Implementing the Next Generation of Ultra Thin Slurry Seals

TxDOT project 5-6615-01

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Published: October 2020

Background

Study 5-6615-01 Evaluation of UT Slurries

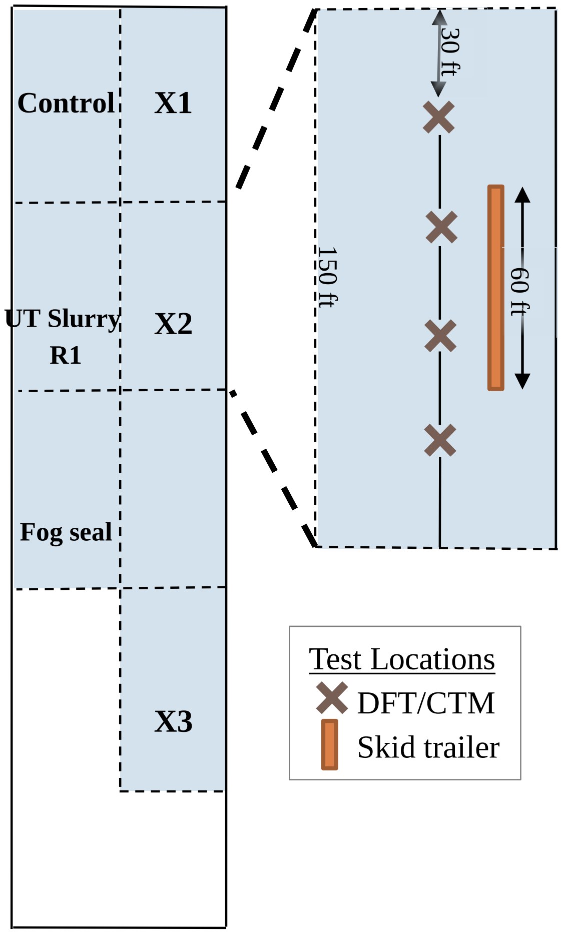
- Designed and constructed under SS 3028 “Frictional Asphaltic Surface Preservation Treatment”
- Promoted as a high speed, low cost maintenance treatment with both safety and pavement preservation applications
- Used widely on shoulders but is the treatment appropriate for travel lanes applications?

Ultra-Thin Slurry Overlays

- Spray applied maintenance treatment.
- Cross between slurry and fog seal.
- Cost $1:10 – $2:00 Sq. yard
  - Chip Seals $2:50
  - Overlays $6 - $8
- Properties:
  - Polymer-mod emulsion.
  - Embedded aggregate.
  - Rapid cure time.
  - Long-term black color.

Background

Test Section Construction 2014 at TTI



Placed on Riverside campus

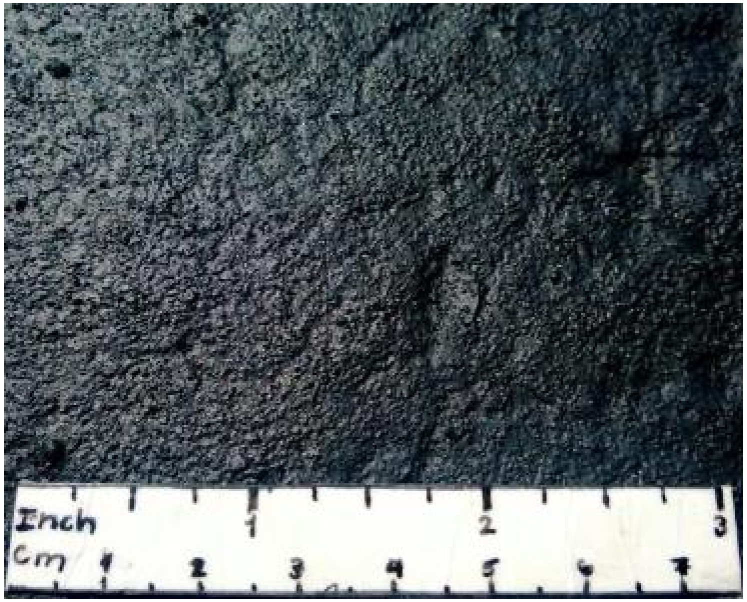
X1, X2, X3

UT Slurry R1

Fog seal squeegee applied

Original Performance Summary

- Higher skid performance over fog seal.
- Macrotexture, highly dependent on existing surface
- Unknown long-term durability.

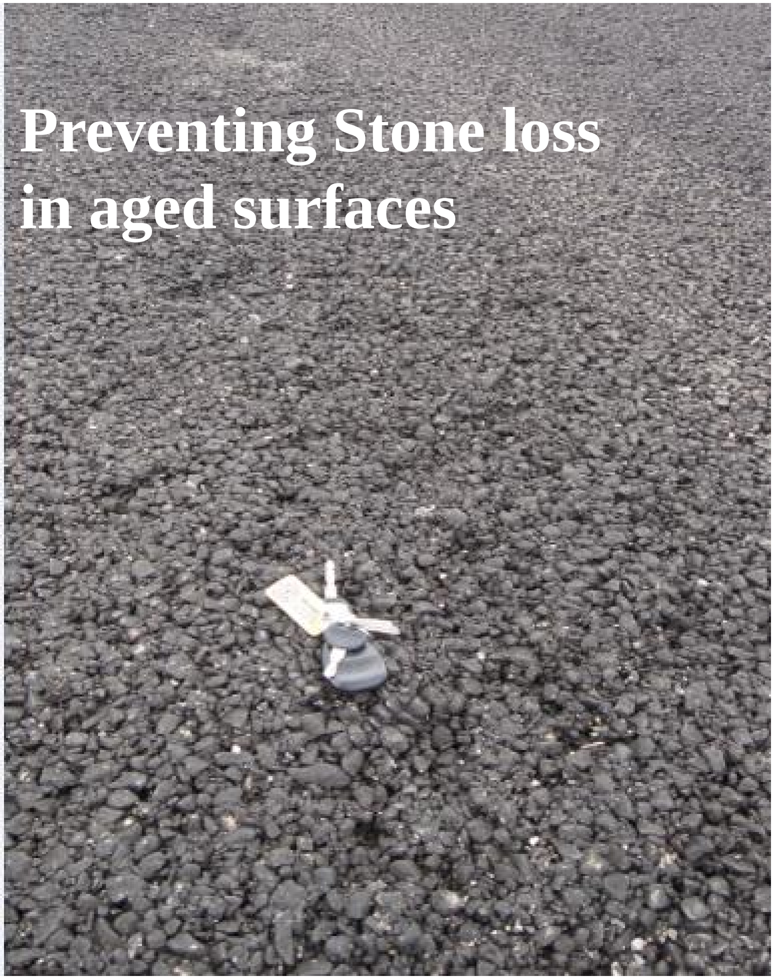


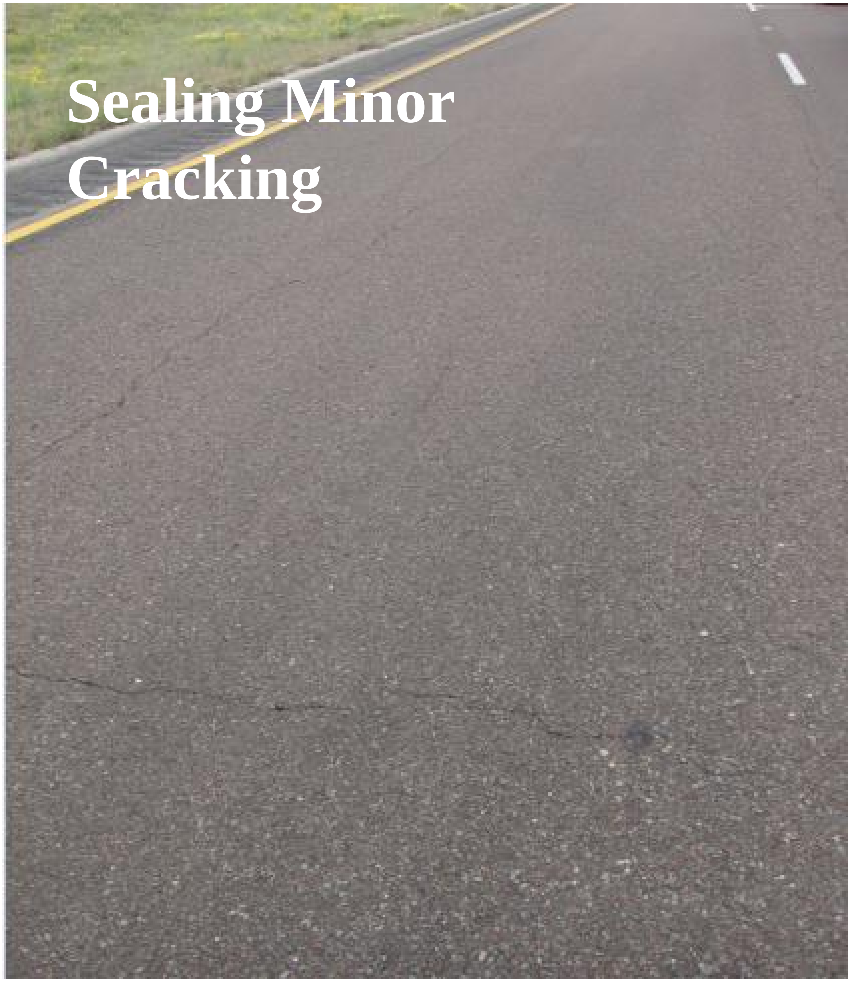
Proposed Safety Applications

Under consideration by TxDOT Districts

Pavement Preservation

Under consideration by TxDOT Districts





Work Plan

- Task 1 Plan Construction of Test Sections
  - Three Districts Austin, Fort Worth and Beaumont
  - Document upfront condition
- Task 2 Update Specifications
  - Existing SS 3028 (largely industry recommendations)
- Task 3 Construct and Monitor test Sections
  - Skid measurements for duration of study
  - Collect samples/Lab testing
  - Performance evaluation

Work Plan Continued

- Task 4 Prepare Workshop training materials
  - Guidelines to TxDOT Districts on where and how to use these Findings of study
- Task 5 Present Training materials Workshop
  - Two training schools

Review of Current Specification

Review of Current Specification

- Largely proposed by Industry

Special Specification 3028

Frictional Asphaltic Surface Preservation Treatment

Texas Department of Transportation

1. DESCRIPTION

Apply a surface preservation treatment consisting of one or more applications of a single layer of asphaltic and aggregate material.

High Quality Aggregate required

Aggregate. Furnish aggregate meeting Item 302, “Aggregates for Surface Treatments,” of the grade shown in Table 2.

Table 2. Aggregates

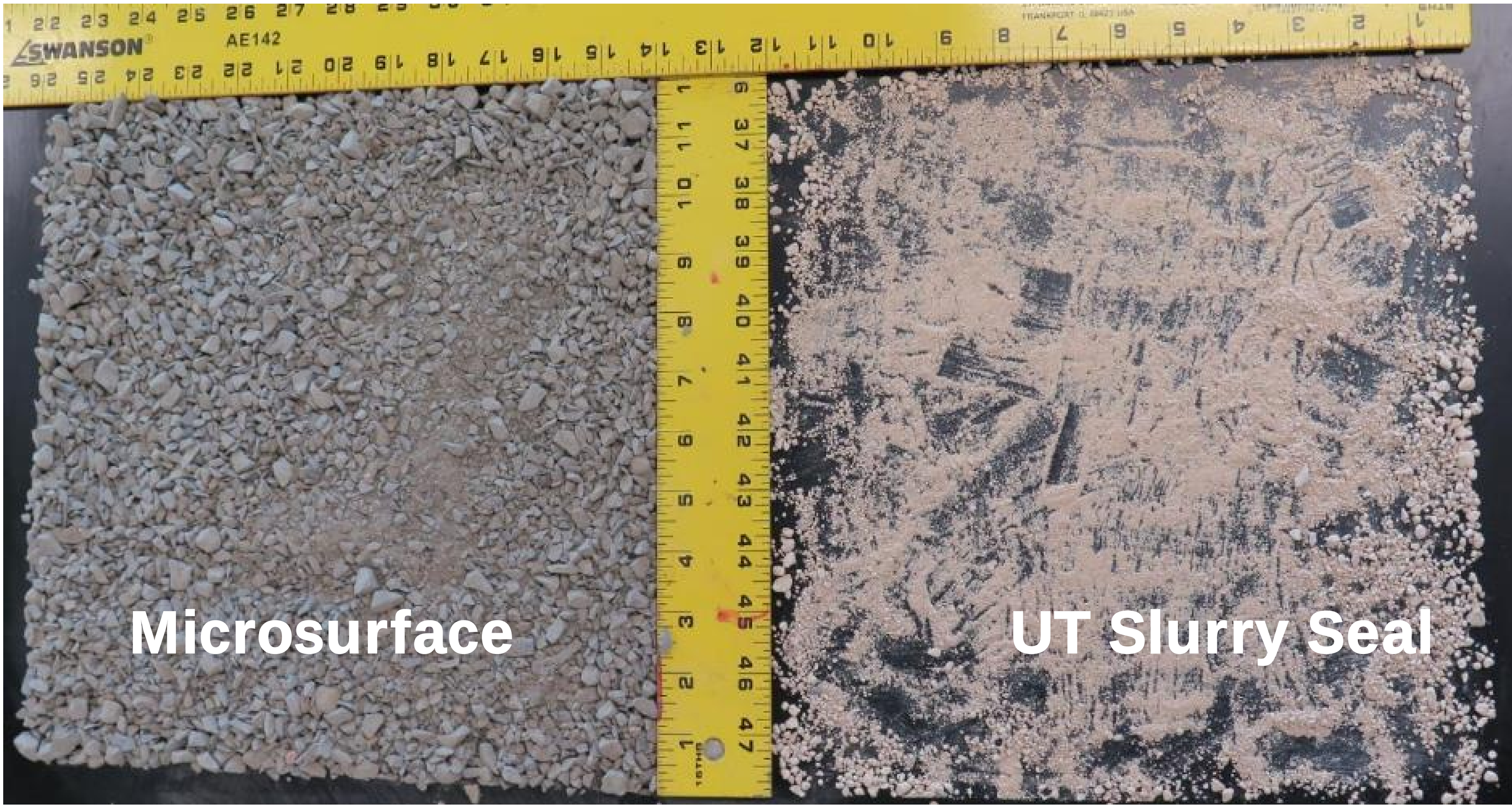
<table>
<tr><th colspan="4">Physical Properties[1]</th></tr>
<tr><th>Property</th><th>Test Procedure</th><th>Min.</th><th>Max.</th></tr>
<tr><td>Water Absorption, %</td><td>T 84</td><td>-</td><td>4</td></tr>
<tr><td>Micro-Deval, %</td><td>D 7428[2]</td><td>-</td><td>20</td></tr>
<tr><th colspan="4">Gradation[3]</th></tr>
<tr><td>Sieve</td><td>Standard</td><td>Master Grading Band Limits Percent Passing</td><td>Target Tolerance</td></tr>
<tr><td>No. 8</td><td>C 136</td><td>100</td><td></td></tr>
<tr><td>No. 16</td><td>C 136</td><td>85-100</td><td></td></tr>
<tr><td>No. 30</td><td>C 136</td><td>75-100</td><td>± 5</td></tr>
<tr><td>No. 60</td><td>C 136</td><td>10-40</td><td>± 5</td></tr>
<tr><td>No. 100</td><td>C 136</td><td>0-10</td><td>± 5</td></tr>
<tr><td>No. 200</td><td>C 117</td><td>0-5</td><td>± 1</td></tr>
</table>

1. Perform physical property tests on aggregates that are received before blending into sealer.
2. Micro-Deval on aggregate larger than No. 60 sieve U.S.

Relative difference in amount of aggregate per sq.yd

Microsurfacing **UT Slurry Seal**

Relative Differences in Aggregate rates



Pavement surface before UT Slurry

Pavement Surface After UT Slurry

- How it works: Decreases permeability of surface although does not seal cracks..

Mix Design Criteria

3. MIX DESIGN

3.1 Furnish a laboratory mix design meeting the requirements shown in Table 3:

Table 3. Laboratory Mix Design

Test	Test Procedure	Min	Max
Wet-Track Abrasion Loss, 3 day soak, g/m^2	D 3910[1]	--	80
Asphalt Content by Ignition Method, %	T 308	30	--
Dynamic Friction Test Number, 20 kph	E 1911[2]	0.90	--

1. Use the modified method to account for realistic application depth and fine emulsion mixture.
2. Establish base friction value using prepared laboratory compacted slab of approved mix as surface to be tested. The Dynamic Friction Test (DFT) number ratio should indicate that after application of the mastic seal, the surface retains required minimum percentage DFT number of the original pavement surface.

Wet track abrasion

Model	Running Time	Conversion Constant - g/ft.^{2}	Conversion Constant - g/m^2	C-100 Correction Factor
C-100	5 min. ± 2 sec.	3.06	32.9	1.00
A-120	6 min., 45 sec. ± 2 sec.	2.78	29.9	1.17
N-50	5 min., 15 sec. ± 2 sec.	3.48	37.5	0.78
Modified N-50	5 min., 15 sec. ± 2 sec.	3.06	32.9	0.78

CALCULATION

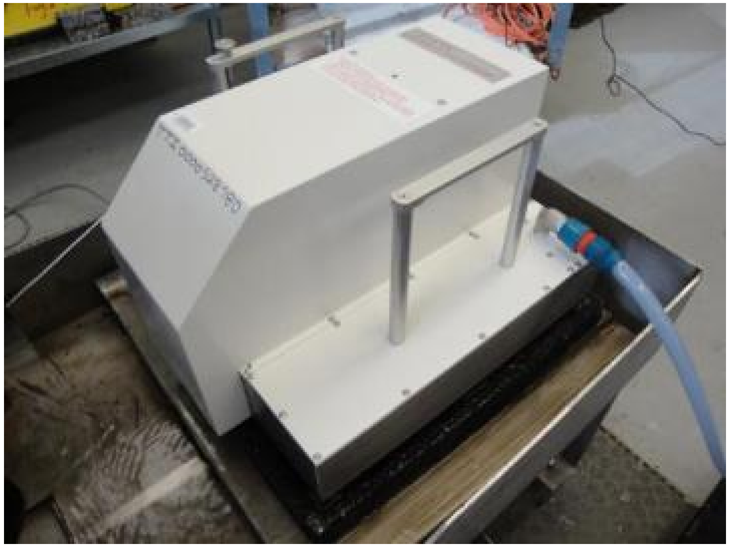
Calculate the loss of material abraded in g/ft^2 or g/m^2 (wear value):

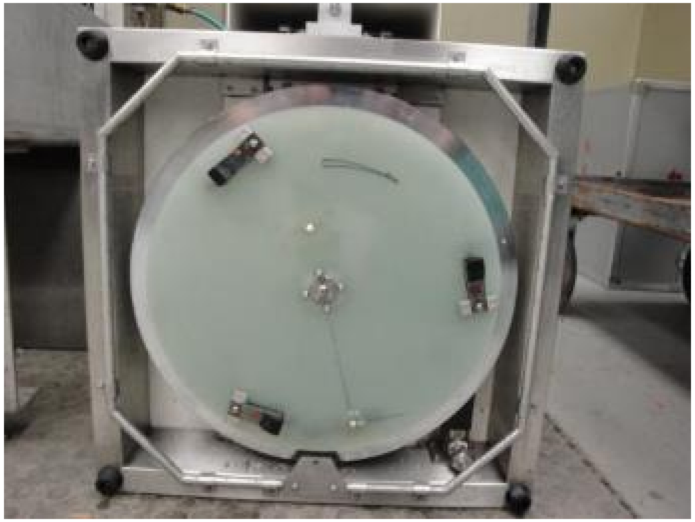
$$wear\ value = (A - B) \bullet C \bullet D$$

Where:
A = Initial dry specimen weight
B = Abraded dry specimen weight
C = Conversion constant from Table 1
D = C-100 correction factor from Table 1.

Dynamic Friction Tester (ASTM E 1911)

- Variable speeds (typical max @80 km/h)
- Wet testing
- Predict Skid Number





Key Construction Requirements

5. CONSTRUCTION

5.1 **Adverse Weather Conditions**. Do not place mixture when, in the Engineer's opinion, general weather conditions are unsuitable. Meet the requirements for air and surface temperature shown below.

5.1.1 **Standard Temperature Limitations**. Apply mixture when air temperature is above 50°F and rising. Do not apply mixture when air temperature is 60°F and falling. In all cases, do not apply mixture when surface temperature is below 60°F.

5.1.2. **Cool Weather Night Air Temperature**. The Engineer reserves the right to review the **National Oceanic and Atmospheric Administration** (**NOAA**) weather forecast and determine if the nightly air temperature is suitable for mixture placement.

5.1.3. **Cold Weather Application**. When mixture application is allowed outside of the above temperature restrictions, the Engineer will approve the mixture and the air and surface temperatures for application. Apply mixture at air and surface temperatures as directed.

Recommended Applications Rates

5.3. **Application.** Apply the mixture when the air temperature is at or above 60°F, or above 50°F and rising. Measure the air temperature in the shade away from artificial heat. The Engineer will determine when weather conditions are suitable for application.

Distribute material at the following rates or as directed:

- First application: 1.0 to 1.5 lbs per SY.
- Second application: 1.0 to 1.5 lbs per SY.
- Total application after the second application: 2.5 lbs per SY minimum.

5.4. **Edges**. Adjust the shot width so operations do not encroach on traffic or interfere with the traffic control plan, as directed. Use paper or other approved material at the beginning and end of each shot to construct a straight traverse joint. Unless otherwise approved, match longitudinal joints with the lane lines. The Engineer may require a string line if necessary to keep the edge straight. Use sufficient pressure to flare the nozzles fully.

Opening typically after 2 hours

5.6. **Opening to Traffic.** Open the treated surface to traffic when directed. Furnish and uniformly distribute clean, fine sand on the surface to blot the excess when an excessive quantity of mixture is applied. Maintain ingress and egress as directed by applying sand to freshly treated areas.

Case Studies

Case Studies

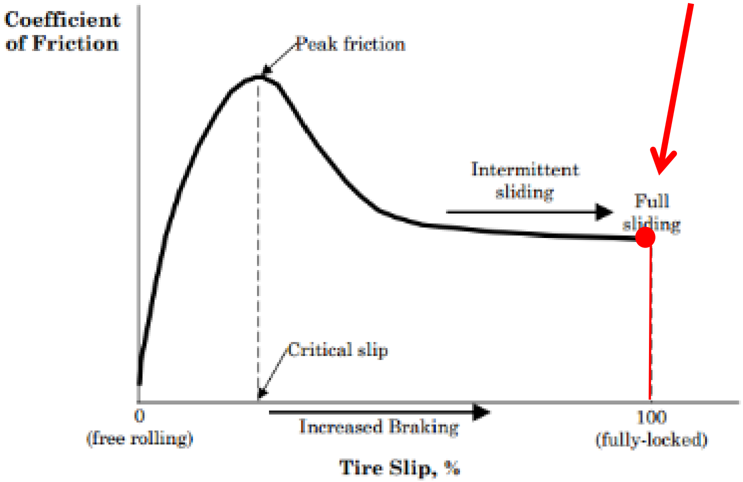
- San Antonio
- Beaumont
- Fort Worth

Monitoring Tools

- Visual Observation
- Locked Wheel Skid Truck
- Dynamic Friction Tester
- Circular Track meter

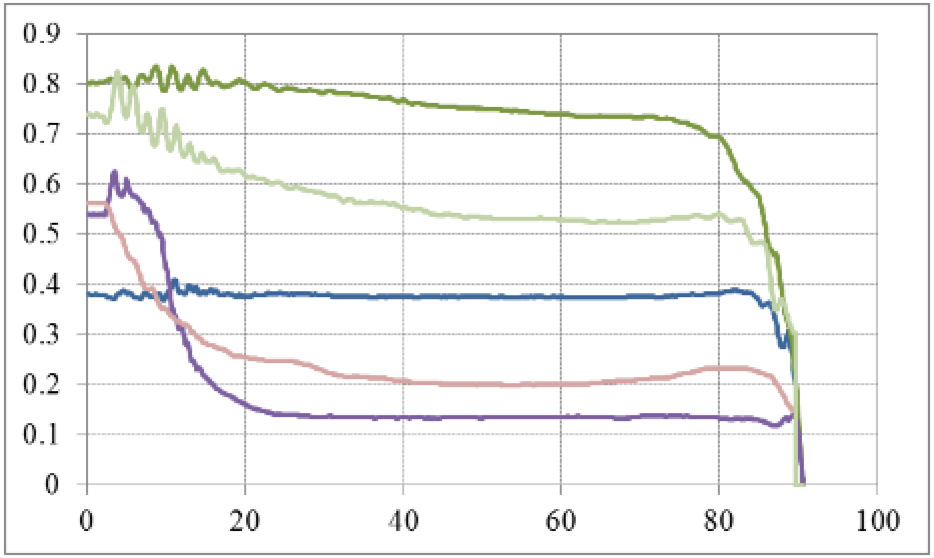
Locked-wheel (ASTM E 274)

- 100% slip
- Tire oriented in direction of travel (no side friction)
- Tested at 40 or 50 mph



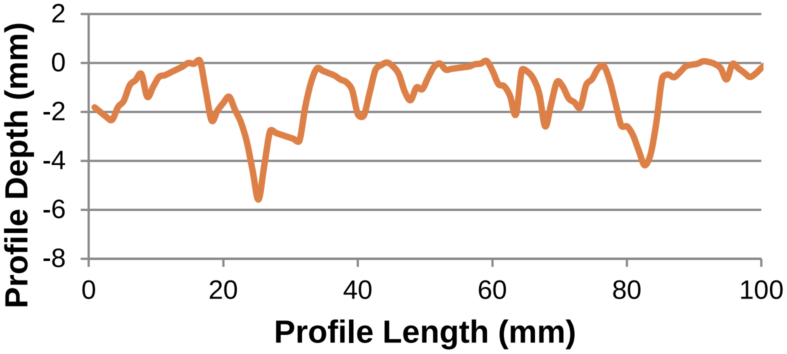
Dynamic Friction Tester

- Requires lane closures
- Spot measurements



Circular-Track Meter (ASTM E 2157)

- **Macro-texture**
- Laser-based measurement
- Measures same track as DFT
- Correlates with sand patch
- Standard to compute IFI
- Lane closures/spot measure



San Antonio IH 35

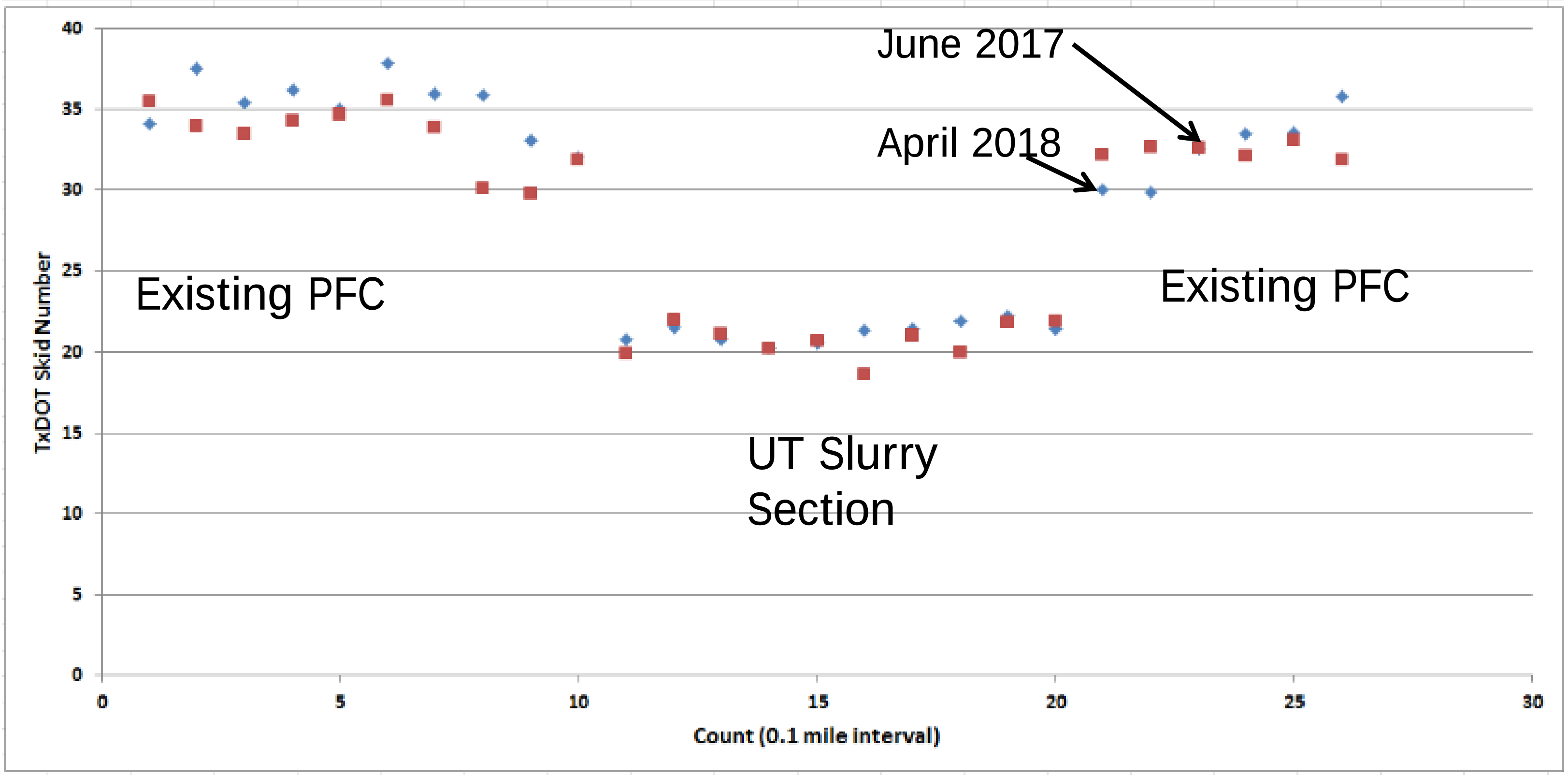
- UT Slurry Seal applied on raveling old PFC to retain rock

San Antonio IH 35

- Condition after 18 months of service
- Wear off in wheel paths – raveling continued

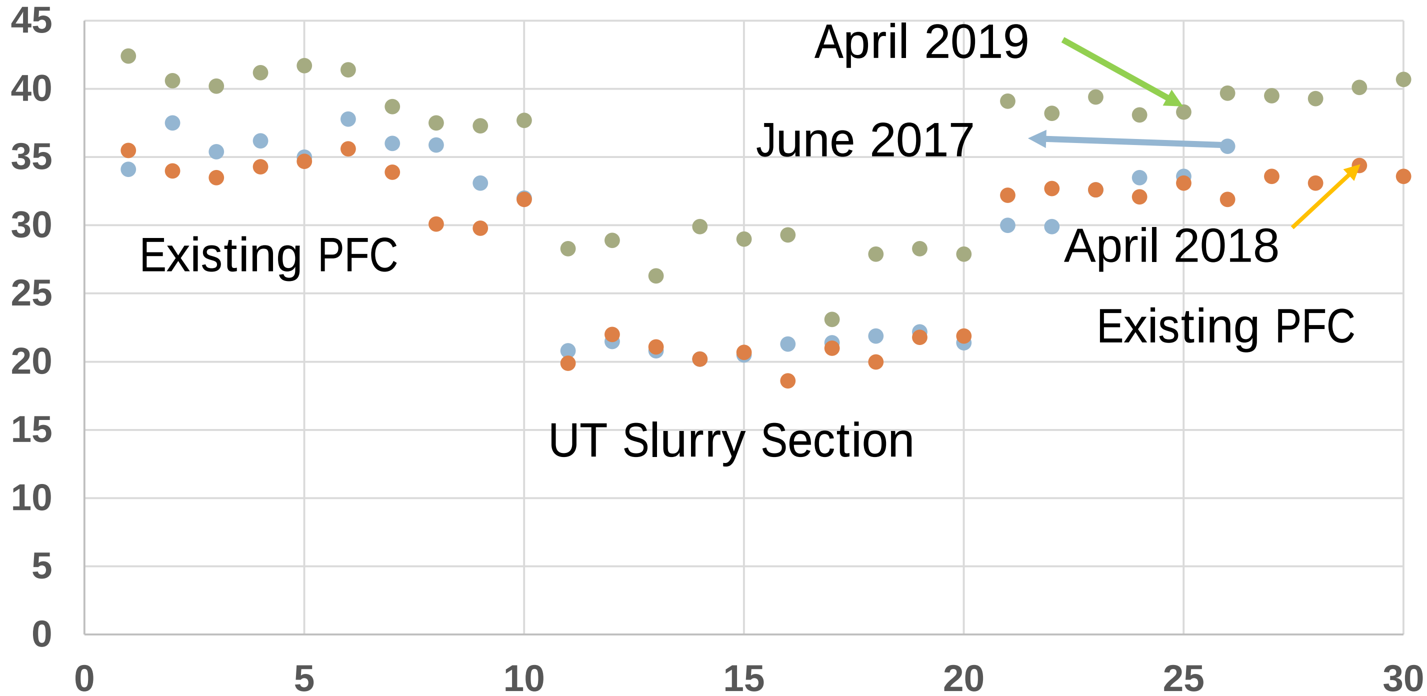
San Antonio IH 35

- Skid reduction on UT slurry sections



San Antonio IH 35

- Skid reduction on UT slurry sections (existing vs slurry)
- Continued raveling increased skid (see test dates)



Beaumont Applications

- Ultra-thin slurry treatment @ Beaumont District

Beaumont Applications

- Ultra-thin slurry was placed on 6 miles long on FM 2518 existing (HMAC)

Beaumont Applications

- Ultra-thin slurry was placed on SH 105 bridge deck

Beaumont Applications

- Skid Numbers on SH 105 bridge deck

	Section	SH 105, K1	SH 105, K6
April 2018	Ultra-Thin Slurry	24.6	24.6
	Pavement between bridges	55.6	55.4
June 2019	Ultra-Thin Slurry	23.9	23.9
	Pavement between bridges	19.6	17.8

Beaumont Applications

- Skid Numbers on FM 2518 existing (HMAC)

	Section	FM 2518, K1	FM 2518, K6
April 2018	Ultra-Thin Slurry	20.1	19.9
	Pavement at end of section	23.7	23.5
June 2019	Ultra-Thin Slurry	16.7	14.9
	Pavement at end of section (new seal)	65.1	61.4

Fort Worth Applications

- Fort Worth District has been using the Thin Slurry mixes on highway shoulders
- In July of 2018, TTI researchers assessed newly installed sections of Ultra-thin slurry on Spur 102 near Keene, Tx and IH 35 Frontage Road
- Used DFT & CTMeter to predict SN50
- DFT and CTM were taken soon after application

Fort Worth Applications

- Shoulder Section on Spur 102 near Keene, TX

Fort Worth Applications

- Fort worth predicted Skid Numbers

	Avg of DFT 20	Avg MPD from CTM	Predicted SN 50
IH 35 Frontage Road			
Treated Shoulder	**0.38**	**0.84**	**28.8**
Untreated Main-lane	**0.39**	**1.03**	**31.8**
Spur 102			
Treated Shoulder	**0.36**	**0.78**	**26.9**
Untreated Main-lane	**0.22**	**0.68**	**18.9**

Issues Current applications

- No matter what the existing skid resistance of the highway, the after treated skid will be around 20. Which is a problem on high speed roadways
- Based on experience the treatment appears to wear off in 12 to 16 months
- Need to investigate in the lab methodologies to get more rock into these slurries

Lab Tests

Overview

- Evaluate the benefits of changing to Light Weight Aggregate (more rock - better skid)
  - Design in lab
  - Validate in Field
- Evaluate application of slurry seals to clog PFC's prior to overlaying them

Objectives

- Develop lab test procedures to measure the impact of UT Slurry Seal on skid resistance
- Develop UT Slurry Seals mixtures for field evaluation
- Validate skid numbers measured in the lab with field performance

Specimen Fabrication

- Used plant prepared mixtures for Slabs & 6-inch molds
- Specimen Mixture types
  - Dense-graded (type D)
  - Permeable friction course (PFC)
  - 7±1% air voids (20 ± 2% air void for PFC)
- Slurry Aggregates mixture
  - Black beauty (BB) and
  - Lightweight aggregates (LWA)
  - passing #6 (1/8”), #8, #16 and #30

UT Slurry Application

- Slurry application on Lab prepared slabs

Measuring 0.125/SY with improvised deep stick .@ Red mark = 1 shot

Applying and uniformly spreading the Slurry on slab surface using a brush

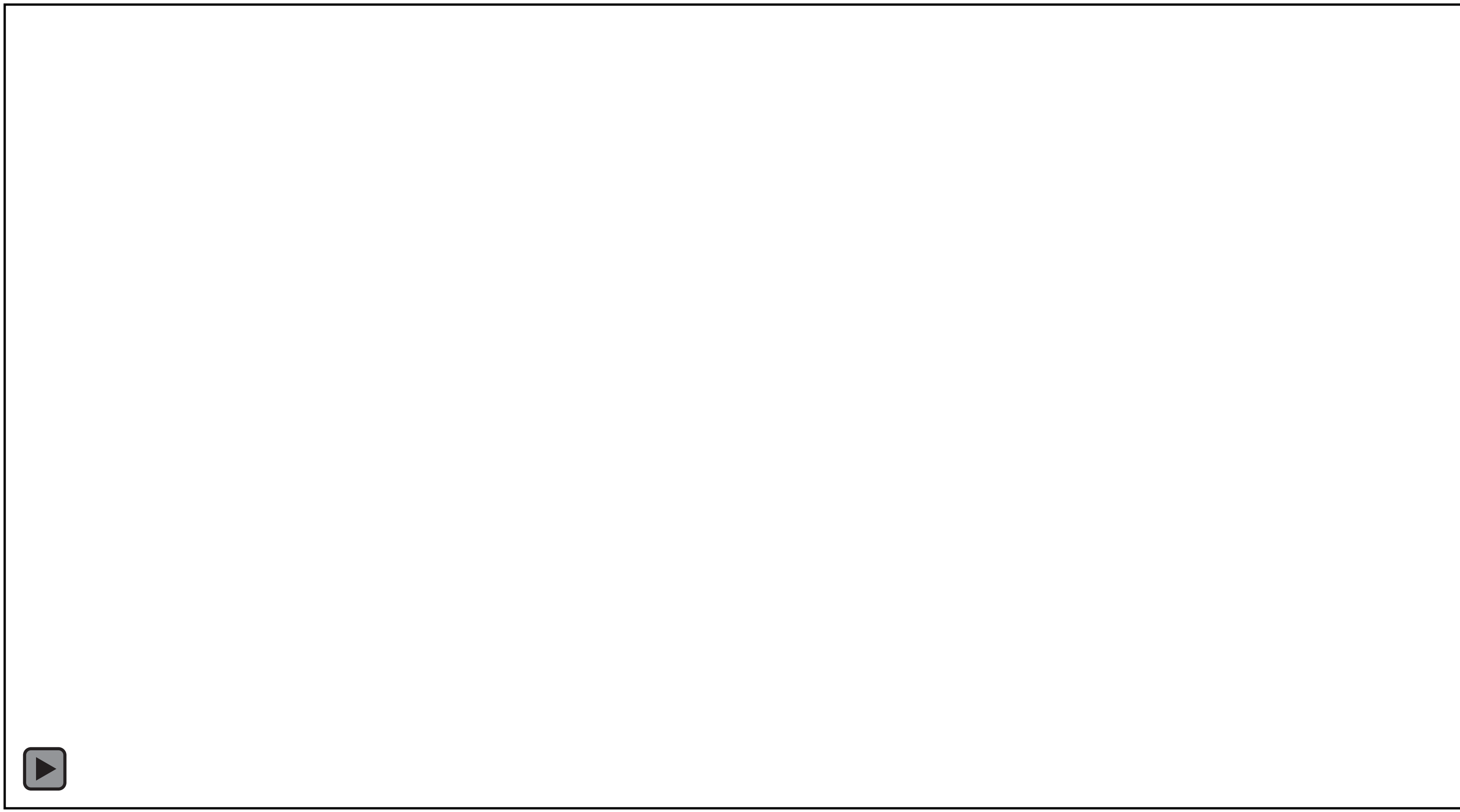
Final look of the Treated slab after 72hrs@60°C curing

UT Slurry Application

0.25gal/sy Light Weight UT Slurry on a Type D slab

0.25gal/sy Black Beauty UT Slurry on a Type D slab

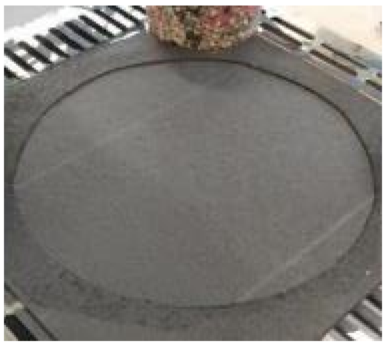
UT Slurry Application

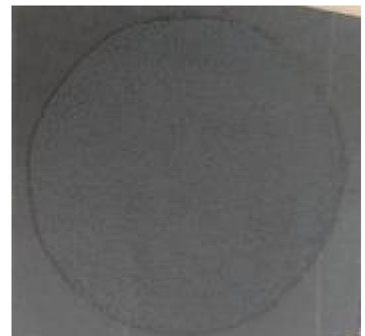


Friction Test

Wet Track Abrasion

Thin sample preparation

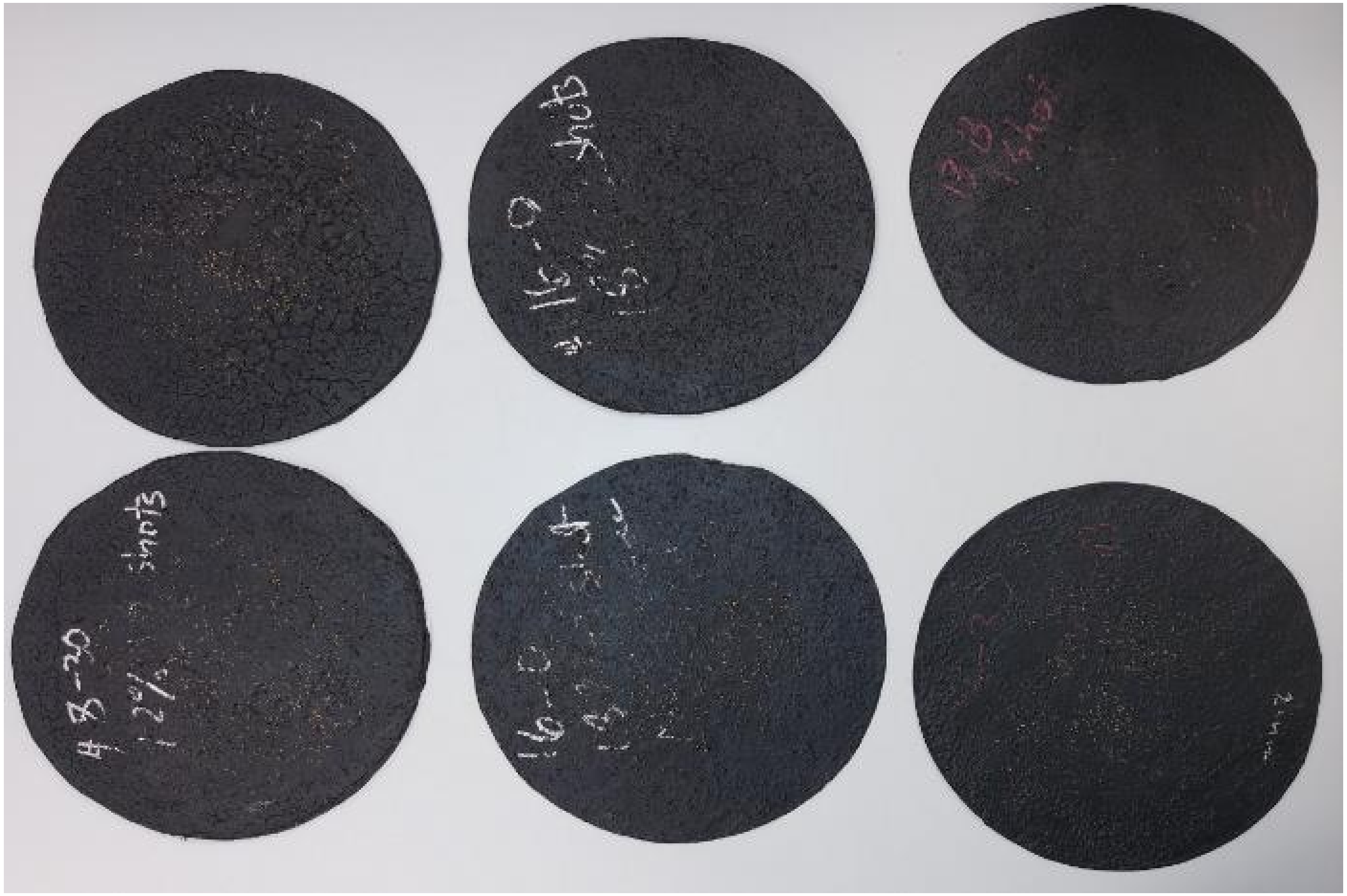




- For determination of the wear value
- Intended to check if the binder is enough or adhere well to the aggregates (Wear <80)
- Other factors such application spray limited the agg %.

Wet Track Abrasion

Thin sample preparation



Wet Track Abrasion

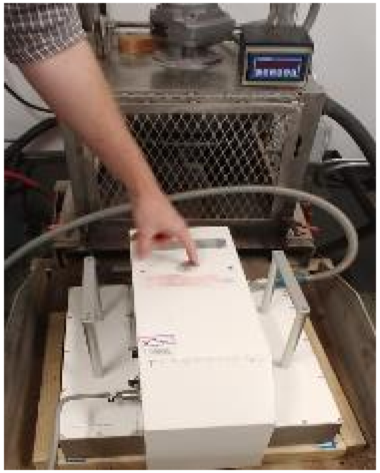
- Wear values

ID	Weight before test (g)	weight after test (g)	weight loss (g)	Wet track value (g/m²)	Description
BB/18%	60.3	57.2	3.1	90.675	WTV>80 (less binder)
BB/18%	74.3	72.6	1.7	49.725	WTV<80 (0k)
BB/18%	82.1	79.7	2.4	70.2	WTV<80 (0k)
LWA8-30/12%	140.3	136.9	3.4	99.45	WTV>80 (less binder)
BB/18%	83.9	78.7	5.2	152.1	WTV>80 (less binder)
BB/18%	129.2	126.2	3	87.75	About right
LWA8-30/12%	140.3	136.9	3.4	99.45	WTV>80 (less binder)
LWA 16-0/18%	132.8	130.5	2.3	67.275	WTV<80 (0k)
LWA16-0/18%	75.1	72.5	2.6	76.05	WTV<80 (0k)
LWA8-30/18%	90.8	89.4	1.4	40.95	WTV<<80 (bleeding or excessive binder)
LWA#16-0/18%	82.1	79.7	2.4	70.2	WTV<80 (0k)
LWA #16-0 /18%	124.2	122	2.2	64.35	WTV<80 (0k)

Impact of UT Slurry on Friction

- The slab is wheel polished
- Fan dried
- MPD determined using CTMeter
- µ determined using DFT



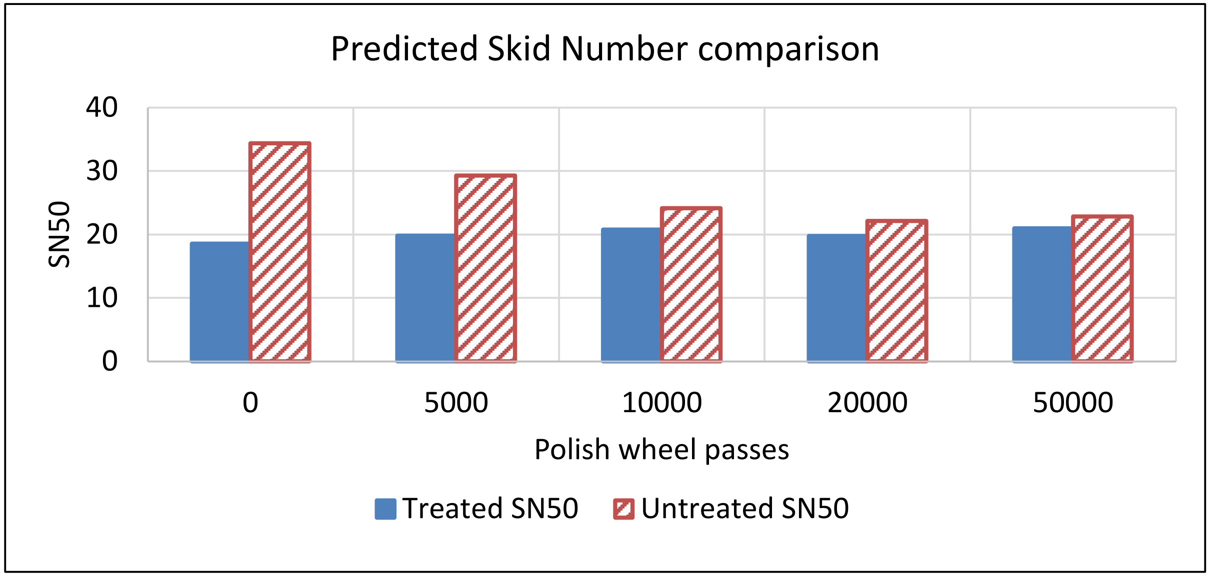
Impact of Slurry Seal on Friction

- Performed on Type D slabs
- First tests was performed on BB based UT Slurry
- Treated and Untreated slabs were compared at different polish wheel passes

Wheel Passes	0	5000	10000	20000	50000
Onyx Treated Slab (D4)					
Untreated Slab (D5)					

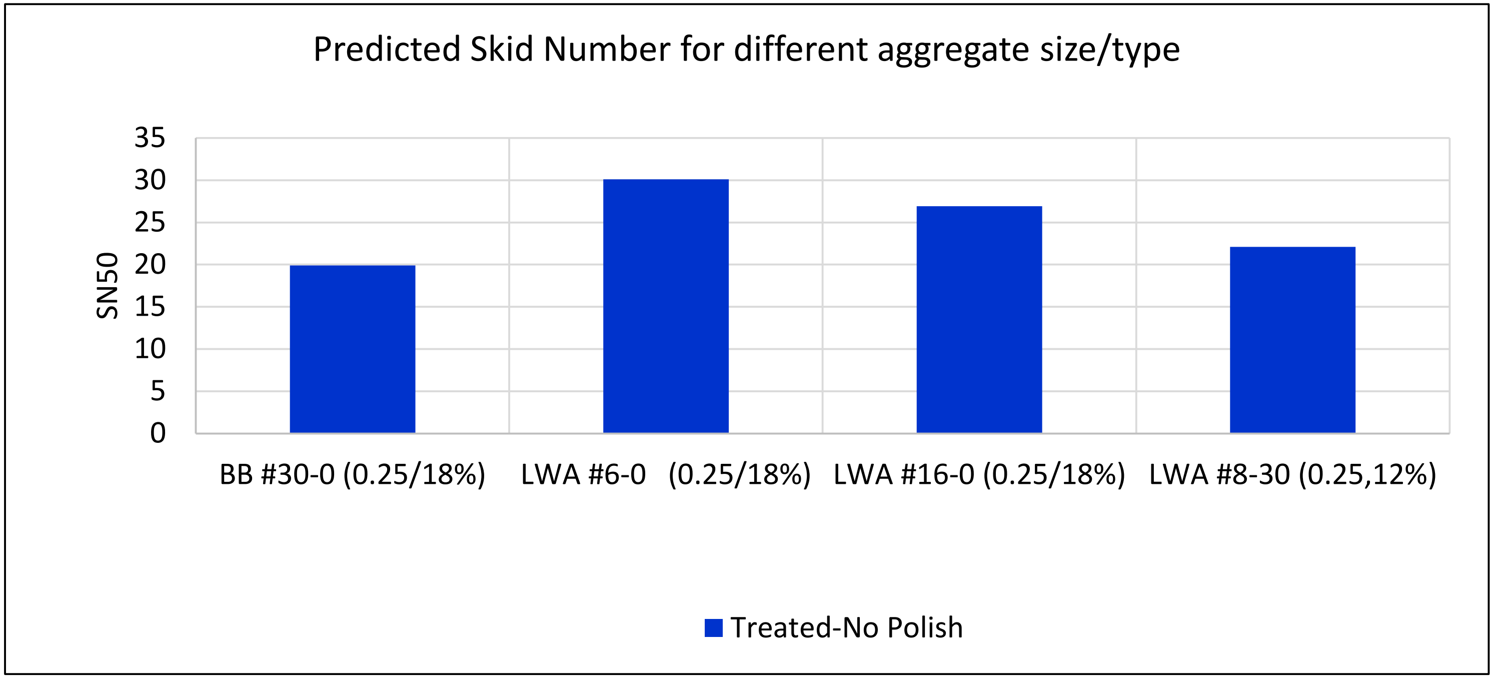
Impact of Slurry Seal on Friction

- Predicted SN for BB-UT slurry slabs.
- SN of the treated slab hovered around 20
- SN of the untreated slab varied from 34 (zero-wheel passes) to 22 (after 50,000-wheel passes)



Impact of Slurry Seal on Friction

- SN Comparison of different BB and LWA-UT slurry mixtures
- LWA fared better; #6-0

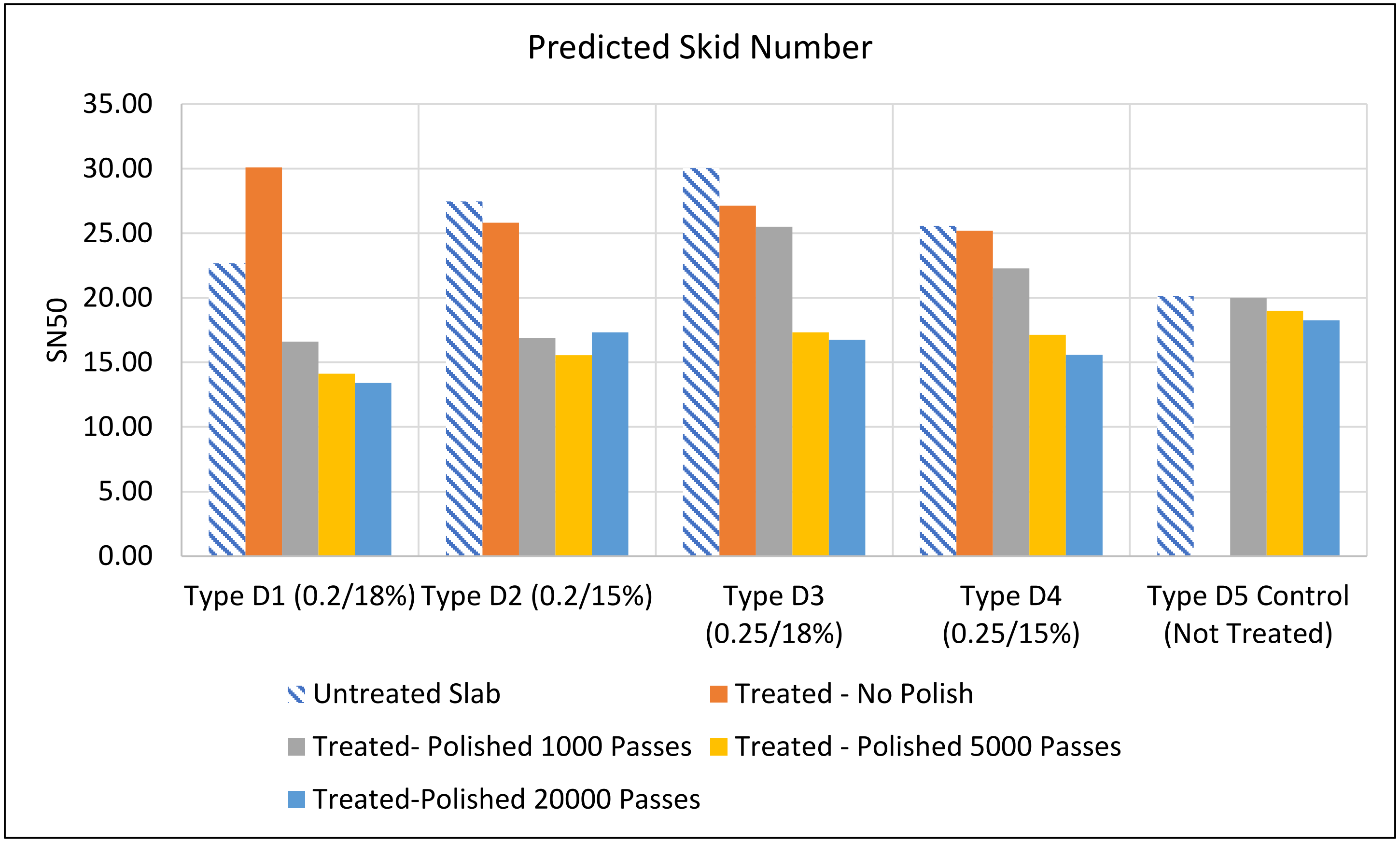


Impact of Slurry Seal on Friction

- A full lab skid test was performed on the UT Slurry mixture comprised of LWA # 6-0 aggregates
  - Four slabs with different UT Slurry treatment combination and one untreated were used
  - The slabs were: Type D1 (0.2/18%), Type D2 (0.2/15%), Type D3 (0.25/18%), Type D4 (0.25/15%), and Type D5 (Control)

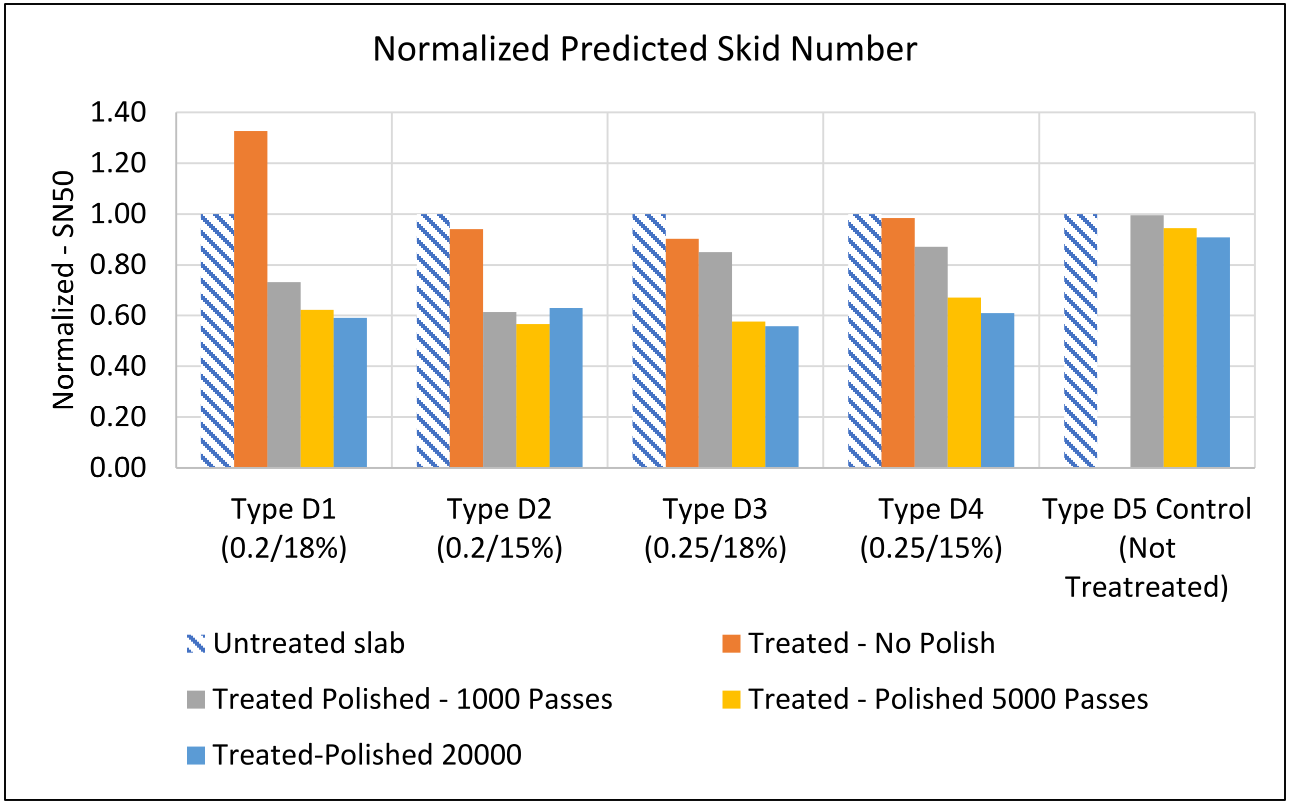
Impact of Slurry Seal on Friction

- The SN for different LWA UT slurry



Impact of Slurry Seal on Friction

- Normalized SN for different LWA UT slurry



Conclusion on Friction Tests

- The skid performance of UT Slurry mixtures can be assessed in the lab using the Polisher, DFT and CTmeter.
- The current UT Slurry mixture based on BB aggregates does not improve the skid of HMA pavement surface.
- An alternative to BB aggregates could be the LWA based UT Slurry applied in two shots of 0.125gal/yd2
- No known correlation between lab polisher and field performance!!.

Recommendation - Friction Tests

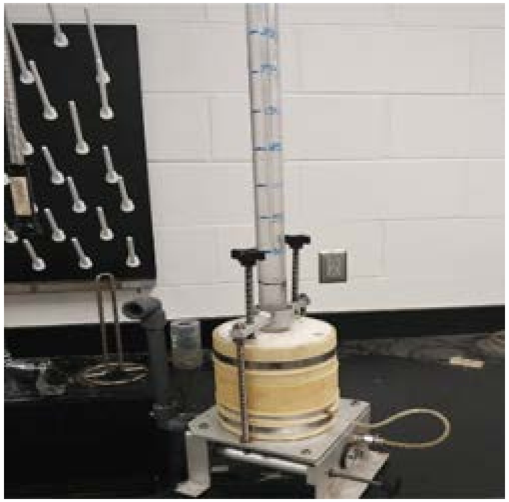
- The research team recommended the following mixtures for further assessment in the Field.
  - #6-0 LWA based UT Slurry (15% aggregates) at two shots of 0.125gal/yd2 each
  - #16-0LWA) based UT Slurry (18% aggregates) at two shots of 0.125gal/yd2 each
  - #60-0 BB - based UT Slurry (18% aggregates) at two shots of 0.125gal/yd2 each. Though it showed relatively poor results in TTI lab, it will give a good comparison in the field

Permeability Tests

Recommendation - Friction Tests

- Varied amount of UT Slurry on lab produced specimens
- Specimens were saturated before testing
- Reported flow time and coefficient of permeability, k



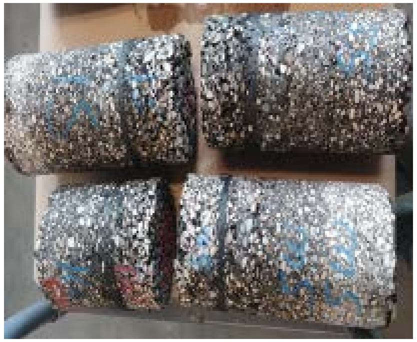


Permeability test - Florida Method

- Performed accordance with Florida Test Method FM 5-565 on 2.5-inch Type D, PFC and Field specimens

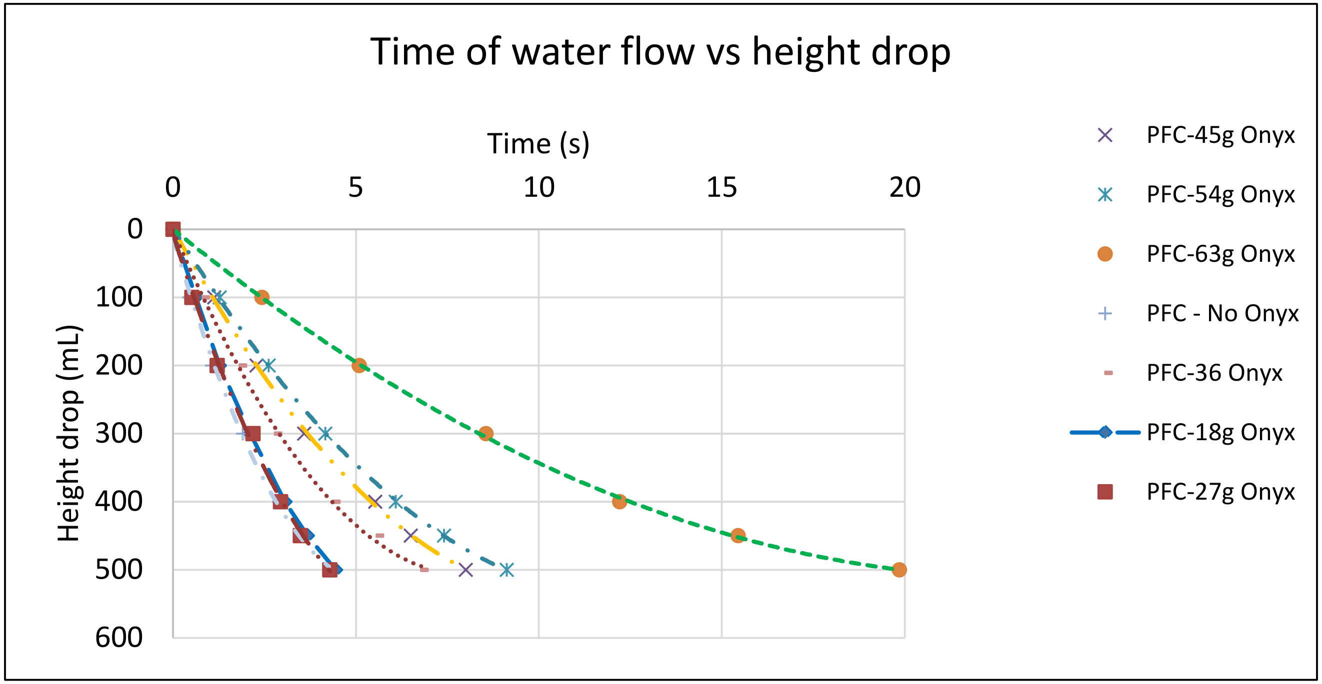
HMA Mixture	UT slurry, g	UT slurry, g	UT slurry, g	Surface UT Slurry (g)	UT slurry, g	UT slurry, g	UT slurry, g
Type D	0	18	27	40	-	-	-
PFC	0	18	27	36	45	54	63

- No UT Slurry was applied on Field Specimens (FM 359)



Permeability test - Florida Method

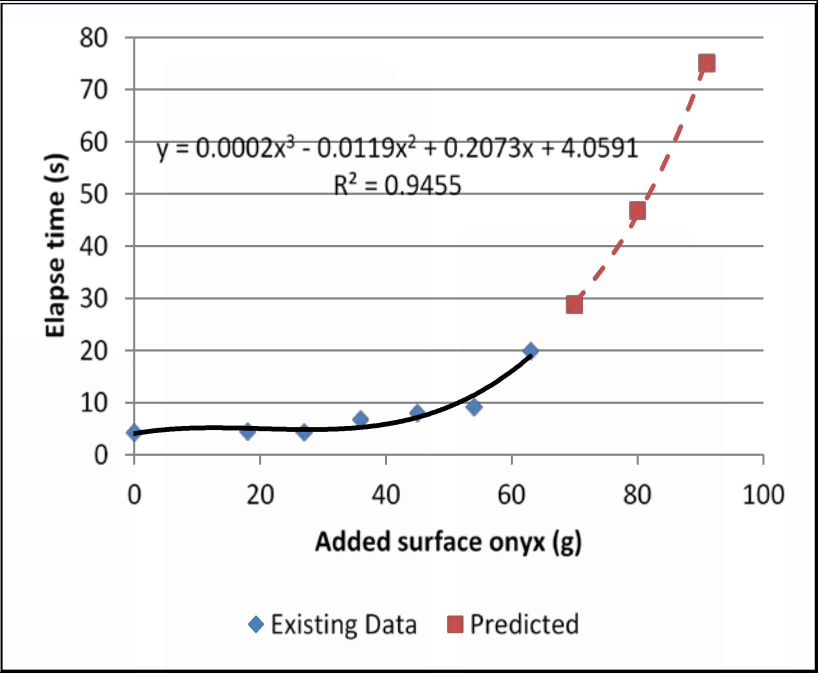
- PFC test results
  - Water flow time increased with increased amount of UT Slurry
  - Initial UT Slurry treatment disappeared into its large voids as such no change was observed at UT Slurry <27 g (= 0.4 gals/yd2)



Permeability test - Florida Method

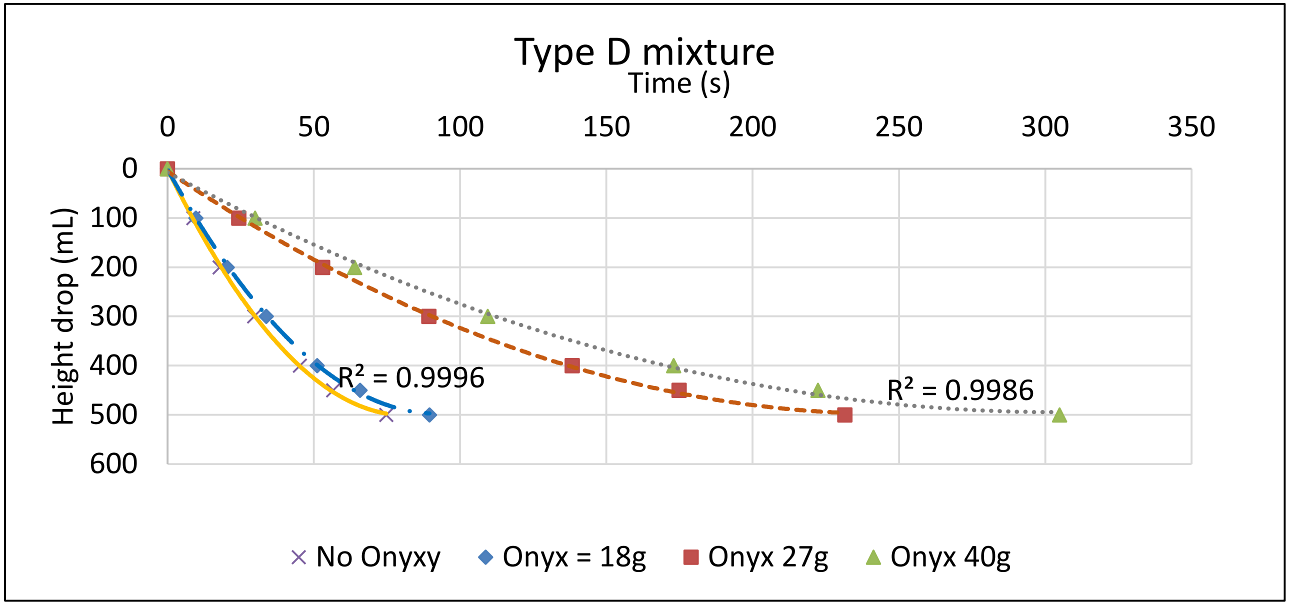
- PFC test results
  - Predicted amount of UT Slurry needed to seal a new PFC
  - Compared to a new type D mixture (flow time = 75 s)
  - 1.25gal/yd2 was needed to fully seal a PFC surface with UT slurry

	Onyx (g)	Time
Measured	0	4.26
	18 (0.25gal/yd^2)	4.44
	27	4.29
	36	6.78
	45	8.00
Predicted	63	9.12
	70	28.86
	80	46.88
	91 (1.25ga/yd^2)	75.09



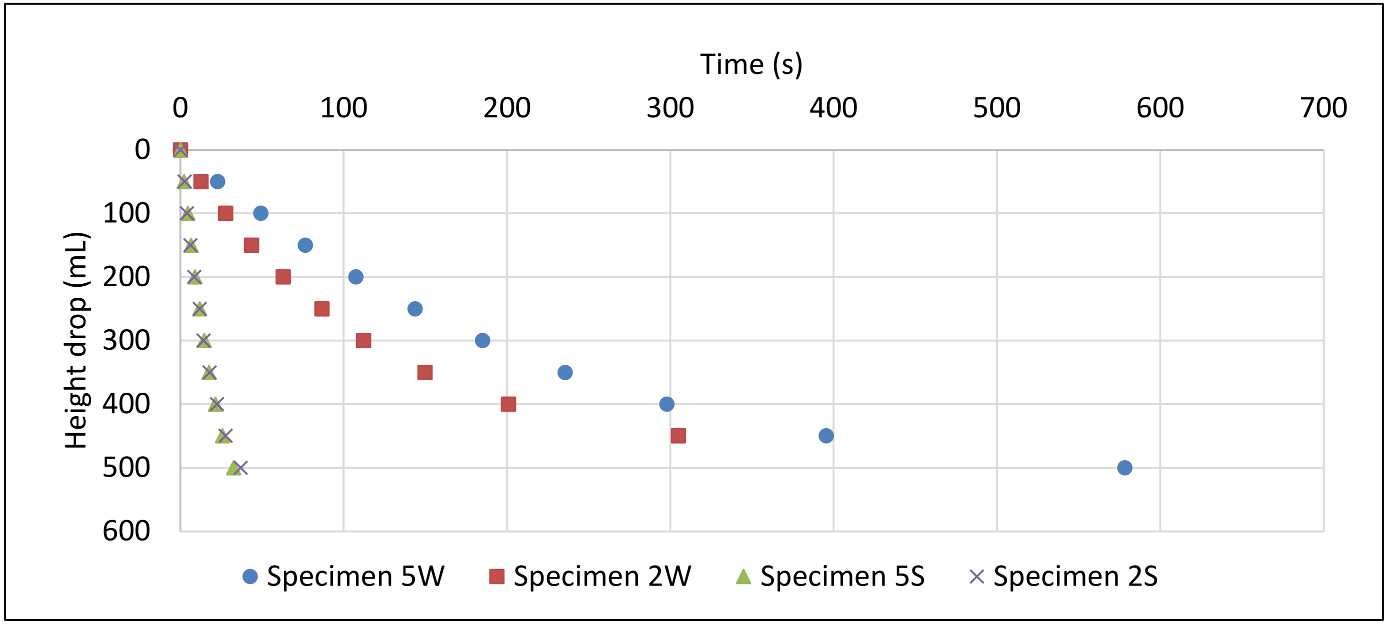
Permeability test - Florida Method

- Type D test results
  - The rate of change of the water flow (ml/s) was high and about the same for a 0 and 18g UT Slurry treatments
  - Water flow dramatically reduced for higher treatments
  - Type D mixture was far better than the PFC mixtures as expected



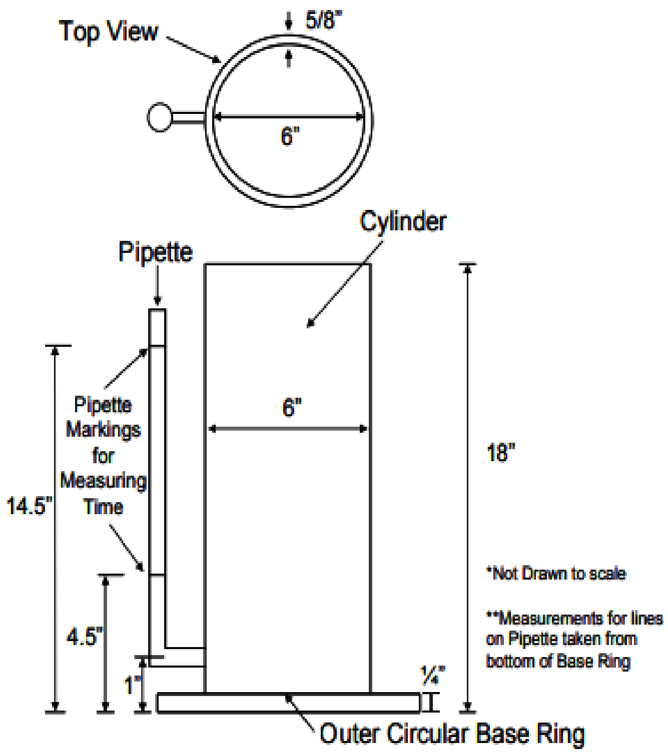
Permeability test - Florida Method

- PFC Field Core test results
  - Two shoulder specimens (denoted with S)
  - Two wheel path (denoted with W)
  - wheel path cores had a higher resistance to water flow
  - The existing PFC was practically sealed



Permeability
Permeameter Method

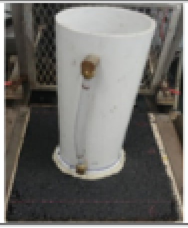
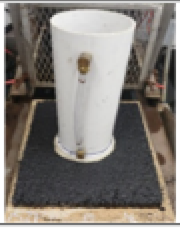
- Performed on PFC in accordance with Tex-246-F



Permeability

Permeameter Method

- On the slabs,
  - flow time increased with increased UT Slurry treatment and increased number of applications.
  - At the same application rate the research did not observe the difference in time flow for slabs treated with 15% and 18% aggregates UT Slurry

UT slurry surface finish	-Control -No UT slurry	-BB UT slurry - 18% Aggregates	-LWA UT slurry - 15% Aggregates	-LWA UT slurry - 18% Aggregates
Pictorial view of the PFC Slabs				
Application rate	N/A	single shot ≈ 0.125gal/yd^2	double shots ≈ 0.25gal/yd^2	double shots ≈ 0.25gal/yd^2
Curing	N/A	72hrs @60°C	72hrs @60°C	72hrs @60°C
Time of water flow	19.88 sec	1min, 13.72 sec	4min, 24.30 sec	4min, 14.73 sec

Permeability

Permeameter Method

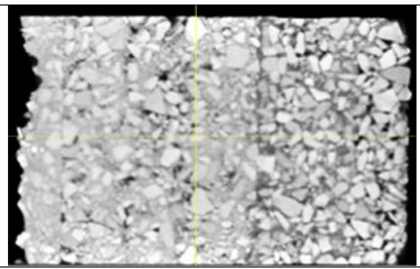
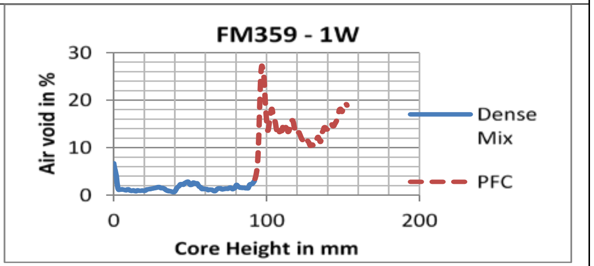
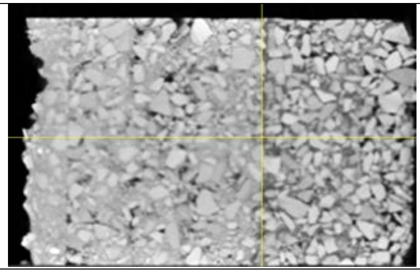
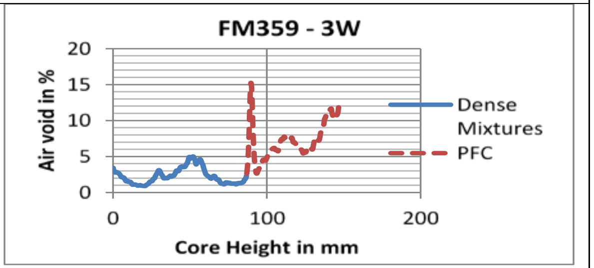
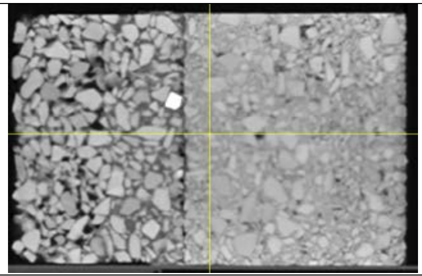
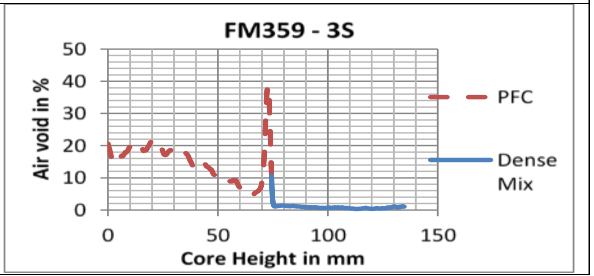
- In the Field, US 359
  - Three locations (shoulder (S), inner (WP) and outer wheel (W))
  - The pavement is practically sealed

#	PFC Slabs		Time of water flow
1		-Shoulder (S)	**13 mins and 56.79 sec**
2		-Outer Wheel (W)	**11 mins and 48.56 sec**
3		-Inner Wheel (WP)	**77 mins and 17.50 sec**

Permeability

CT-Scan

- CT Scan Results are shown below,

ID	CT Scan	Air Void Plot
1W		
3W		
3S		

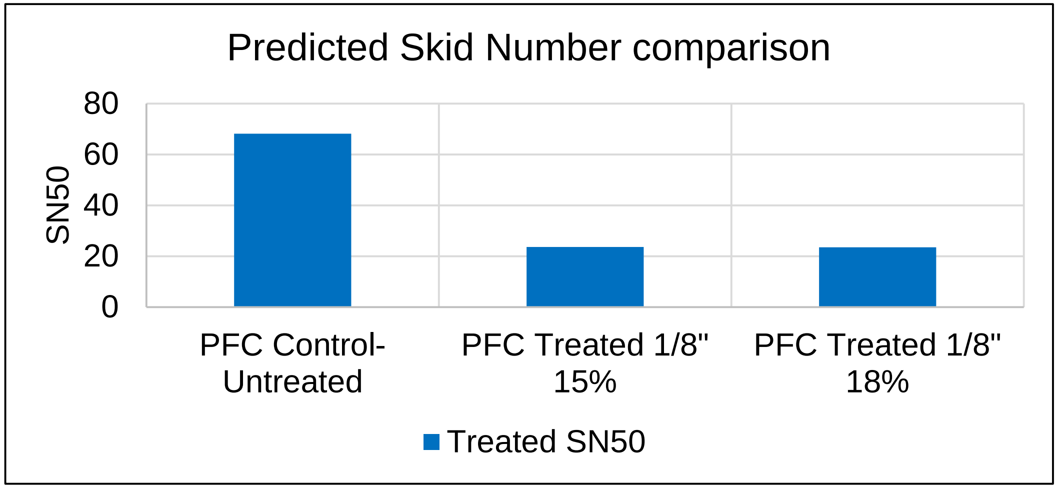
Conclusion – Based on Permeability

- The permeability of UT Slurry treated can be assessed with field permeameter (on slabs) or Florida test method on field cores/lab molds.
- The field flow test and CT scan on cores indicated that after a long time of service, PFC pavements become sealed.

Predicted Skid Number

PFC Slabs Treated with UT Slurry -LWA

Slab/Slurry type	DFT µ@20km/hr	CTM - MPD	Sp	IFI	Predicted SN50
PFC Untreated	0.81	1.77	172.97	0.55	68.1
PFC Treated 1/8" 15%	0.26	0.96	100.31	0.21	23.6
PFC Treated 1/8" 18%	0.25	1.01	104.80	0.21	23.5



Conclusions from lab Studies

- The transition to lightweight aggregate and heavier shot rates has a beneficial impact on short term skid resistance
- Long term skid resistance as inferred from the polisher is still questionable
- The application of the UT slurries does significantly cut the water flow into PFC;'s but it has a negative impact on skid resistance
- Testing of old PFC's in Houston found them to be already closed up with water flow over 10 minutes

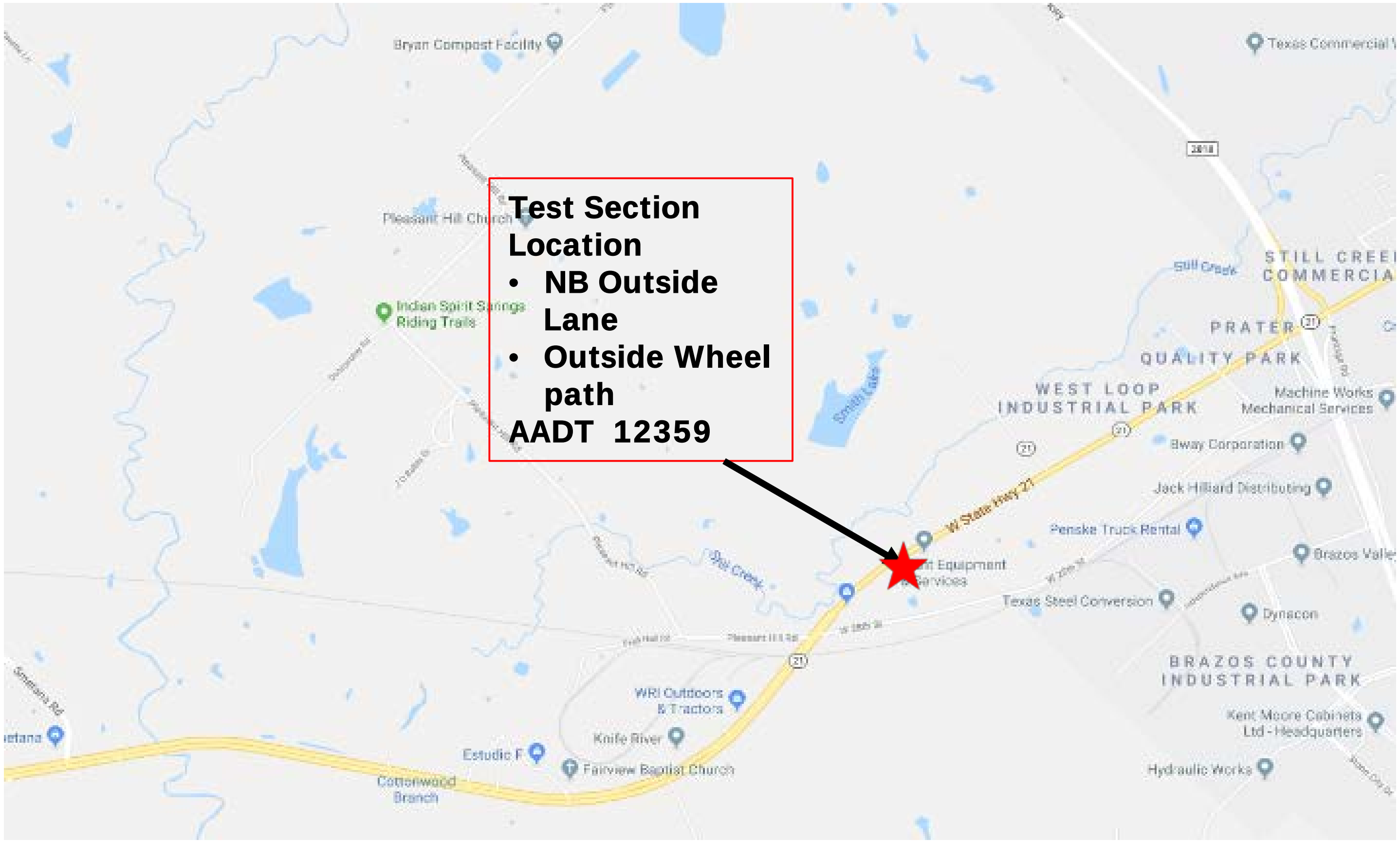
New Field section evaluation

Field Section Evaluation

- The UT Slurry was applied on 5 sections of 3ft x 3ft
- Different UT Slurry mixture combinations were applied manually on each of the sections
- Each application was split in small 4 equal bays to avoid the temperature effects and setting
- Two shots were applied (spaced at about 1hrs)
- 2-hours after applying the last coat on the sections, friction and profile data were collected using the DFT and CTmeter respectively

Field Section Evaluation

- SH21test section



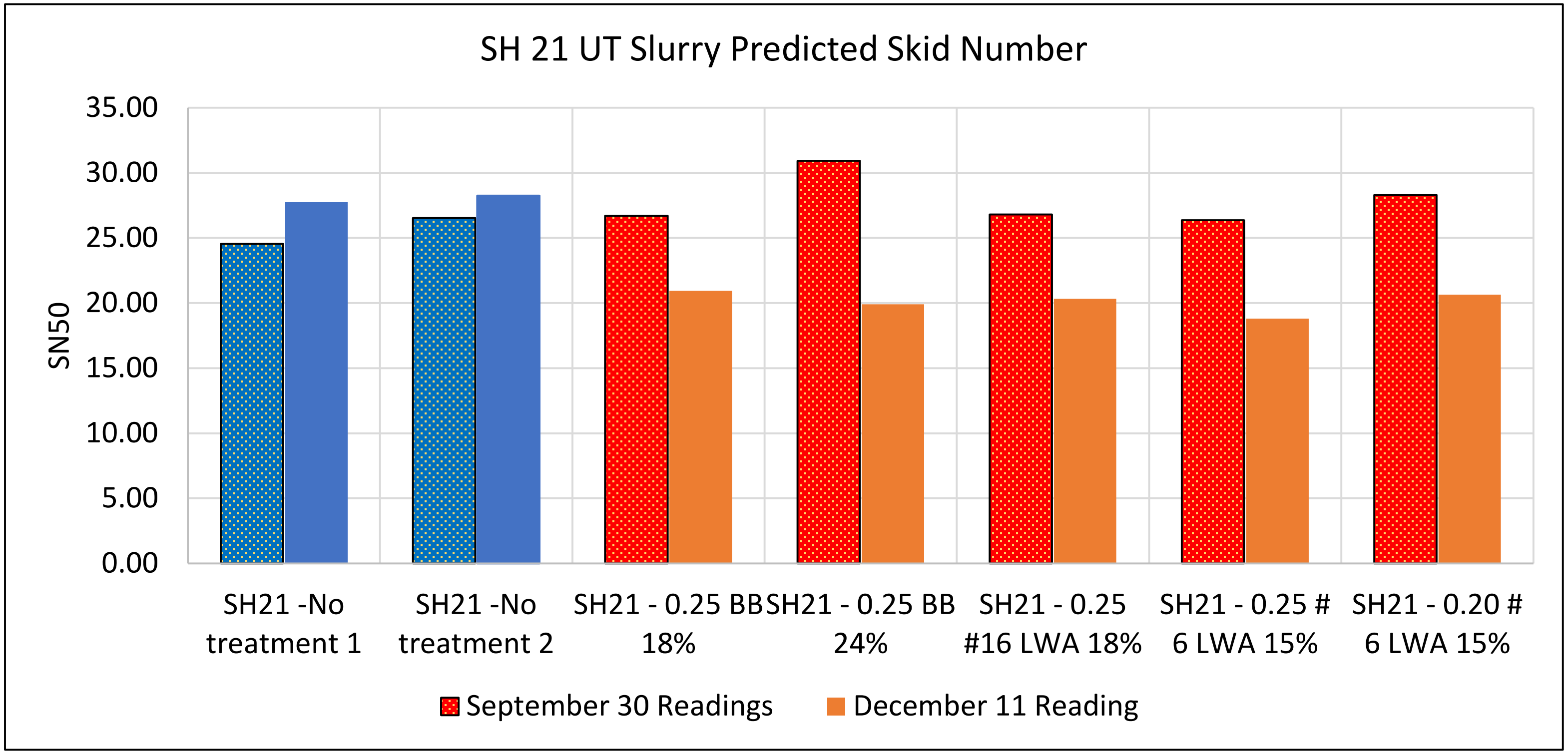
Field Section Evaluation

Field Section Evaluation

- Friction evaluation before and after traffic passes

Field Section Observation

- Field SN test results



Field Section Observation

- Crack sealing failure

Field Test Observation

- The initial SN of LWA treated sections hovered around 28,
- Whereas for BB with 24% agg, SN = 31
- Note: the BB mixture that showed SN = 31 had 6% extra aggregates
- The initial average SN of the Untreated sections was at around SN = 26

Field Test Observation

- After 2 months of traffic, the Skid Number (SN) on treated locations reduced to 20 whereas
- The SN of the Untreated sections remained relatively the same at around SN = 27
- The UT Slurry did not seal the cracks
- The UT Slurry in its current form should not be used for High traffic volume roads because of loss of skid

Field Test Conclusion

- The SN of the Ultra-thin slurry always dropped to 20 after traffic passes; in the lab the SN =20 was reached after about 1,000-10,000 polishing passes
  - For different mixtures (agg. type and percentage)
  - Existing surface
- The Ultra-thin slurry could not seal cracks
- The Ultra-thin slurry can not be used for High traffic volume roads
- The Ultra-thin slurry improved the black top surface of the pavement

New Developments

New developments

- Improved Construction techniques developed by Industry - offers potential for improvement

New developments

Topics for Discussion

- In its current form the UT slurry even with the use of Light-Weight and heavier shot rate has a negative impact on skid and wears off within a few months
- The new construction technique offers potential to radically increase the amount of rock in this product.
- More work is needed to redesign these slurries
- Specifications need to be revised to include a DFT/Polisher requirement. For example “50,000 passes of the polisher with less than a 10% loss in skid”
- Will in be cost effective ?
- Will it look the same as a grade 5 chip seal ?

Thank you