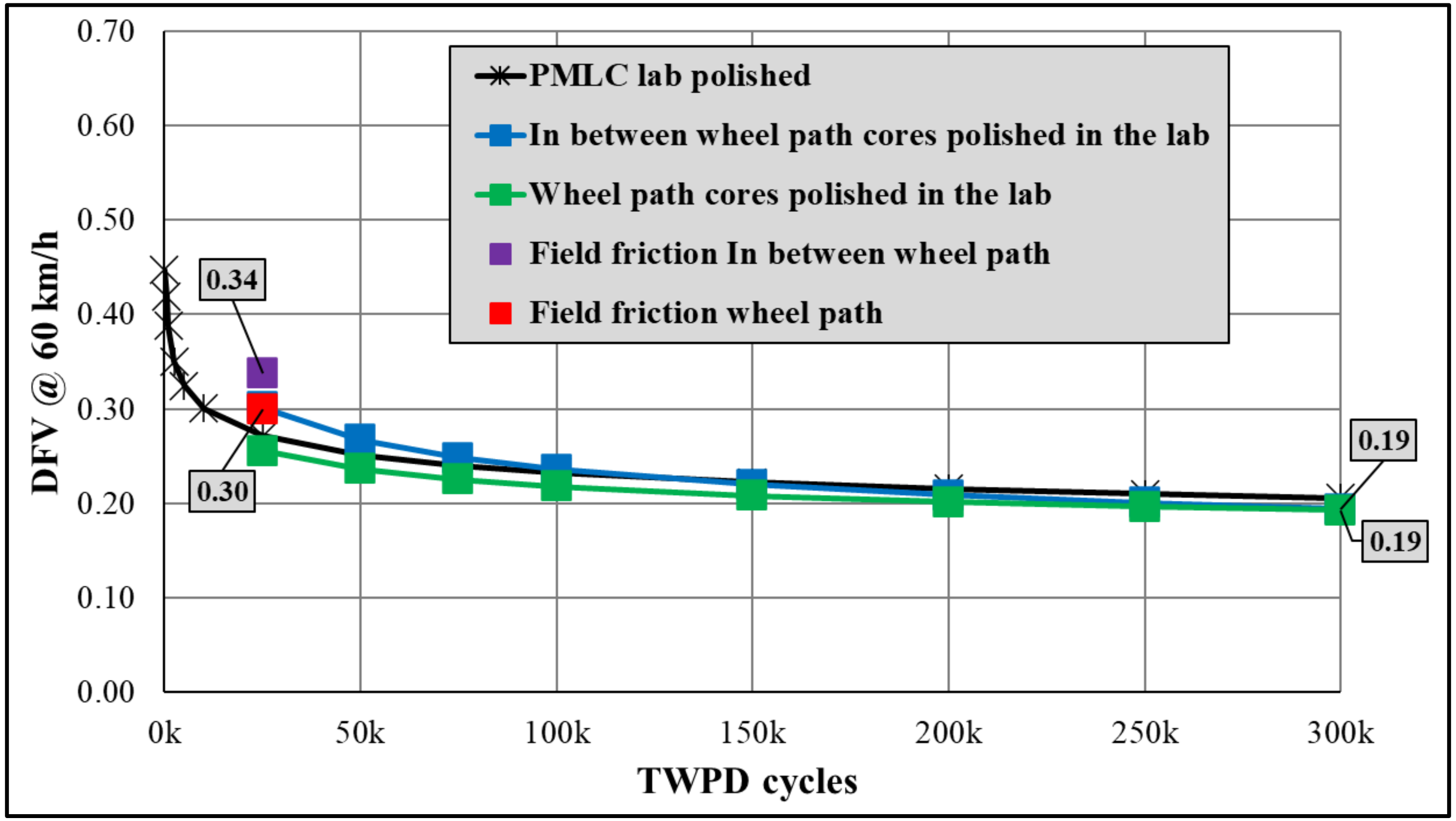

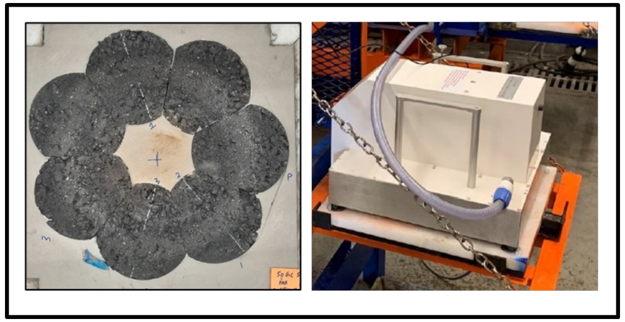

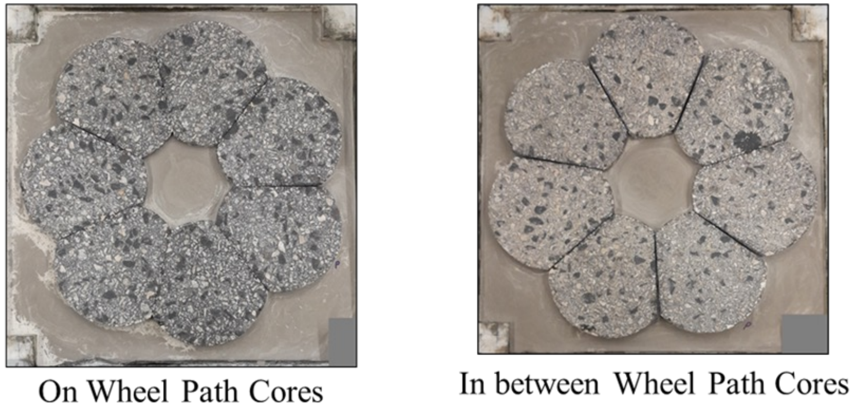

SAT SL337 Section 2 Asphalt Rings

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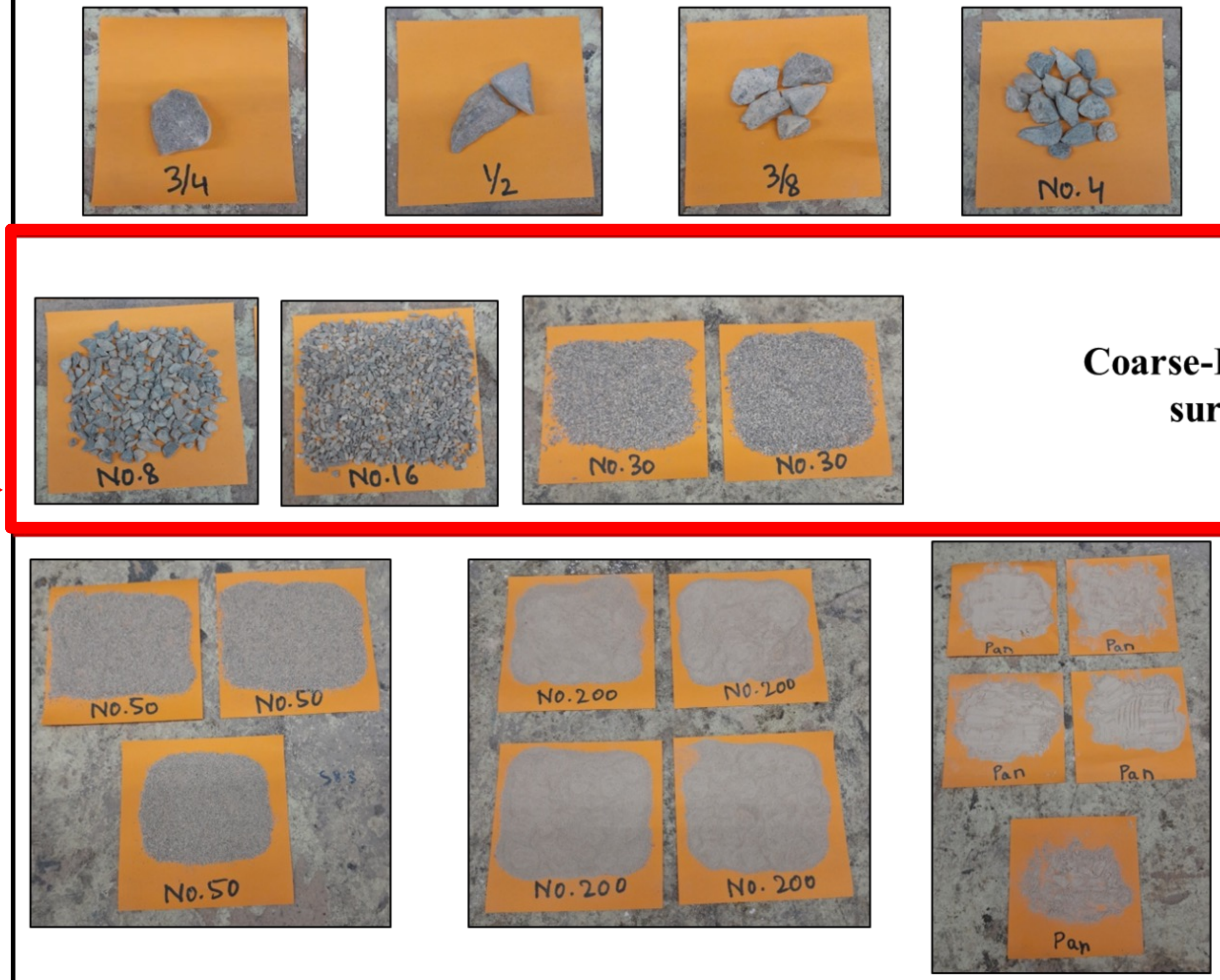
6. Final Specification

Upcoming Field Pilot Test Sections

Asphalt mixture
▪ Binder percentage ▪ Binder grade ▪ Air voids percentage ▪ Aggregate gradation ▪ Asphalt gradation ▪ **Aggregate quality**

Surface area illustration of 10 grams of aggregate of each size



Coarse aggregate surface area

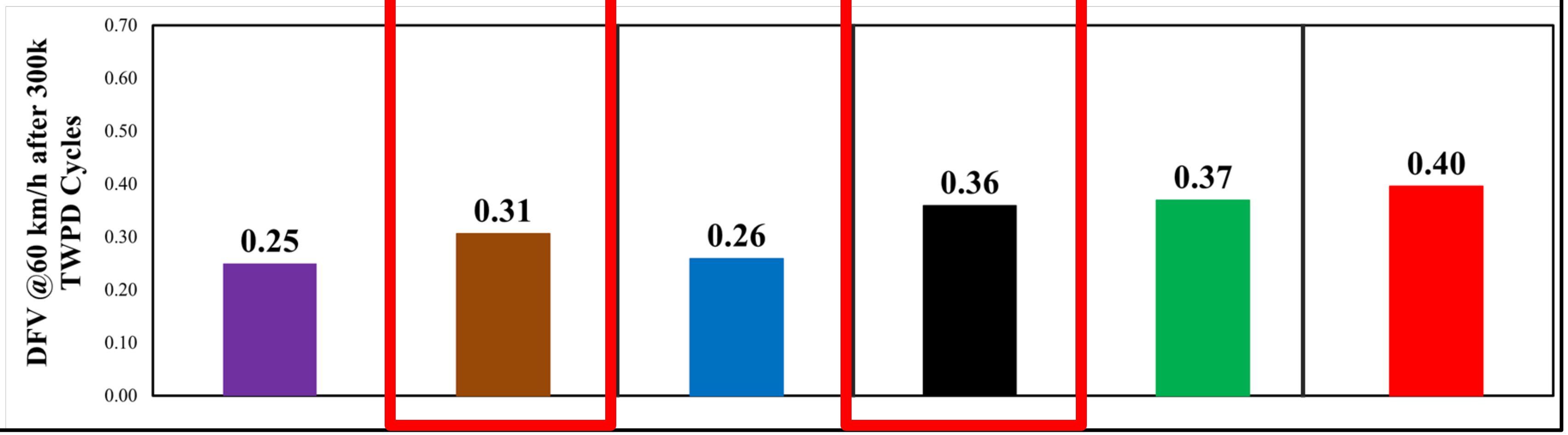
Coarse-Fine aggregate surface area

Fines surface area

Upcoming Field Pilot Test Sections

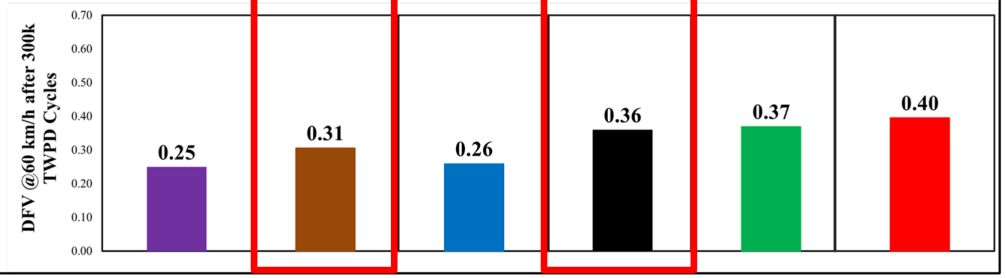
Asphalt mixture
▪ Binder percentage ▪ Binder grade ▪ Air voids percentage ▪ Aggregate gradation ▪ Asphalt gradation ▪ **Aggregate quality**

Sieve sizes (Passing – Retained)	Aggregate type in asphalt mixture					
	Mix 1	**Mix 2**	**Mix 3**	**Mix 4**	**Mix 5**	**Mix 6**
P 3/4" – R No. 4 (Coarse)	Limestone_ Dolomite (100%)	Sandstone (50%)	Limestone_ Dolomite (50%)	Limestone_ Dolomite (50%)	Limestone_ Dolomite (50%)	Sandstone (100%)
P No. 4 – R No. 30 (Coarse-fine)		Limestone_ Dolomite (50%)	Limestone_ Dolomite (50%)	Sandstone (50%)	Sandstone (50%)	
P No. 30 – Pan (Fines)			Sandstone (50%)	Limestone_ Dolomite (50%)		

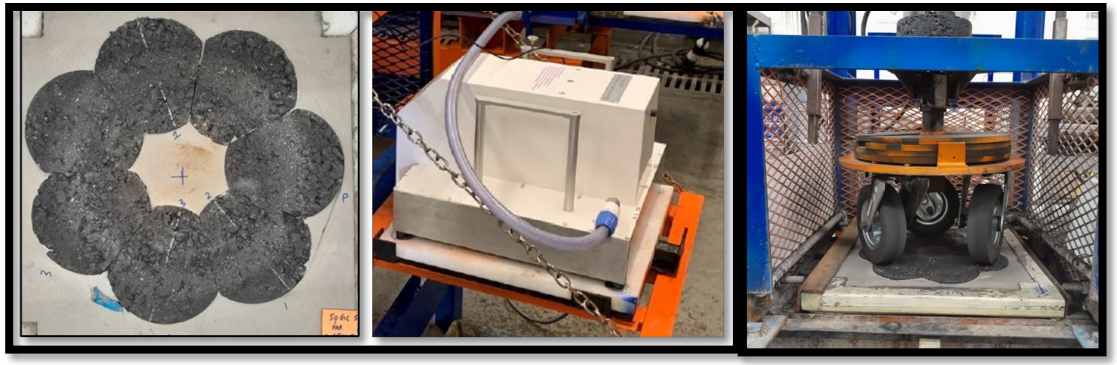


Upcoming Field Pilot Test Sections

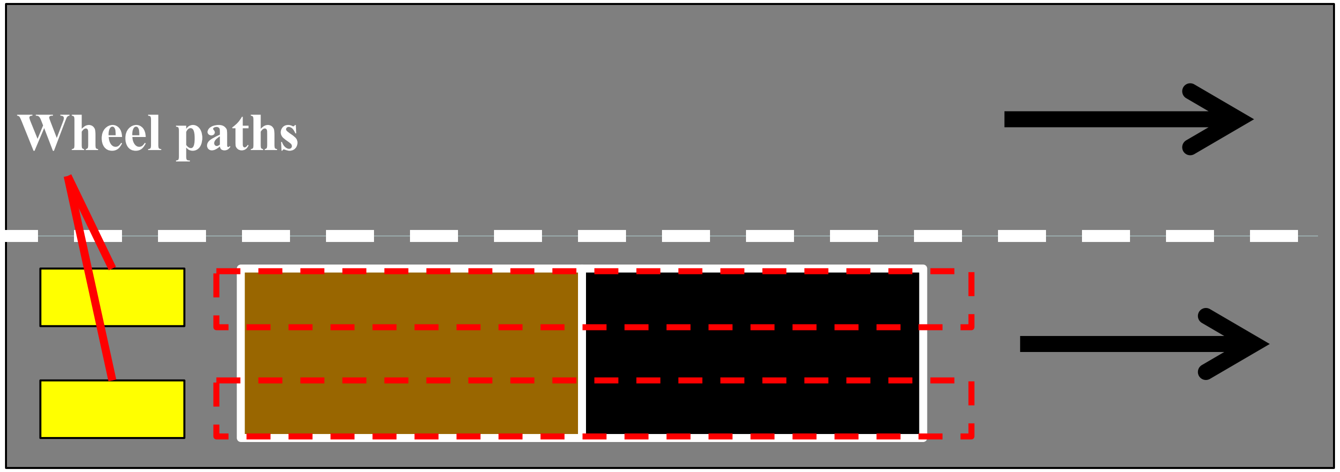
Sieve sizes (Passing – Retained)	Aggregate type in asphalt mixture					
	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
P 3/4" – R No. 4 (Coarse)	Limestone_ Dolomite (100%)	Sandstone (50%)	Limestone_ Dolomite (50%)	Limestone_ Dolomite (50%)	Limestone_ Dolomite (50%)	Sandstone (100%)
P No. 4 – R No. 30 (Coarse-fine)		Limestone_ Dolomite (50%)	Limestone_ Dolomite (50%)	Sandstone (50%)	Sandstone (50%)	
P No. 30 – Pan (Fines)			Sandstone (50%)	Limestone_ Dolomite (50%)		



Field Testing



Lab Testing



Lab produced mix

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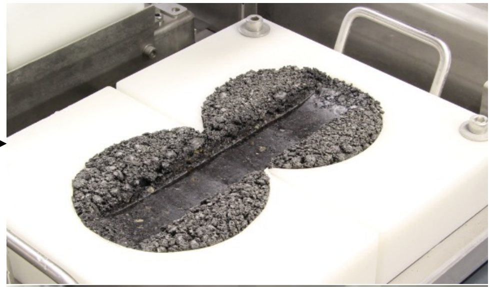
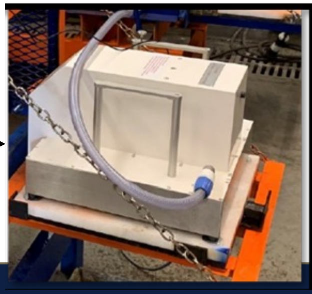
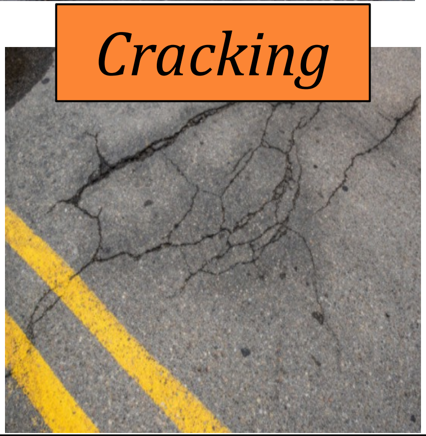
The End Goal – Design (Project 0-7108)

Provide TxDOT a guideline or procedure for AC mixes to improve the skid resistance. Specifically, provide guidelines to ensure adequate skid resistance for mixes that are balanced.







Thank you