PERFORMANCE EVALUATIONS

Of
FOG SEALS
And
REJUVENATORS

Fog Seal Applications

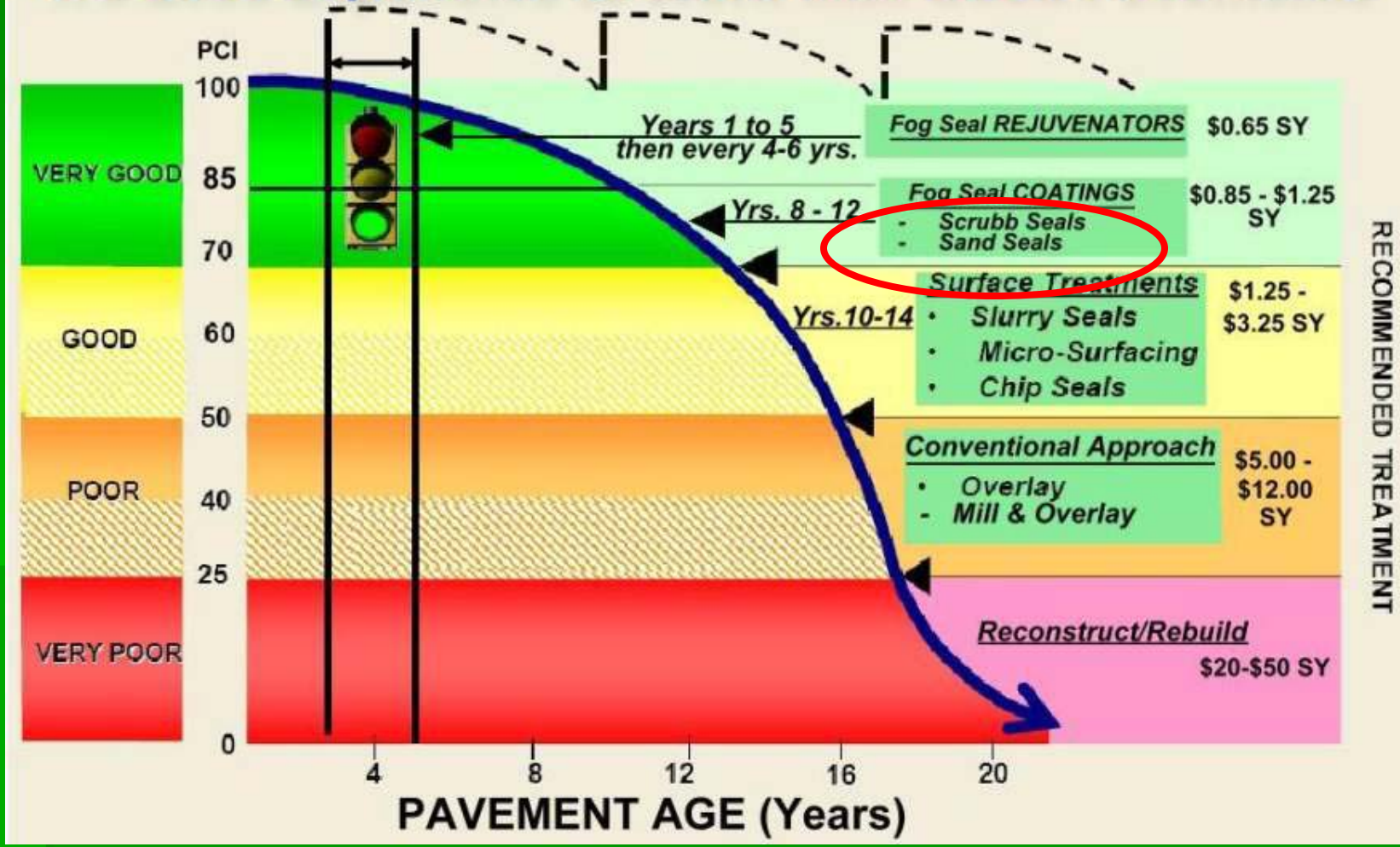
- Dense-Graded HMAC

- OGFC

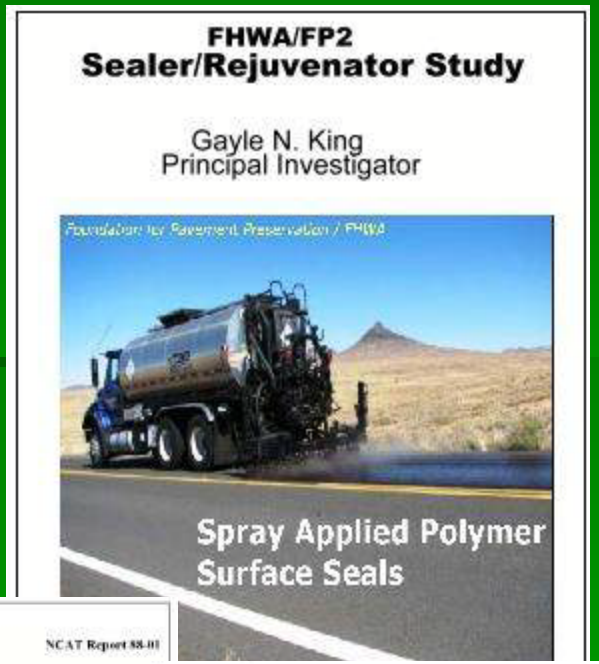
- Chip Seals

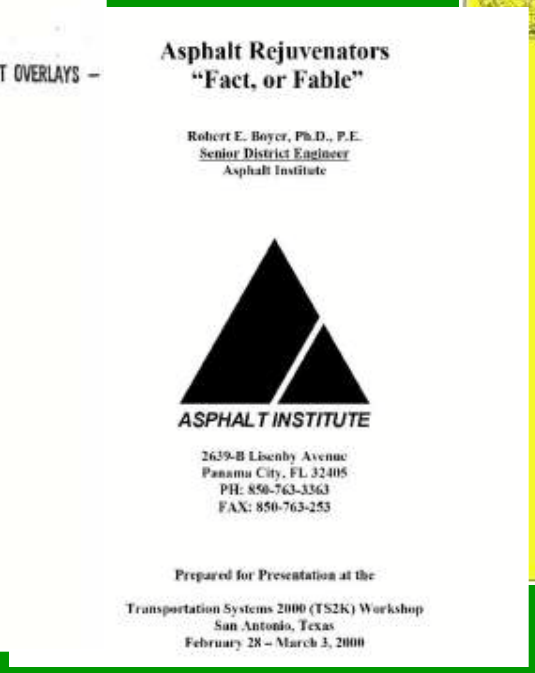
PAVEMENT PRESERVATION

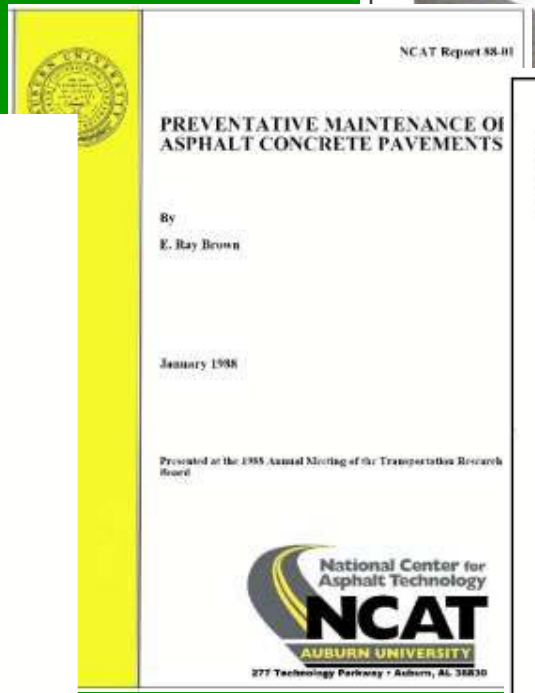
It's Less Expensive to Work with Good Pavements

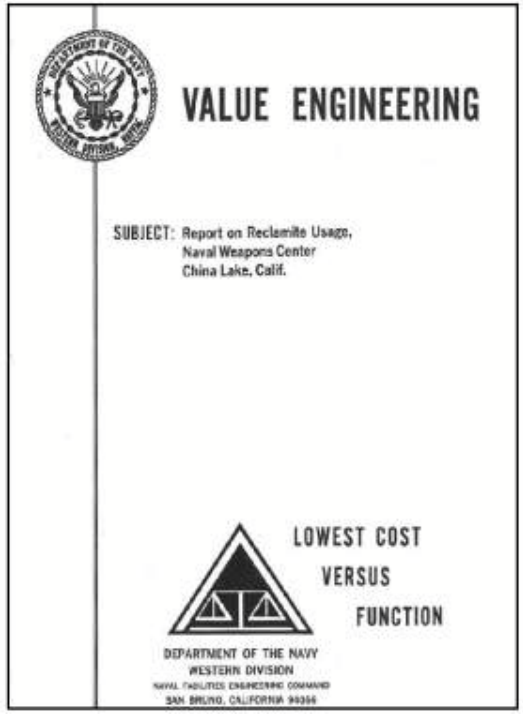


Various studies and reports conducted over the past 30+ years have confirmed the effectiveness of fog seal / fog rejuvenators and seal coats in extending pavement life.









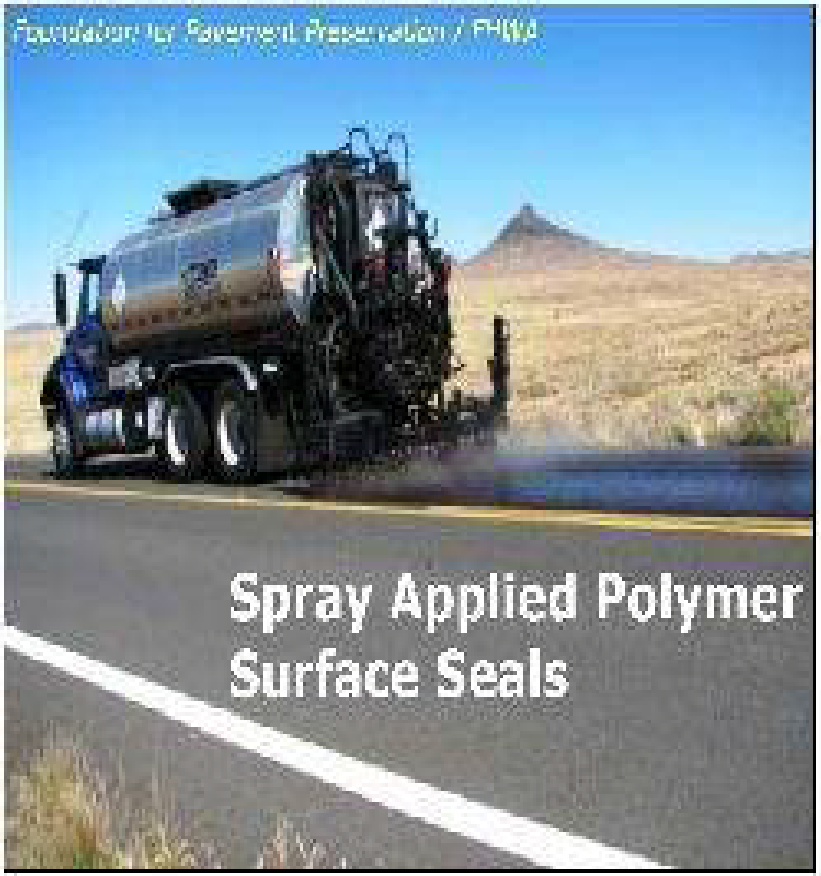
The most current and arguably the most comprehensive study was completed within the last two years

This study compared several types of fog seals with respect to their performance over time

A large portion of the performance data presented here is attributed to this Sealer/Rejuvenator Study

FHWA/FP2
Sealer/Rejuvenator Study

Gayle N. King
Principal Investigator



How do we develop specifications for fog seal emulsions

1. Define performance criteria
2. Develop tests for performance
   - On-the-road performance criteria
   - Emulsion requirements
     - **Determine emulsion performance-related criteria**
     - **Determine residue performance-related criteria**
       - **Establish residue recovery method**
3. Write specifications with defined limits

Differentiate needs for:

- HMAC, OGFC, Chip Seal

Fog Seal for Dense HMAC

- Objectives:
  - **Penetrate into & renew aged asphalt binder**
  - **Seal small cracks and surface voids**
  - **Prevent raveling**
  - **Skid number maintained**
- Emulsion grades:
  - **Aromatic/Naphthenic rejuvenator oils: (ETR-1; ARA-1; Reclamite®)**
  - **AC/rejuvenator oils: (Cyclogen®)**
  - **PMAC/rejuvenator oils: (Pass®)**

Rejuvenator Fog Seals

on

Dense HMAC Pavements

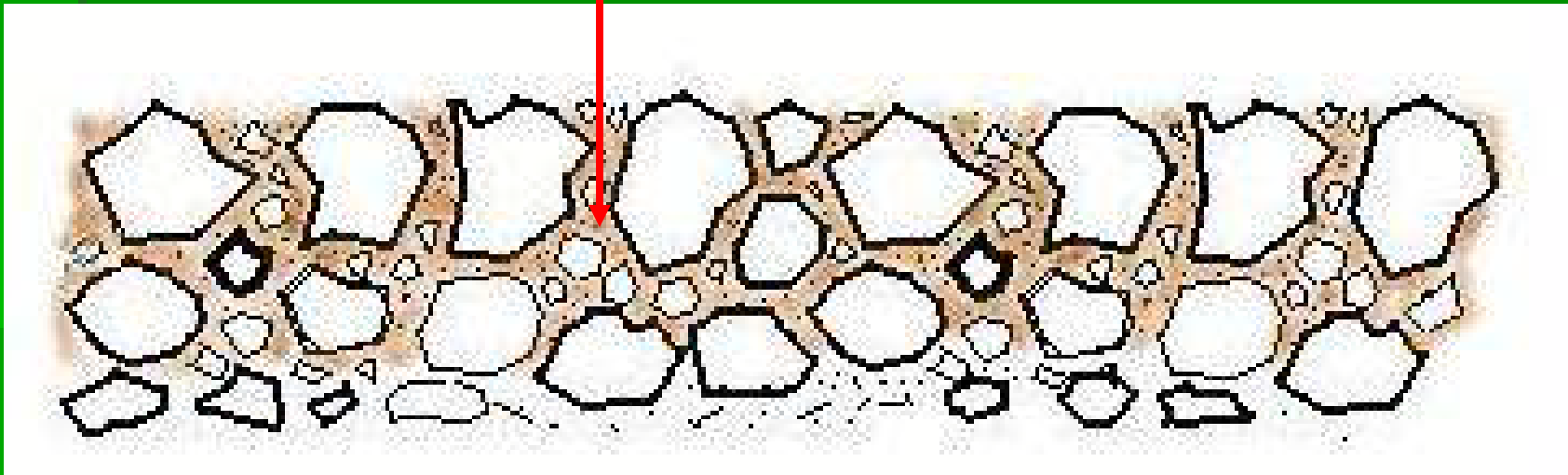
ASPHALT PAVEMENT

94%
Sand & Stone

6%
Asphalt Cement
[liquid]

Penetrate Into the Pavement

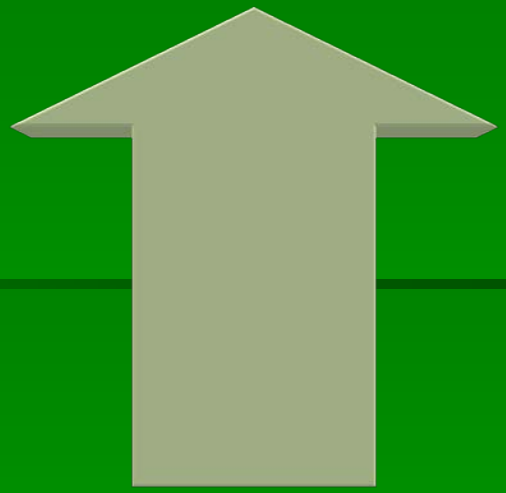
Maltenes must penetrate into the pavement



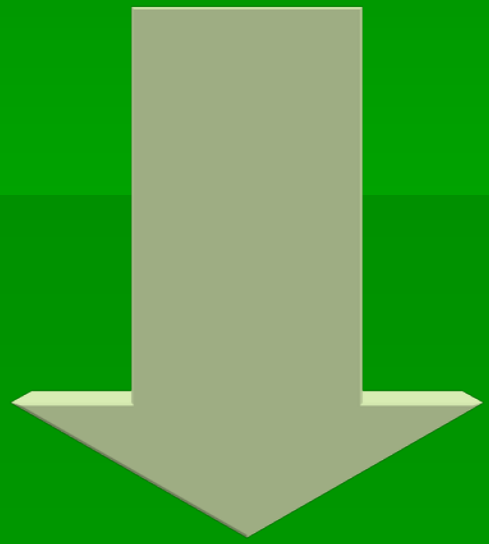
Asphalt Binder Evaluation

- **Viscosity Test**
- **Penetration Number Test**

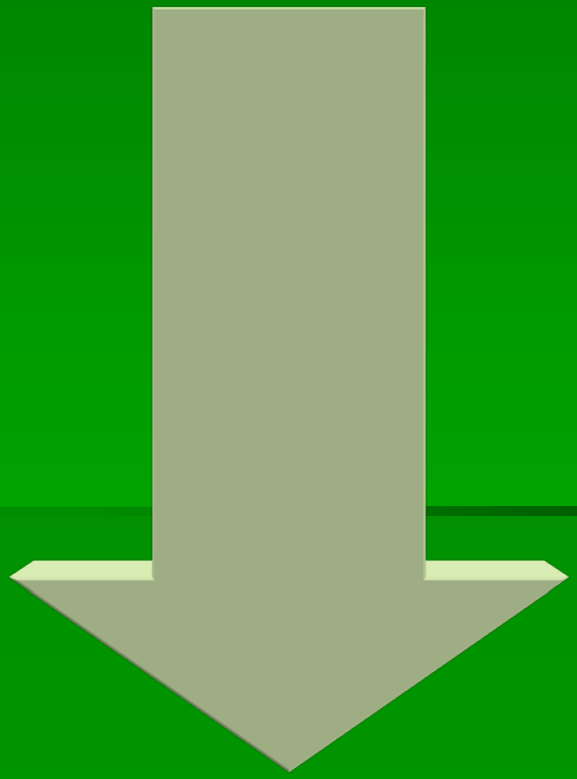
When viscosity goes up

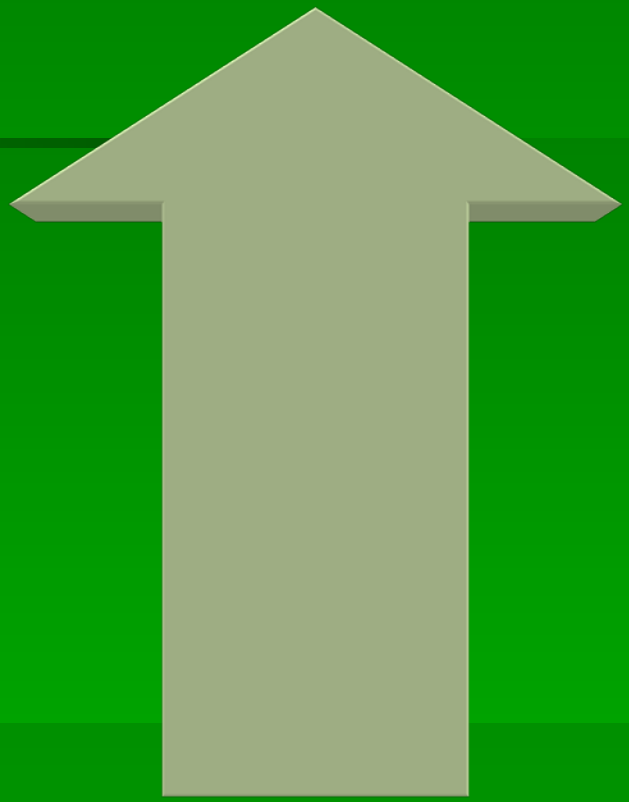


Asphalt Cement Hardness Increases and Pavement Flexibility goes down



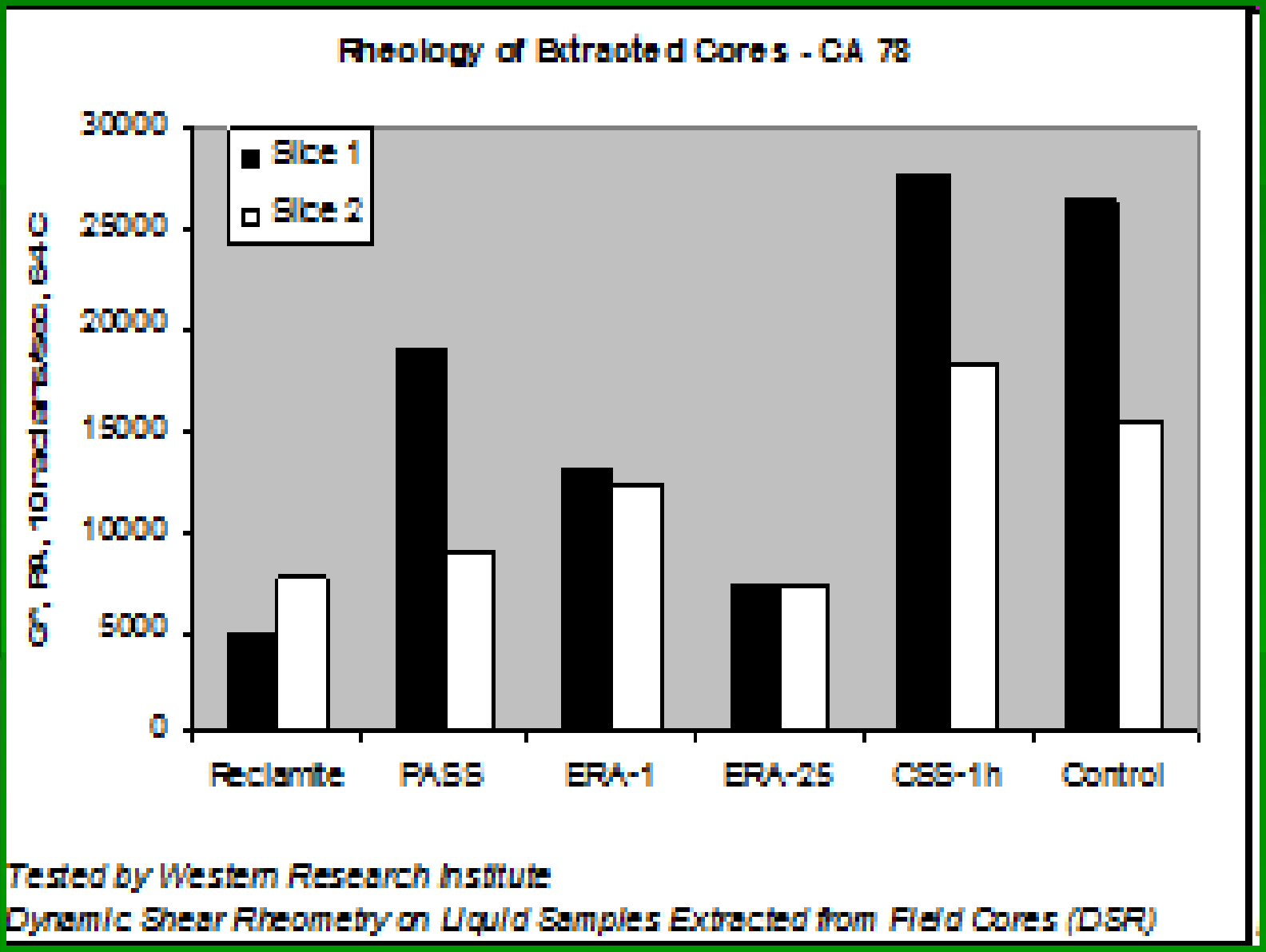
Penetration numbers go down





Asphalt Cement Hardness goes up

Rheology


Rheology of Extracted Cores - CA 78
G*, RA, 10radians/sec, 64 C
30000
25000
20000
15000
10000
5000
0
Slice 1
Slice 2
Reclamite
PASS
ERA-1
ERA-25
CSS-1h
Control
Tested by Western Research Institute
Dynamic Shear Rheometry on Liquid Samples Extracted from Field Cores (DSR)

Test Results on Recovered Binder
City of Nashville, TN – Centennial Blvd.

Core Sample	Viscosity@60°C, Poises	Phase Angle, °	M O D U L U S, Pa		
			Complex	Elastic	Viscous
Core # 1: Treated Core A	4824	85.4	4836	387	4821
Core # 2: Untreated Core A	9086	83.2	9110	1076	9046

Evaluation of Seal Coat Runway 16–34 Lajes Field, Azores

by
J. E. Pickett

Geotechnical Laboratory
U.S. Army Engineer Waterways Experiment Station
P.O. Box 631
Vicksburg, Mississipi

March 1983

11 Layout of sampled areas Lajes Rejuvenation Project, AZ 820019

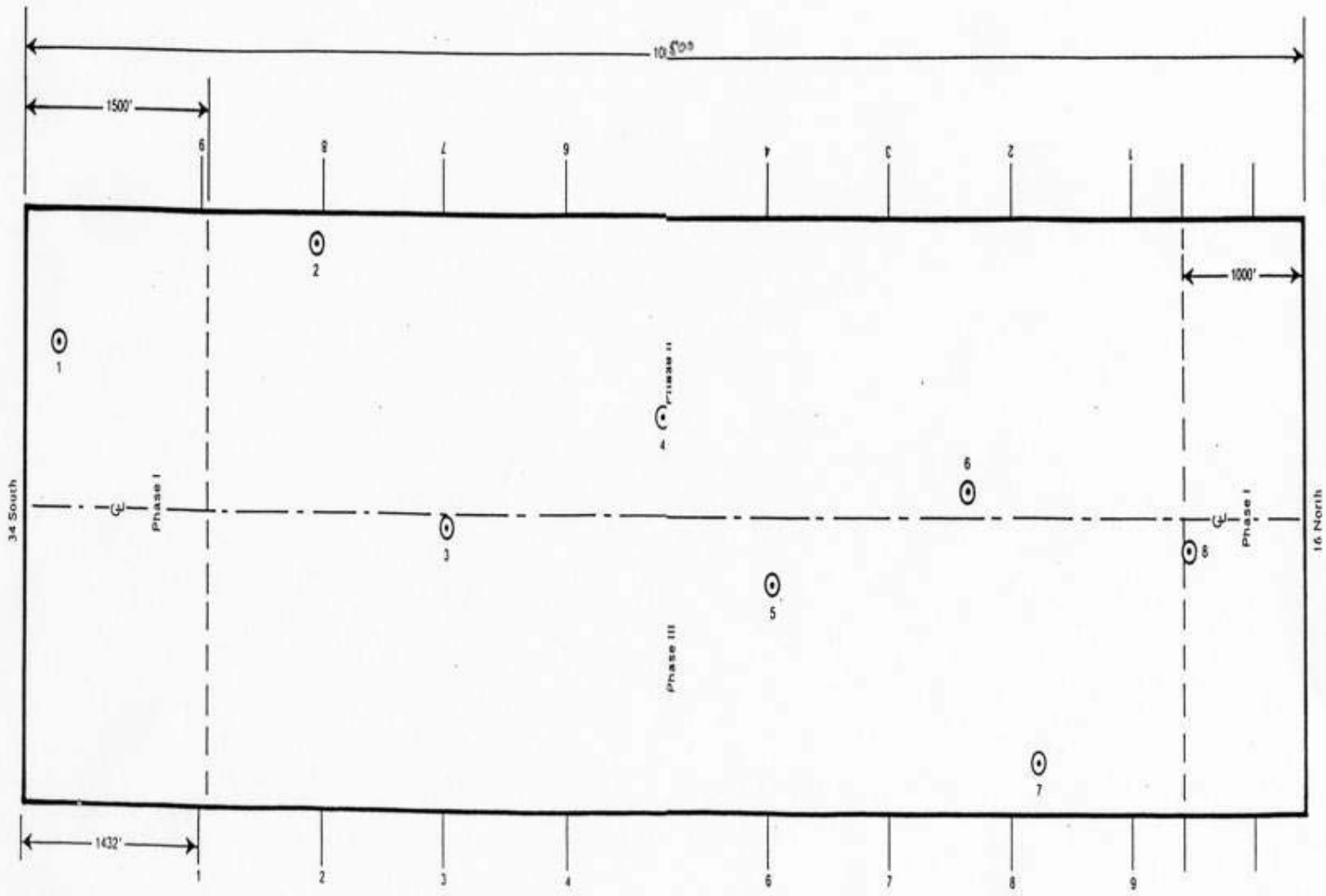


Table I

Lajes Rejuvenator, 1983

Sample Number	Station From South End R/W & C	Penetration 77°F (25°C) 100 g, 5 sec 0.1 mm		Absolute Viscosity 140°F (60°C) 300.0 mm Hg Vacuum, Poises	
		Untreated	Treated	Untreated	Treated
1	2+43, 83.7 ft W	11.00	20.00	401, 351	65, 420
2	23+55, 134.9 ft W	11.00	23.00	449, 520	62, 011
3	34+34, 5.1 ft E	13.00	31.00	242, 293	32, 860
4	52+07, 51.3 ft W	9.00	27.00	1, 852, 362	43, 497
5	64+36, 32.4 ft E	4.00	17.00	2, 774, 367	177, 941
6	80+67, 14.6 ft W	9.00	22.00	863, 971	62, 736
7	86+86, 121.4 ft E	6.00	34.00	1, 263, 880	23, 444
8	99+17, 17 ft E	6.00	29.00	1, 318, 687	41, 392
Average		8.63	25.38	1, 145, 804	63, 663
Change (%)		Penetration	194.00	Viscosity	94.40
			Increase		Decrease

Runway 16–34 was satisfactory. The penetration test shows an increase of approximately 194 percent and the viscosity test shows a decrease of approximately 94 percent. The specification requires the average penetration to be increased by 20 percent and the average viscosity to be decreased by 40 percent.

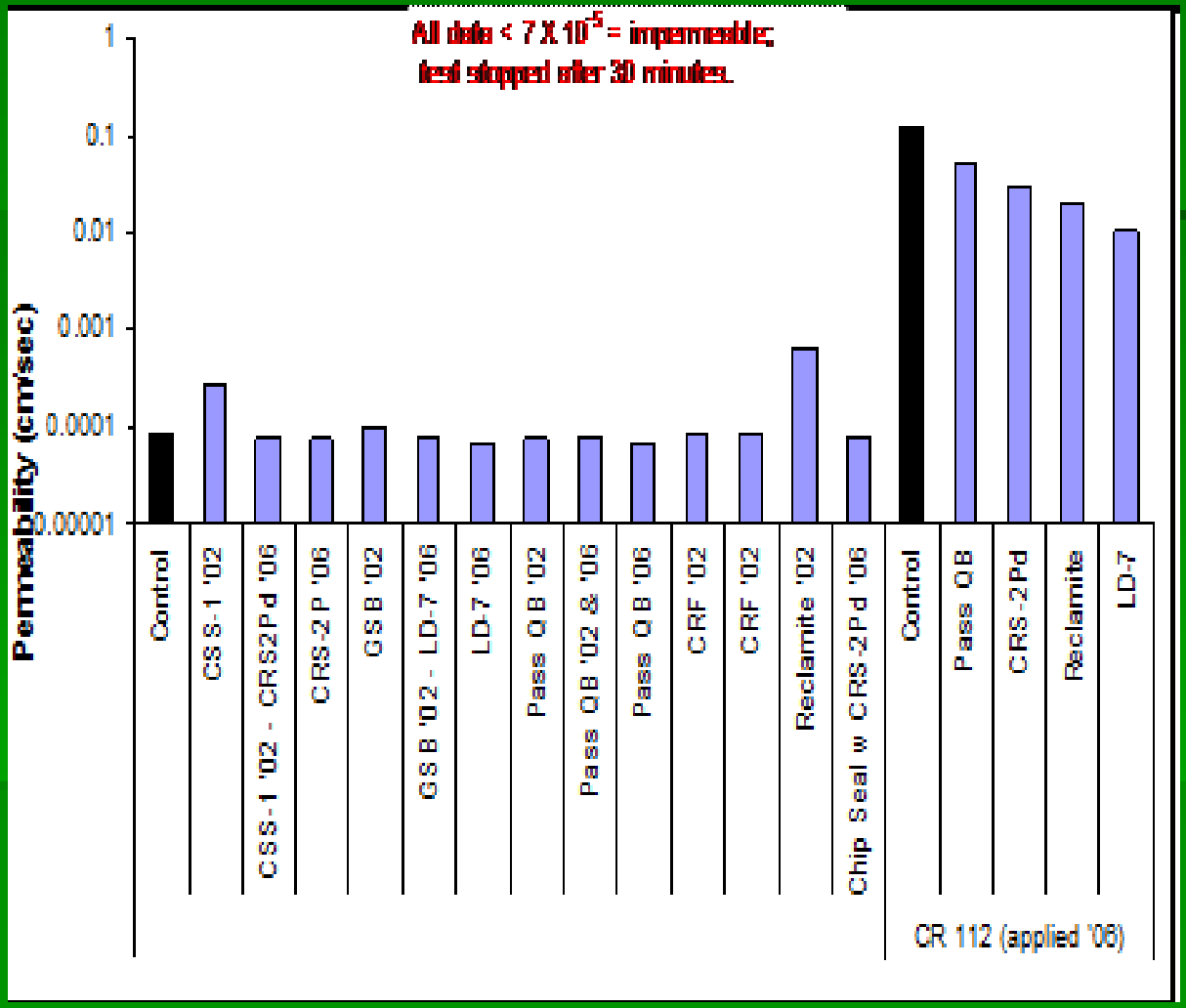
4. The contractor for the project was Mr. Colin M. Durante, Pavement Technology, Inc., 11260 Berett Road, Cleveland, Ohio 44102. He elected to use Reclamite, a proprietary material manufactured by the Golden Bear Division of Witco Chemical Corporation, Bakersfield, California, as a rejuvenator. Reclamite is a resin-based emulsion that leaves an oily residue and is applied with a bituminous distributor. The Reclamite material was mixed at the job site in a two to one ratio with water, two parts Reclamite to one part water. The Reclamite mixture at ambient temperature (60–70°F) was sprayed onto the runway pavement by using a 1140 gal bituminous distributor equipped with a 10-ft spray bar. Application rates were varied intentionally to avoid excess rejuvenator in areas, such as recently patched areas, and areas with rubber build-up. Areas outside regular traffic were sprayed heavier, which would not bother air traffic, in case of excess rejuvenator on the surface. Dates of treatment and application rates (gal/yd²) are shown in Table II. The remainder of the material was used to spray various taxiways and parking aprons.

Table II

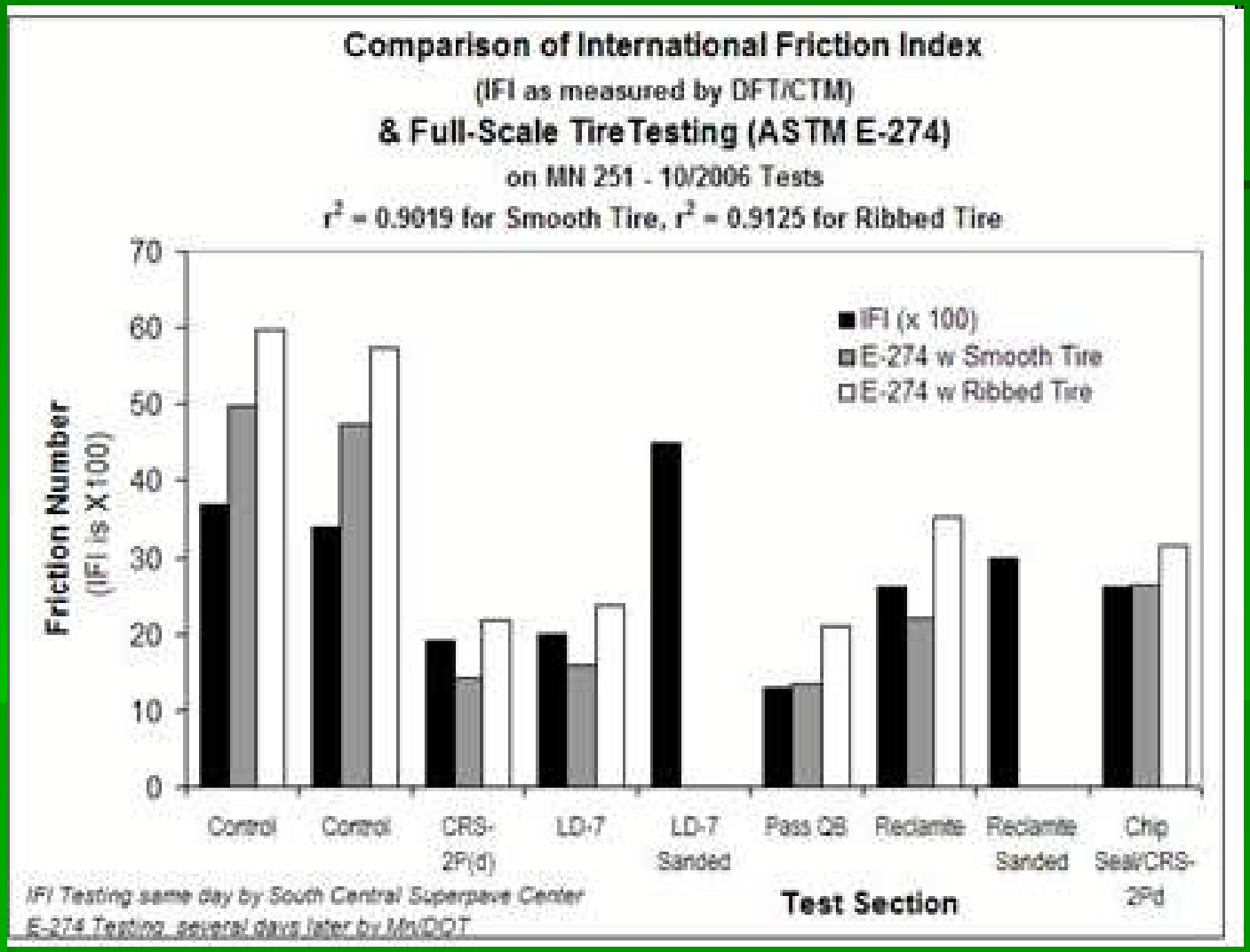
Phase I	
Center 100-ft-wide area	0.053 gal/sq yd
All other areas	0.061 gal/sq yd
Phase II	
From center line runway out 50 ft	0.055 gal/sq yd
All other areas	0.066 gal/sq yd
Phase III	
From center line runway out 50 ft	0.058 gal/sq yd
All other areas	0.074 gal/sq yd

Jack E. Pickett
Materials Engineering Technician
Pavement Systems Division
Geotechnical Laboratory

Permeability



Friction


Comparison of International Friction Index
(IFI as measured by DFT/CTM)
& Full-Scale TireTesting (ASTM E-274)
on MN 251 - 10/2006 Tests
r² = 0.9019 for Smooth Tire, r² = 0.9125 for Ribbed Tire
Friction Number
(IFI is X100)
70
60
50
40
30
20
10
0
IFI (x 100)
E-274 w Smooth Tire
E-274 w Ribbed Tire
Control
Control
CRS-2P(d)
LD-7
LD-7 Sanded
Pass QB
Reclamite
Reclamite Sanded
Chip Seal/CRS-2Pd
Test Section
IFI Testing same day by South Central Superpave Center
E-274 Testing several days later by MnDOT

In 2002 the City of Oak Ridge had Reclamite applied to a 2 year old shoulder on SR62. The results again are very clear.

Two years later the results are clear!

Asphalt Emulsion Fog Seals

on

Dense HMAC Pavements


FRESH

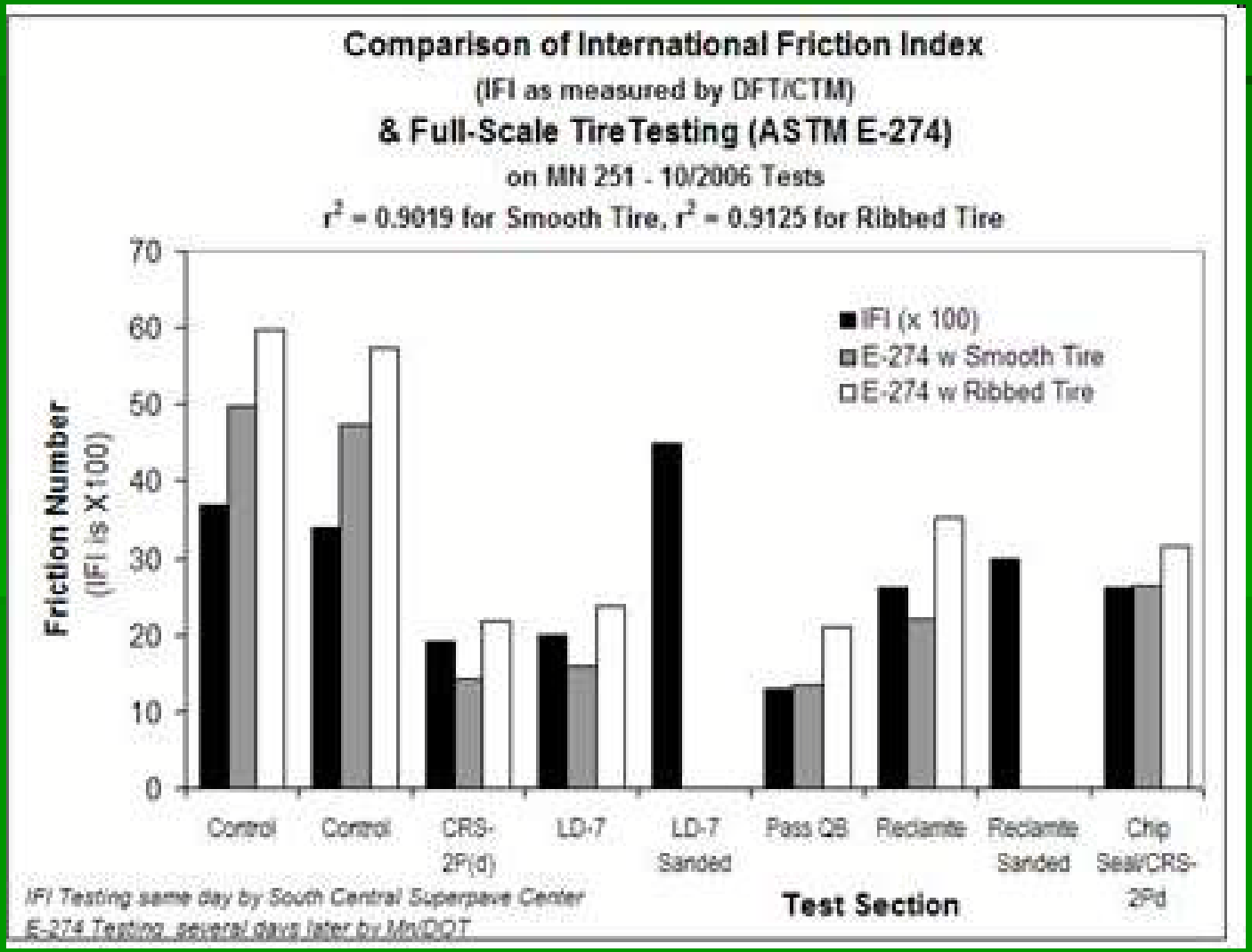
Require sufficient voids

Asphalt Emulsion Fog Seal

Before

After

Friction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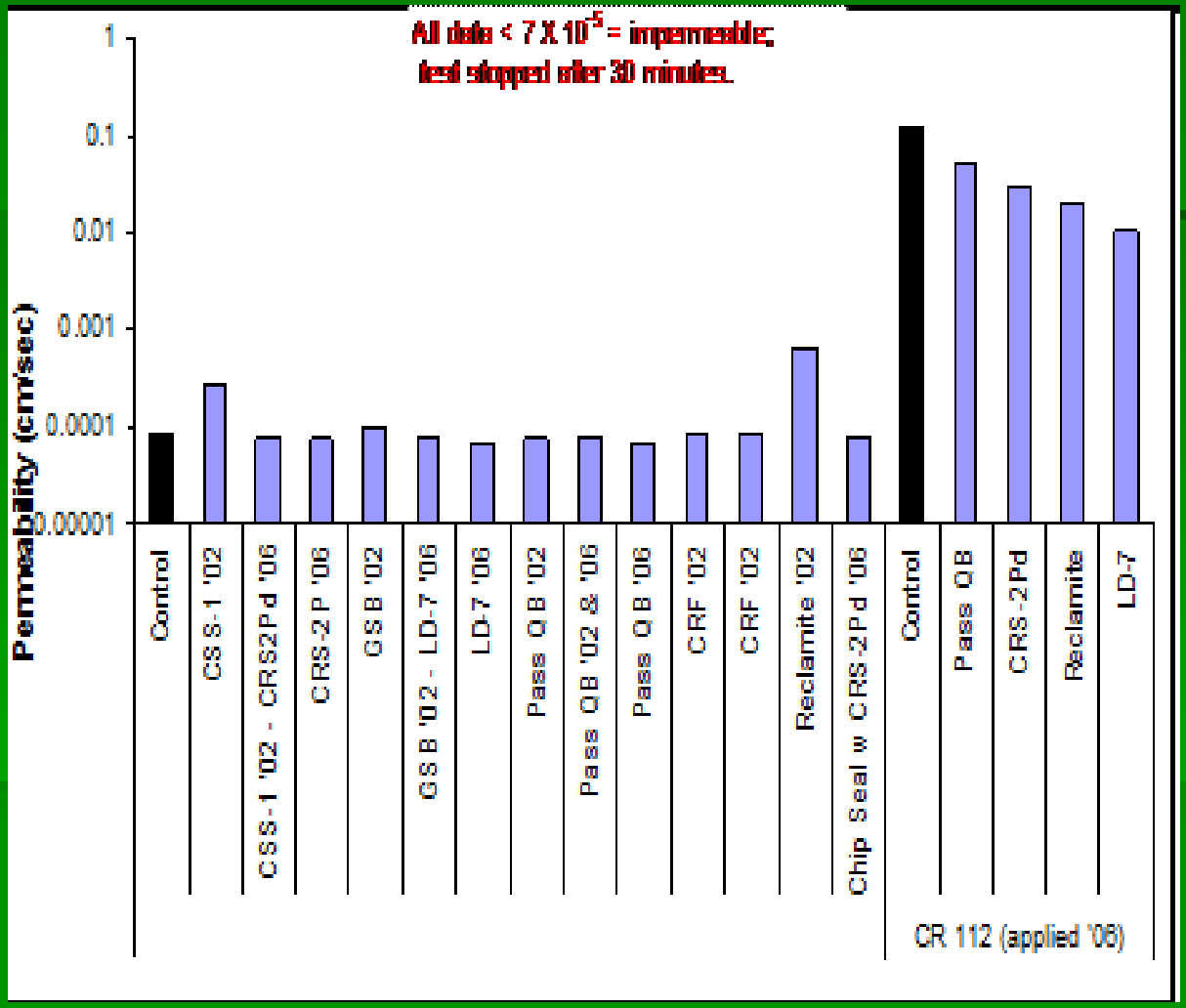

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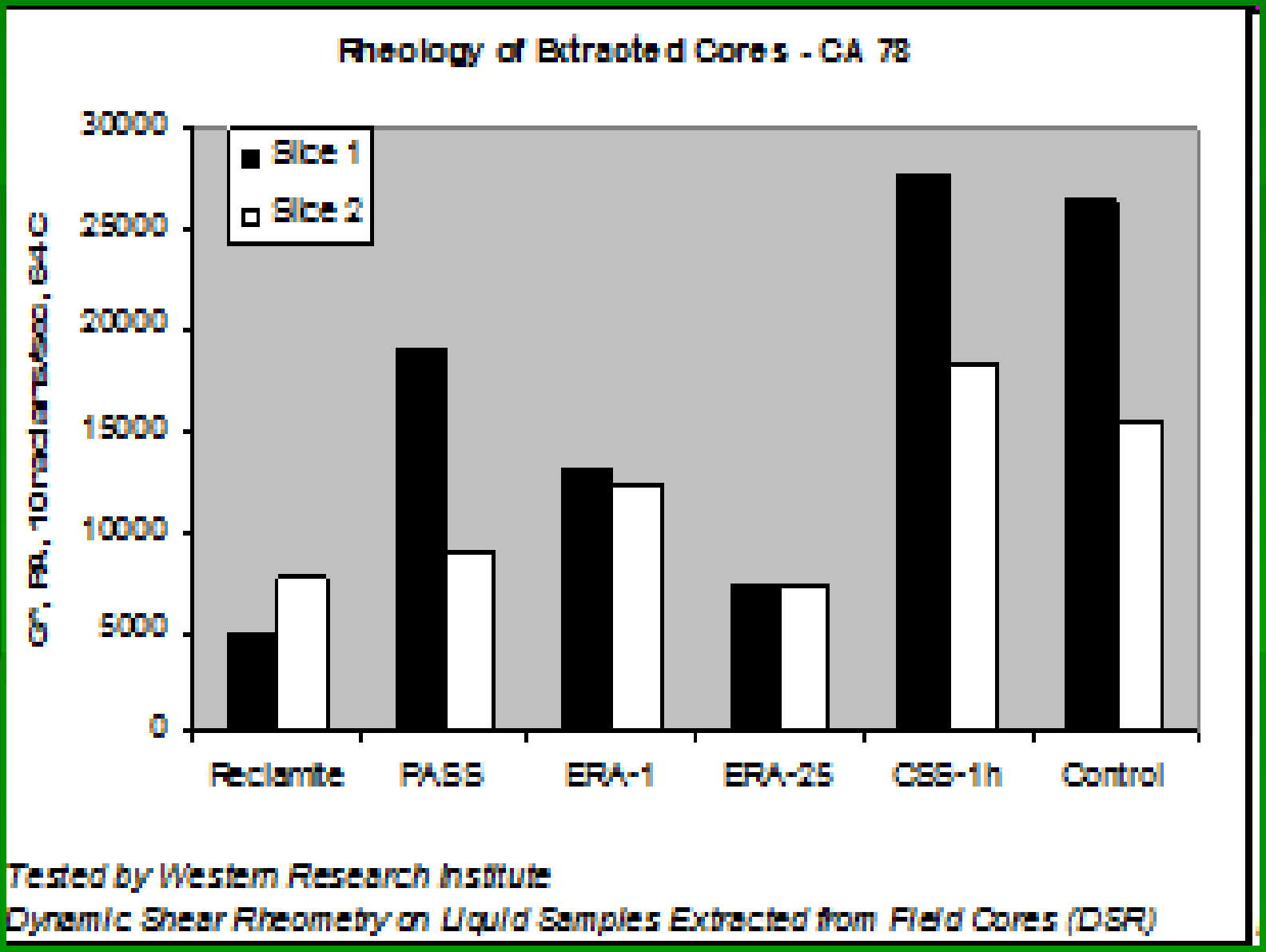
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Impact on skid numbers?

Topical fog seals can leave a thick coating on the aggregate surface

They also fill in the voids with new material

Emulsion Type may effect performance


DRIVE
THRU

Fog Seals for HMAC Define Performance?

- Properties of restored HMAC
  - **Resistant to rutting, fatigue, thermal cracking**
  - **Does not ravel**
  - **Small surface cracks are filled and heal**
  - **Permeability reduced**
  - **Age harden binder improved**
  - **Quick release to traffic**
  - **Acceptable skid numbers after application**
    - **Emulsion penetrates into HMAC**
- Provides a Cost/Benefit

Fog Seal for OGFC

- Objective:
  Restore aged asphalt binder properties to reduce raveling and cracking
- Maintain open gradation
- Emulsion grades:
  - **Maltene based rejuvenator**
  - **PMA/rejuvenator oil blends (diluted)**

Rejuvenator Fog Seals

on

OGFC Pavements

Rheology

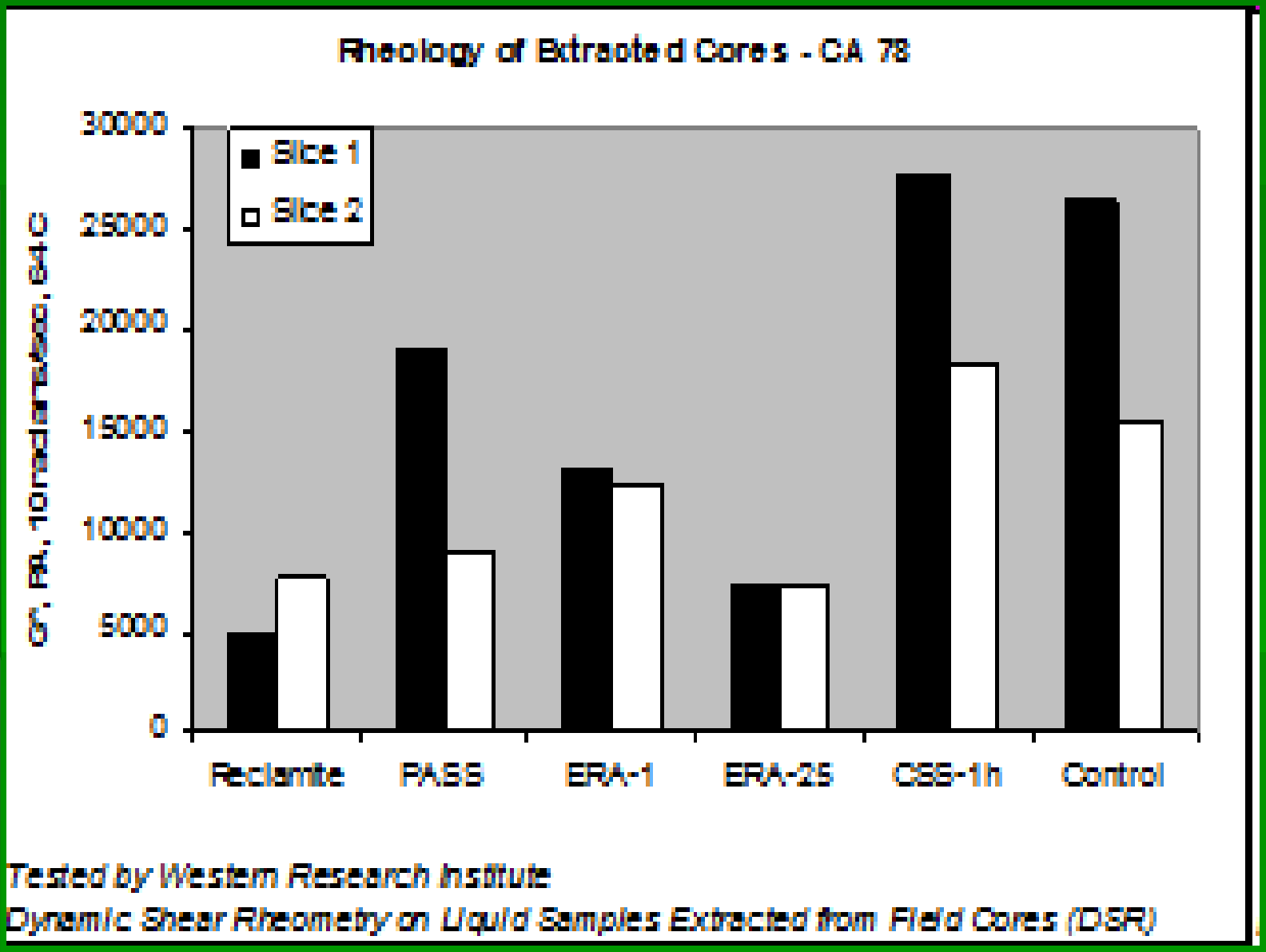
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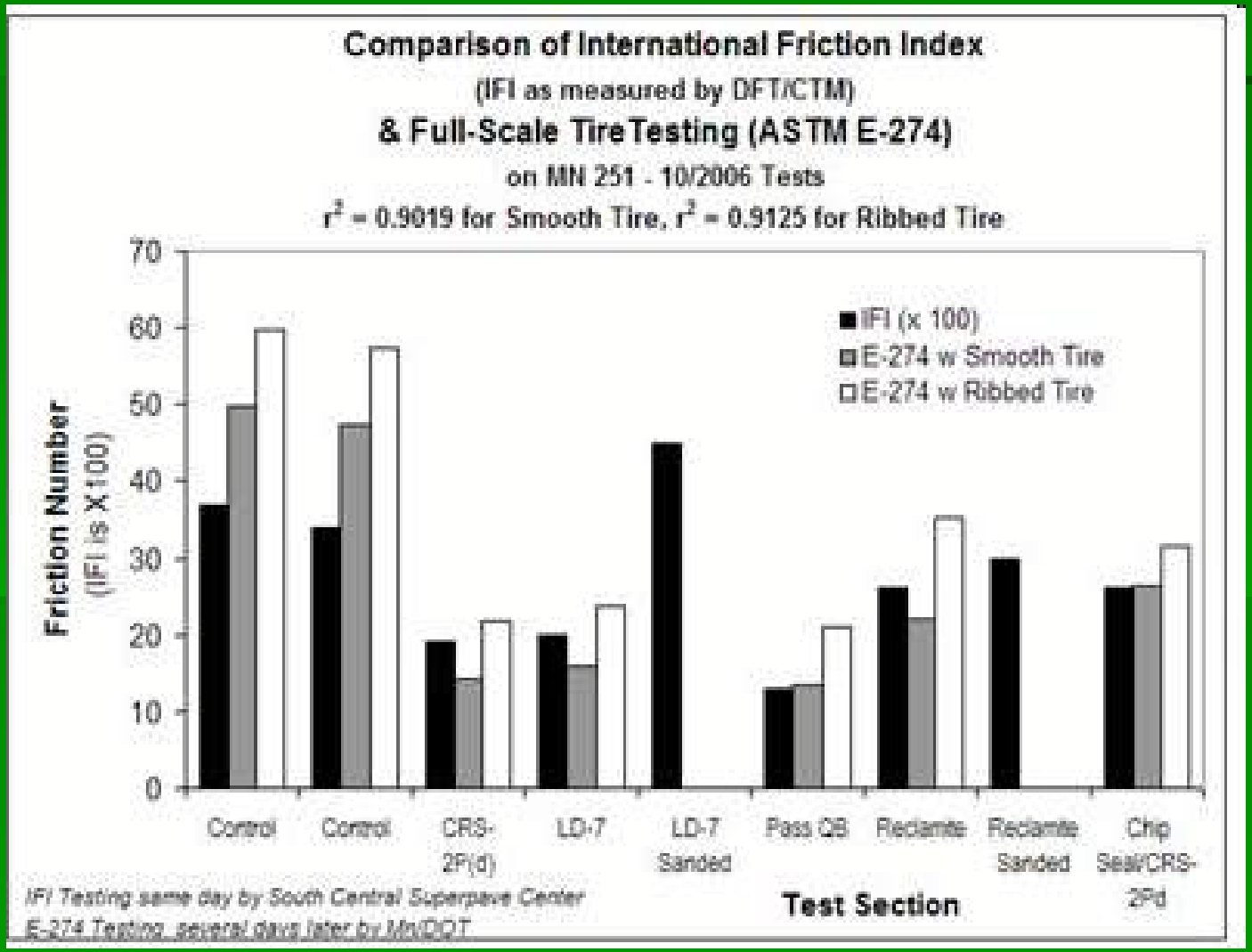
Table I
Core Samples
Panama City, Bay County, Florida
Micro viscosity Test Data

Malaga Road **Standard Asphalt, Close-Graded Mix** **Core #6** **(Treated @ 1:1, 0.07gsy)**	Micro viscosity, 25°C, MP		Equivalent
	$0.05\ sec^{-1}$	$0.001\ sec^{-1}$	Penetration
Top ¼-inch			
Treated	40.2	268	16
Untreated	53.8	275	14
Second ¼-inch			
Treated	42.0	355	16
Untreated	47.0	540	15

Table I
Core Samples
Panama City, Bay County, Florida
Micro viscosity Test Data

Beach Street Open-Graded, Large Aggregate, Cold Placed Core #8 (Treated @ 1:1, 0.15gsy)	Micro viscosity, 25°C, MP		Equivalent
	0.05 sec^{-1}	0.001 sec^{-1}	Penetration
Top ½-inch			
Treated	24.5	120	20
Untreated	Too Hard to Record		<5
1-inch to 1 ½-inch			
Treated	27.5	86.0	19
Untreated	250	790	7

Friction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PMA / Rejuvenator oil blend Fog Seals

on

OGFC Pavements


PVA 6878

Fog Seals for OGFC Define Performance?

- Properties of renewed OGFC
  - **Resistance to raveling**
  - **Sensitivity to cracking**
  - **Binder rheology improved to resist aging/moisture**
  - **Permeability**

Fog Seal over Chip Seal

- Objective:
  Tie down loose aggregate & suppress dust
- Emulsion Grades:
  - **SS/CSS**
  - **CRS/RS/HFRS**
  - **Polymer-modified emulsions**

Avoid over application

Fog Seals over Chip Seal Define Performance?

- Chip retention
  - **Broken Windshields**
  - **Long-term aggregate loss**
  - **Minor crack sealing**
- Dust/particulate emissions

Outcome of Research - Knowledge & Specifications

- Define fog seal applications
  - What materials add life-cycle value
  - What tests define performance
  - How important is product consistency
  - Impact on traffic & safety (skids, cure)
- Specifications (HMAC, OGFC, Chip Seal)
  - Performance tests & failure criteria
  - Emulsion/residue specs

New uses for the fog seal concept

- Stabilizing the area around the longitudinal joint in new construction
- Working in tandem with surface retexturing on high volume pavements

Polymer Maltene Emulsion Being Applied To The Longitudinal Joints


Performance
After 3 years


Applied to rumble strips
On centerline


Centerline area


Skidabrader
Express

Maltene Rejuvenator APPLIED BEHIND THE SKIDABRADER

Any agency can implement the use of rejuvenators and/or fog seals by simply deferring a small amount of resurfacing.

Miles of HMA Overlay	FOR	Miles of Fog Seal
5 Miles	→	50 Miles
2 Miles	→	20 Miles
1 Miles	→	10 Miles
1/2 Mile	→	5 Miles

QUESTIONS ?